Kenya Meteorological Department

REPUBLIC OF KENYA

This state of the climate report Kenya 2024 provides a snapshot of the state of the climate in Kenya during the year 2024. It examines key weather events during the year, puts them in the context of 1990-2020 climatology and highlights the impacts of the same on key socioeconomic sectors in Kenya.

This complete report can be found at www.meteo.go.ke and at http://196.202.217.199

Lead Authors: Patricia Nying'uro, Dr Joyce Kimutai, Chris Kiptum

Contributing Authors: Sarah Kimani, Dr. Philip Okello, Christine Mahonga, Pamela Muange, Faith Kogo, Nixon Lagat, Dr. Willis Ochieng' (KENGEN)

Reviewers: Claire Ransom, Omar Baddou, Dr. David Gikungu

Editing & Design: Claire Ransom – WMO

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Contents

List of Figures

Figures

Tables

Key Messages

Rising Temperatures:

Kenya experienced above-normal temperatures across most regions in 2023, continuing a long-term warming trend in line with global climate change patterns.

Rainfall Variability:

The year saw higher than normal rainfall in coastal, western, and central highlands, while other regions experienced significant dry spells.

Severe Flooding:

Heavy rains led to widespread flooding, particularly in river basins like Tana and Lake Victoria, causing displacement, property damage, and loss of life.

Sea Level Rise:

Sea levels around Kenya are rising faster than the global average, posing a growing threat to coastal communities.

Extreme Weather Events:

Kenya faced a series of extreme weather events, including prolonged droughts and severe flooding, which significantly impacted agriculture, infrastructure, and energy production.

Socioeconomic Impacts:

The extreme weather had widespread socio-economic impacts, particularly on agriculture and hydropower generation, exacerbating food insecurity and energy challenges.

Chapter One: Introduction

The climate of Kenya is highly variable both in time and space. Just like the rest of East African and other parts of the tropics, Kenya is prone to climate extremes such as floods, landslides, and droughts. In the last decade alone, the frequency and severity of climate extremes is increasingly evident as the climate continues to warm (Holden et al., 2022; IPCC, 2021; Lott et al., 2013)

Kenya is in Eastern Africa between latitudes 5°North and 5° South and between longitudes 34°East and 42° East. It borders Ethiopia in the North, Somali in the East, Tanzania in the South, and Uganda in the West. Its total land area is about 569,137 km^2. Generally, its agro-climatic characteristics vary between arid and semi-arid in the Northwestern, Eastern and some parts of the South-eastern regions and semi-humid to humid in central, western, and some parts of the coastal region. Rainfall in Kenya is seasonal and follows a bimodal distribution pattern.

The main rainfall season “long rains'' occurs from March to May (MAM) and the “short rains” season from October to December (OND. Some areas of the country, particularly the coastal region, the highlands west of the Rift Valley and the Lake Victoria Basin experience a third rainfall season between June and August (JJA).

The long-rains season is regarded as the most important for agricultural production in Kenya, contributing to 26% of the national gross domestic product (GDP) and an additional 27% of GDP from indirect linkages with other sectors (CBK, 2023)

The agriculture sector in Kenya employs more than 40% of the total population and more than 70% of the rural population (ASTGS, 2019). Various other sectors depend on the weather for their optimum functioning. In total, 70% of the Kenyan workforce is employed in a climate-sensitive sector. This includes sectors such as agriculture, tourism, energy, health, water, and housing/settlements. For example, temperature fluctuations and the severity of extreme weather events – such as heavy rains resulting in floods – can damage energy and transport infrastructure. These impacts influence the risk of delays, disruptions, damage, and failure across land-based, air, and marine transportation systems. The impact of drought on hydro-generated electricity is also well understood in Kenya.

This report is structured as follows: Chapter 2 describes trends and observed weather/climate changes in 2023; Chapter 3 describes the observed climate drivers in 2023; Chapter 4 describes the socio-economic impacts of extreme events in various sectors of the economy, Chapter 5 describes the observed extreme events in 2023; Chapter Seven describes projected Climate patterns for 2024 and possible socio-economic impacts.

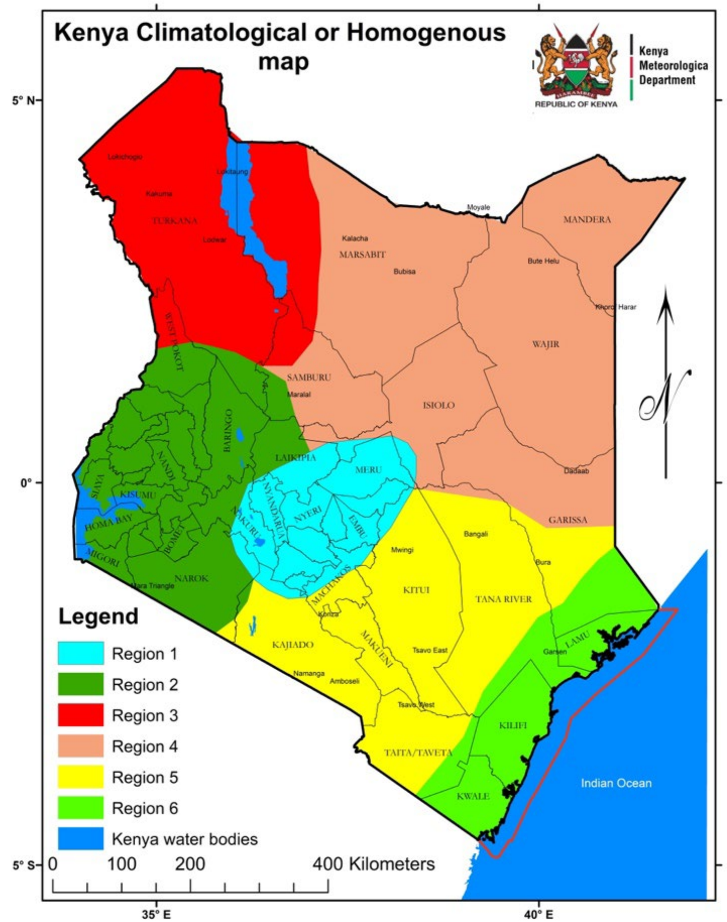


Figure 1: The six climatic zones in Kenya: Central Highlands (Region1), Lake Victoria Basin and Highlands west of the Rift Valley (Region 2), North-western (Region 3), North-eastern (Region 4), South-eastern (Region 5), The Coastal strip (Region 6). The water bodies shown are Lake Victoria to the west and the Indian Ocean to the east. Source: KMD,2020.

Climate Drivers

The climate of Kenya is influenced by several major climate drivers, notably the Intertropical Convergence Zone (ITCZ), the Indian Ocean Dipole (IOD) and the El Niño-Southern Oscillation (ENSO). These phenomena play a critical role in shaping the weather patterns and climatic conditions across the country.

The Intertropical Convergence Zone (ITCZ)

The Intertropical Convergence Zone (ITCZ) is a belt of low pressure near the equator where the trade winds of the Northern and Southern Hemispheres converge. It is characterised by convective activity, cloudiness, and heavy rainfall. In Africa, particularly in the tropics, the ITCZ plays a significant role in driving the wet and dry seasons. In Kenya, the behaviour of the ITCZ influences the country's weather patterns, particularly during the rainy seasons. The ITCZ typically influences Kenya's climate during two main periods:

- Long Rains: During this period, the ITCZ moves southward, bringing moist air masses from the Indian Ocean. As a result, many parts of Kenya experience significant rainfall, with the coastal areas and regions around Lake Victoria receiving particularly high amounts of precipitation. In 2023, during the MAM season, both the Meridional and Zonal arms of the ITCZ were positioned over Kenya, resulting in rainfall levels ranging from near average to above average.
- Short Rains: During this period, the ITCZ moves northward again, bringing another round of rainfall to Kenya. However, the short rains are generally less intense compared to the long rains. In OND 2023, the ITCZ experienced a slight delay and diffusion in October before consolidating its position over the country towards the end of the month. This delay led to delayed onset in some parts of Kenya. Nonetheless, the season was marked by enhanced rainfall owing to the prevailing El Niño conditions and the positive Indian Ocean Dipole (IOD).

The behaviour of the ITCZ can vary from year to year, leading to fluctuations in rainfall patterns and amounts across different regions of Kenya.

Oceanic Teleconnections

El Niño-Southern Oscillation (ENSO)

The evolution of El Niño began in May 2023. The Kenya Meteorological department gave updates on the status of the development of El Niño in the months of May, June, September and during the release of the October, November, and December seasonal forecast where the chance of occurrence was at 90%.

Since December 2023, positive Sea Surface Temperature (SST) anomalies have weakened slightly across most of the Pacific. More significant weakening has occurred in the far eastern Pacific. A transition to ENSO-neutral was anticipated by April-June 2024 (73% chance)

Table 1. Showing El Nino Indices in the last 3 years (2021, 2022, 2023) to highlight the high index values in 2023

YEAR	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2021	-1.0	-0.9	-0.8	-0.7	-0.5	-0.4	-0.4	-0.5	-0.7	-0.8	-1.0	-1.0
2022	-1.0	-0.9	-1.0	-1.1	-1.0	-0.9	-0.8	-0.9	-1.0	-1.0	-0.9	-0.8
2023	-0.7	-0.4	-0.1	0.2	0.5	0.8	1.1	1.3	1.6	1.8	1.9	2.0

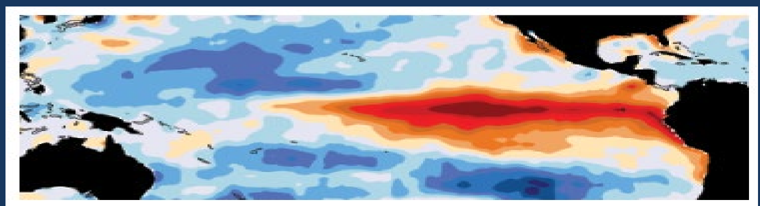
Indian Ocean Dipole

In 2023, the Indian Ocean Dipole was positive and thus had an impact on the enhanced rainfall experienced in Kenya, especially during the OND season. It led to floods over most places, which consequently led to loss of lives and destruction of property, displacement of people and loss of livestock. The Indian Ocean Dipole (IOD) returned to neutral, with the weekly IOD index (in 4 February 2024) being below +0.4 °C for the second consecutive week. Due to the strength of the positive IOD in 2023, the event decay was later than usual.

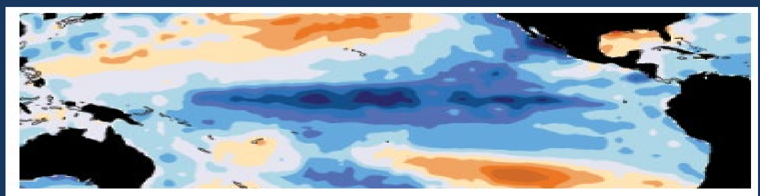
Box 1: What are "Climate Drivers"?

El Niño/La Niña Southern Oscillation (ENSO)

El Niño/La Niña Southern Oscillation (ENSO) is a naturally occurring phenomenon which involves fluctuating ocean temperatures in the central and eastern equatorial Pacific Ocean, coupled with changes in the atmosphere. El Niño refers to a warming of the ocean surface, or above-average sea surface temperatures, in the central and eastern tropical Pacific Ocean. This results in the low-level surface winds, which normally blow from east to west along the equator ("easterly winds"), to weaken or, in some cases, to start blowing the other direction (from west to east or "westerly winds"). El Niño recurs irregularly, from two years to a decade, and no two events are exactly alike. La Niña refers to the periodic cooling of sea-surface temperatures across the east-central equatorial Pacific. It represents the cold phase of the ENSO cycle. During La Niña events, trade winds are even stronger than usual, pushing more warm water toward Asia. Off the west coast of the Americas, upwelling increases, bringing cold, nutrient-rich water to the surface.



El Niño: Warmer than normal tropical Pacific sea surface temperatures



La Niña: Cooler than normal tropical Pacific sea surface temperatures

Figure 3: Sea surface temperatures in ENSO phases.

Indian Ocean Dipole (IOD)

The Indian Ocean Dipole (IOD) is defined by the difference in sea surface temperatures between the eastern and western tropical Indian Ocean. It has three phases: neutral, positive and negative. Events usually start around May or June, peak between August and October and then rapidly decay after the October, November and December (OND) season.

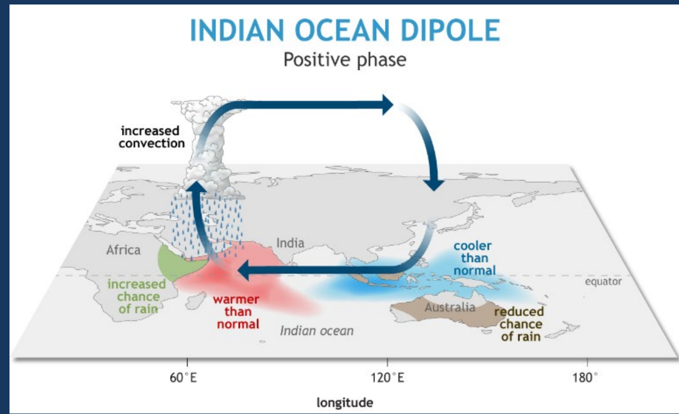


Figure 4: The positive phase of the Indian Ocean Dipole (IOD). Source: NOAA

During the positive phase of the Indian Ocean Dipole, cooler-than-normal sea surface conditions west of Indonesia and warmer-than-normal conditions in the western Indian Ocean alter the atmospheric circulation in the Indian Ocean region. Indonesia and Australia tend to be drier than normal, which increases the chances of bushfires, while eastern Africa tends to be wetter than normal, increasing the likelihood of floods.

Did you know? *The name "El Niño" is Spanish for "the Christ child" Why is it so named? Fishermen off the west coast of South America were the first to notice appearances of unusually warm water that occurred at year's end. The phenomenon became known as El Niño because of its tendency to occur around Christmas time. The name "La Niña" means Little Girl in Spanish. La Niña is also sometimes called El Viejo, anti-El Niño, or simply "a cold event."*

Chapter Two: Observed Climate in 2023

This section describes observed climatic changes in the 2023 with respect to the climatological period 1990-2020.

Temperature

Globally, 2023 was the warmest year on record (WMO, 2023).

An analysis of CPC temperature data from 1979 to 2023 indicates a clear warming trend across Kenya. In the late 1970s, average maximum temperatures in Kenya were generally around 29.0°C, but by the early 2020s, average temperatures have risen to around 30.5°C. This represents an increase of approximately 1.5°C over the period. This upward trend in temperatures aligns with global patterns of climate change, reflecting the broader impacts of increasing greenhouse gas concentrations and other anthropogenic influences on the climate system.

Analysis of the monthly temperatures shows that above normal temperatures were experienced in most parts of the country in 2023, following the trend of warmer-than-average temperatures across the entire country. However, there were instances where daytime (maximum) temperatures in specific areas, including the Central highlands, Nairobi area, and isolated regions in the Southeastern lowlands (Ngong), occasionally fell below 18°C.

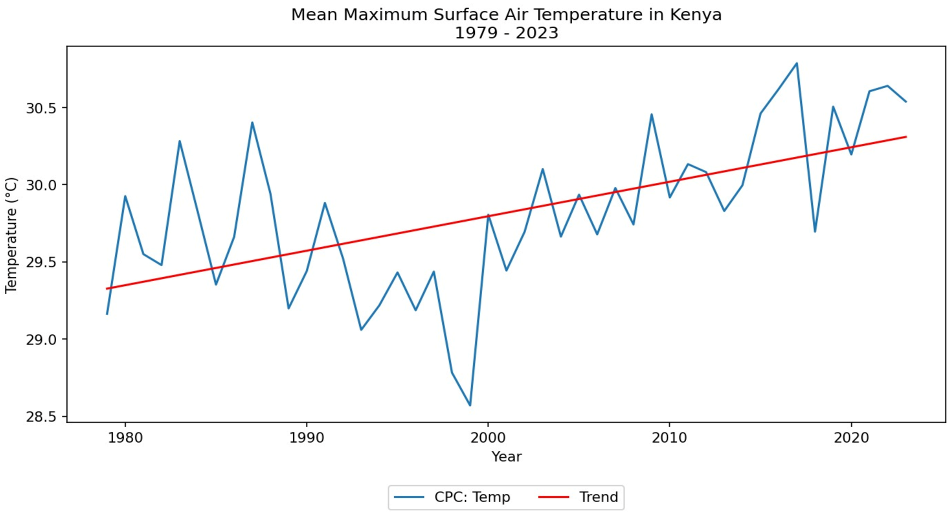


Figure 5: Average mean surface temperature in Kenya 1979-2022. Source: CPC

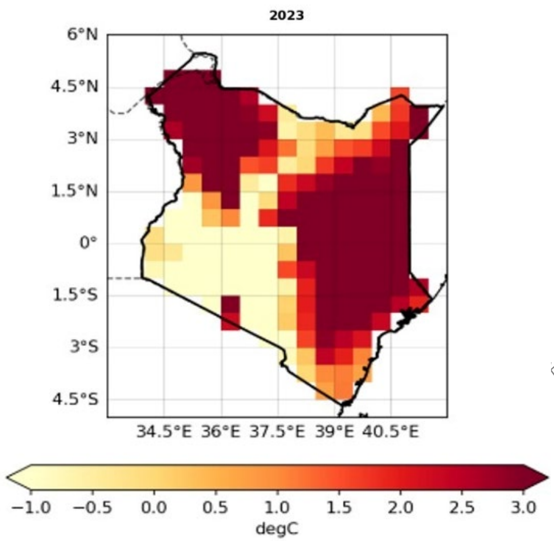


Figure 6: Temperature anomalies across Kenya in 2023 with respect to 1990-2020. Based on CPC gridded dataset.

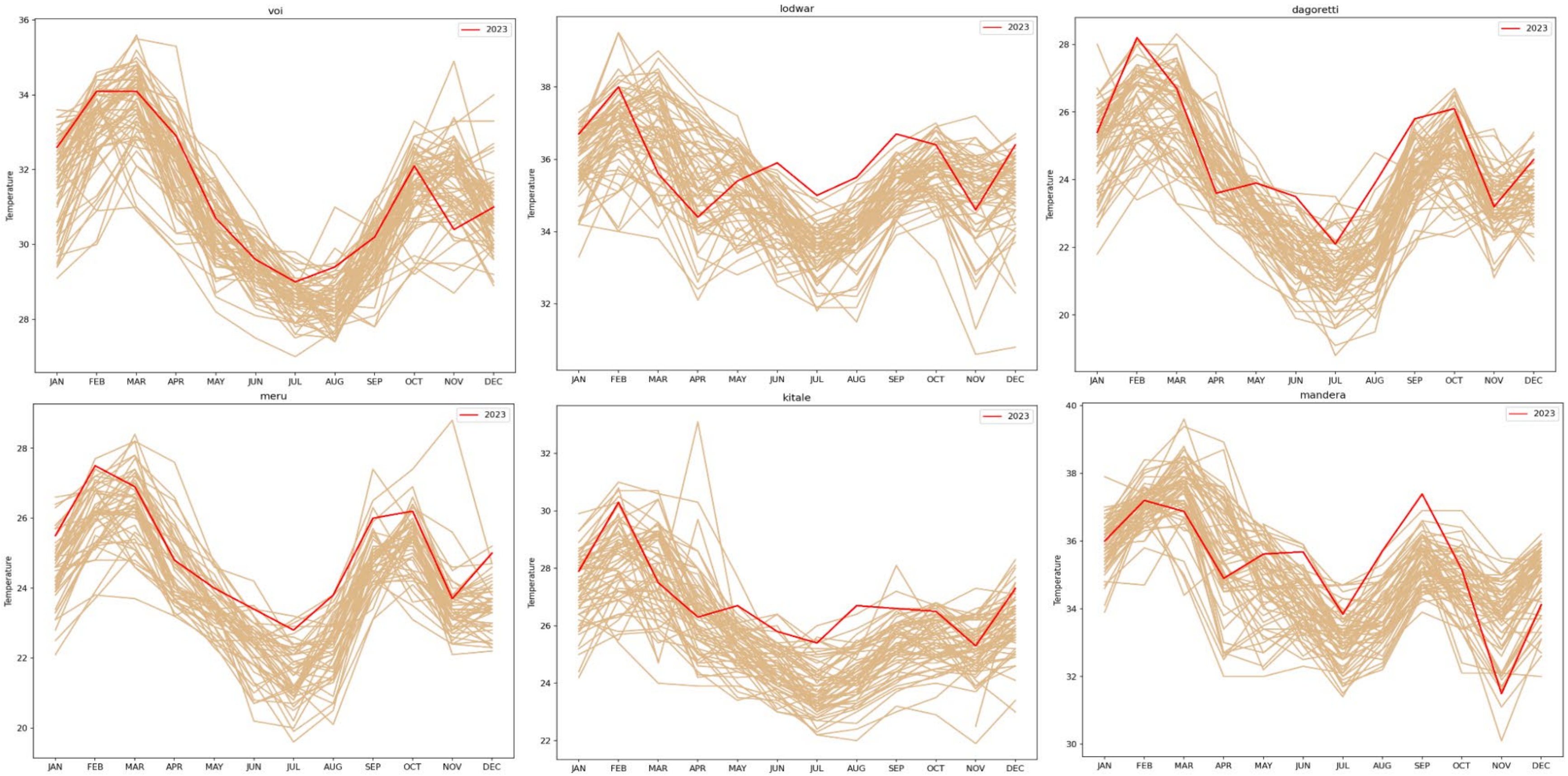


Figure 7: Monthly anomalies recorded across six stations for the year 2023 with respect to 1990-2020. The stations are representative of the different climatological zones in Kenya. Based on CPC gridded dataset.

Above normal temperatures were experienced in most parts of Kenya in 2023.

Rainfall

Kenya's climate is characterized by significant spatial and temporal variability in rainfall, influenced by factors such as altitude, proximity to large water bodies, and regional climate systems like the Indian Ocean Dipole (IOD) and the El Niño-Southern Oscillation (ENSO).

The country typically experiences two main rainy seasons: the long rains (March-April-May, MAM) and the short rains (October-November-December, OND). In recent years, Kenya has seen a pattern of increased variability in precipitation, with periods of intense rainfall leading to floods and extended dry spells resulting in droughts. These extreme weather events have significant impacts on agriculture, water resources, and overall socio-economic conditions.

March-April-May (MAM)

During the MAM season, most parts of the country experienced near to above-average rainfall, except for a few coastal areas that recorded below-average rainfall. Rainfall was particularly heavy in the last weeks of March and most of April, with dry spells in early March and dry conditions in May. Significant rainfall occurred in the southwestern and Lake Victoria Basin, while Taita Taveta and Kwale counties experienced late onset in April. Severe storms marked the season, influenced by Cyclone "Freddy" and the Madden-Julian Oscillation (MJO).

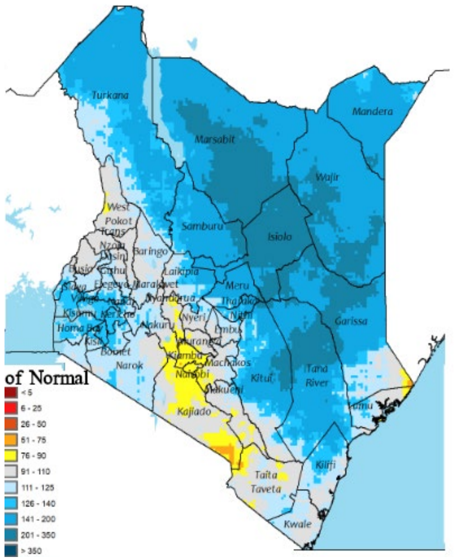


Figure 8: Rainfall performance in March-April-May as a percentage change from the 1990-2020 climatological period.

June-July-August (JJA)

The JJA season was generally dry, with most regions experiencing below-average rainfall. However, regions including the Highlands West of the Rift Valley, the Lake Victoria Basin, the Central and South Rift Valley, the Coastal region, and select areas in the Highlands East of the Rift Valley, Southeast, and Northeast received rainfall. Kitale Meteorological station recorded the highest seasonal rainfall total at 387.7 mm (92.1% of long-term mean), followed by Kakamega with 375.9mm (70.3% of long-term mean). Highlands East of the Rift Valley, including Nairobi County, and parts of Southeastern lowlands had occasional cool and cloudy conditions with light rains.

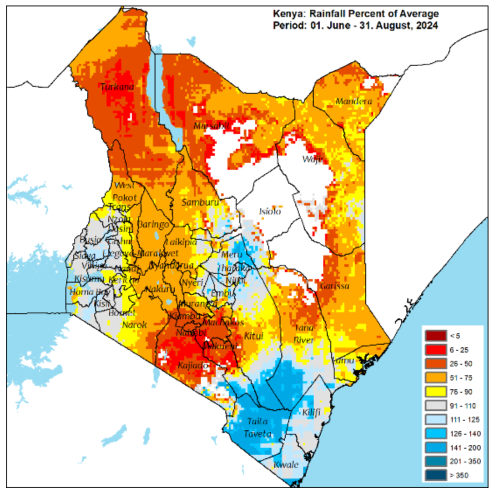


Figure 9: Rainfall performance in June-July-August as a percentage change from the 1990-2020 climatological period.

October-November-December (OND)

The OND season exhibited varied rainfall patterns across the country. The onset of the seasonal rains occurred during the third to fourth week of October for most regions, though some areas experienced a dry spell following the onset. The rainfall distribution was generally even in October and November and uneven in December across most parts of the country. **Severe storms characterised the season, particularly in November, affecting the coastal region, South-eastern lowlands, Northeastern, and Highlands East of the Rift Valley**. Notable rainfall totals included Lamu station with 636.1 mm of rainfall (294.77% of long-term mean) and Mombasa with 934.2 mm (288.5% of its LTM) Garissa, Mandera, Wajir, and Mtwapa also reported notable rainfall percentages above their LTMs.

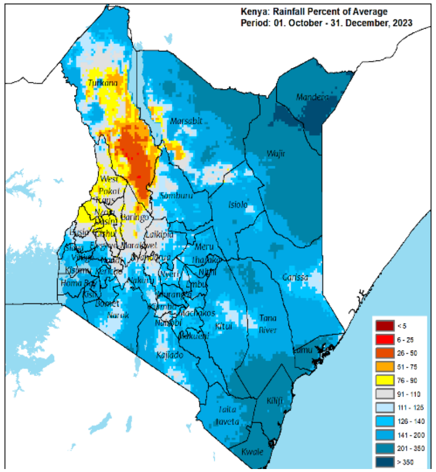


Figure 10: Rainfall performance in October-November-December as a percentage change from the 1990-2020 climatological period.

Anomalies

Overall, in 2023, the coastal region, western and central highlands, and few parts of the northern region experienced above-normal rainfall as the rest of the country experienced dry conditions. Notably, localised, and widespread flash flooding was experienced in the eastern sector of the country, particularly in the Northeastern counties, the coastal strip, and parts of southeast lowlands (WWA, 2023)

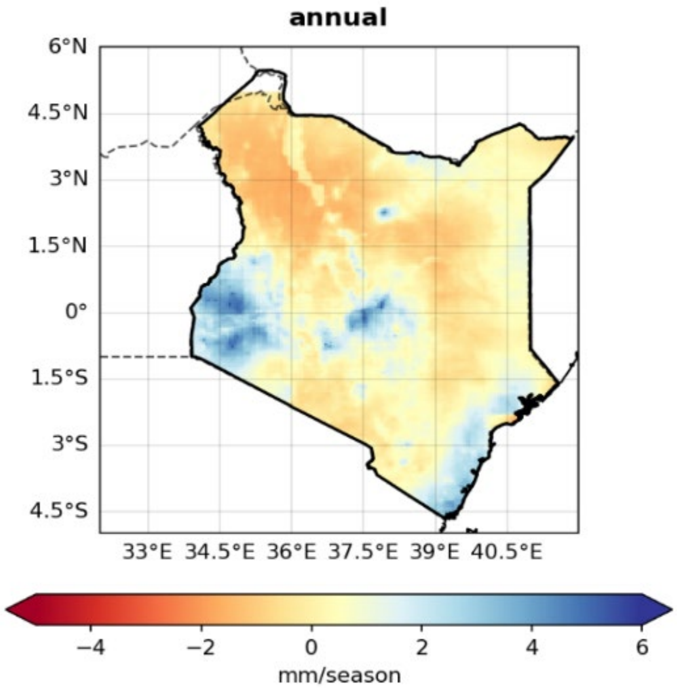


Figure 11: Observed rainfall anomalies in 2023 with respect to 1990-2020 climatological period. The analysis is based on CHIRPS gridded dataset.

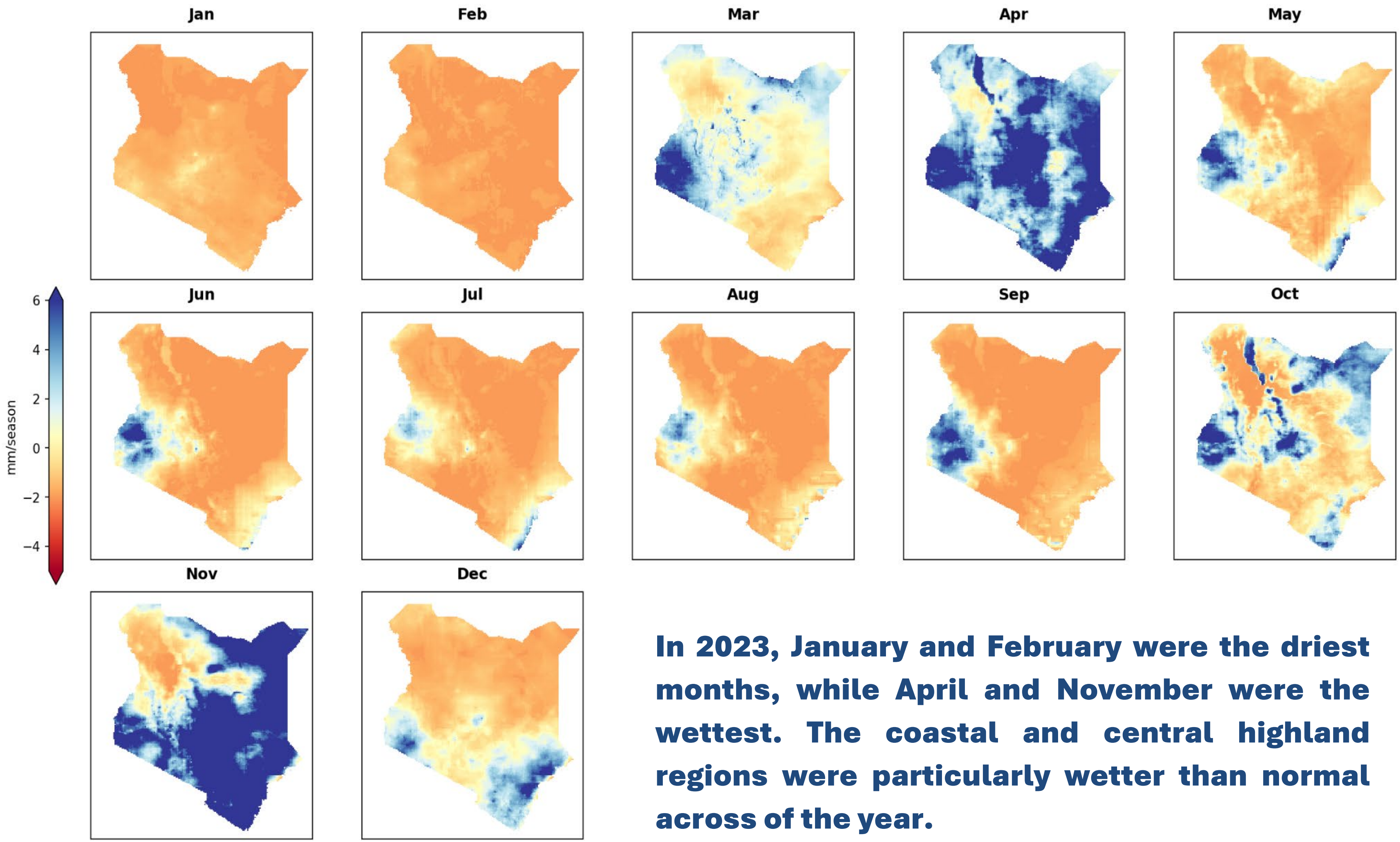


Figure 12: Observed anomalies in monthly rainfall in 2023 with respect to 1990-2020 climatological period based on CHIRPS gridded dataset.

In 2023, January and February were the driest months, while April and November were the wettest. The coastal and central highland regions were particularly wetter than normal across of the year.

Ocean Indicators & Marine Weather

Kenya's coastal region is significantly influenced by marine weather phenomena, particularly tropical cyclones. These powerful storms, originating from the Indian Ocean, bring heavy rainfall, strong winds, and storm surges that often result in coastal flooding and infrastructure damage. The coastal strip, including major cities like Mombasa, is periodically affected by these cyclones, which disrupt maritime activities, fisheries, and tourism, posing a considerable risk to the local economy and livelihoods.

In addition to the immediate threats from tropical cyclones, Kenya's coastline faces long-term challenges due to rising sea levels and increasingly frequent high tides. The gradual increase in sea level, driven by global warming and melting polar ice caps, leads to the erosion of beaches, inundation of low-lying areas, and salinization of freshwater resources. These changes not only threaten coastal ecosystems but also exacerbate the vulnerability of coastal communities, necessitating urgent measures for adaptation and resilience building.

High tides

Monitoring high tide levels in Kenya is crucial for mitigating the impacts of coastal flooding, erosion, and saltwater intrusion, which threaten coastal communities, infrastructure, and ecosystems. Figure 13 provides a preliminary look at the recent or past water levels compared to the long-term records and climatology at the tide gauge station with respect to the Mean High High Water (MHHW) level. Updates are typically available by the 15th day of each month using the Fast Delivery of tide gauge data for Mombasa Kenya.

Overall, in 2023, observed tidal heights were higher than the 1986-2001 average. The highest tidal waves were received in the months of November and December 2023.

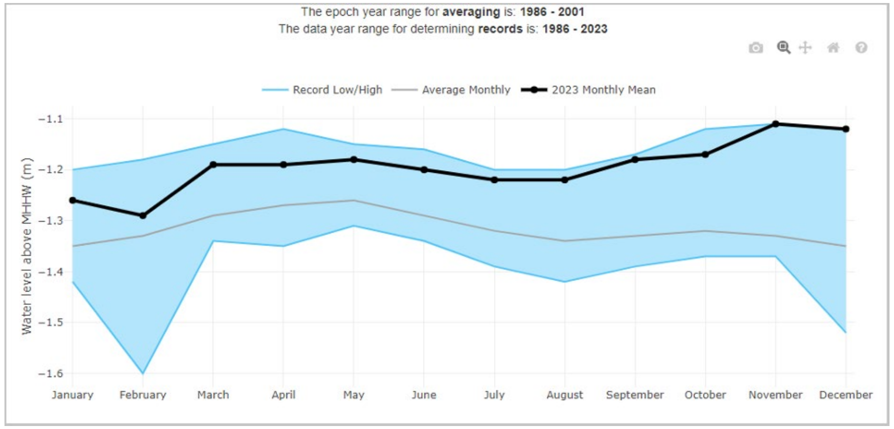


Figure 13: Monthly Means of the observed tidal heights.

Sea level rise

Globally, the long-term rate of sea level rise has more than doubled since the start of the satellite record, increasing from 2.13mm per year between 1993 and 2002 to 4.77mm per year between 2014 and 2023. Figure 14 shows altimetry-based regional sea level trends in Africa from the coast to 50 km offshore over January 1993 to June 2024. In the Western Indian Ocean (Box 2), sea level has risen at a rate of 4.0± 0.2mm per year, higher than the global average of 3.4 +/- 0.3 mm per year.

Along the coast of the Western Indian Ocean, sea level is rising faster than the global mean.

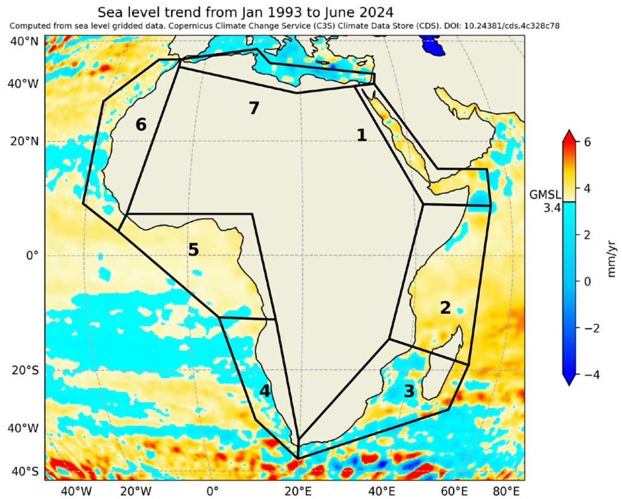


Figure 14. Spatial Sea-level trends in the seven coastal regions of Africa covering the period from January 1993 to June 2024. Source: Copernicus Climate Change Service (C3S).

Wind Patterns

The state of the sea over Western Indian Ocean (WIO), is influenced by the seasonal monsoon winds. Figure 15 illustrates the 10m winds direction (vectors) and 10m wind speed (shading) over the WIO adjacent to Equatorial East Africa (EEA). Wind speeds and direction are characterised by monsoon flows which are seasonally dependent in reference to the overhead solar insolation. During the NE monsoon occurring during DJF as shown in figure 15 (d), the wind speeds over the EEA coast are low as compared to the during SE monsoon occurring during JJA as shown in figure 14 (b). The reduction in wind speeds is characterised by the transition period during SON season when the sun is overhead over EEA. It is evident that during the NE monsoon, high wind speeds are observed along the Somali coast, while during SE monsoon the entire WIO basin is dominated by high wind speeds. The NE monsoon winds are lighter and predominantly northerly, while the SE monsoon winds are strong and mainly southerly. The SE monsoon season is characterised by rough seas caused by strong winds of more than 17 knots and high waves of more than 2 metres.

Tropical Cyclones

The 2022-2023 cyclone season was characterised by near-normal activity in the South-West Indian Ocean cyclone basin. The tropical cyclone season in the southwest Indian Ocean always starts Early November and ends in April of the following year. In a large-scale context like 2022, the genesis areas were favoured over the eastern half of the basin. Overall, the privileged tracks should be oriented towards the west or southwest, which could lead some of the phenomena to threaten or hit the inhabited lands of the western part of the basin (the eastern coast of Madagascar, the Mascarene Islands and possibly the seaboard of Mozambique and spreading to Malawi).

No major impacts associated with tropical cyclones were recorded along the Kenyan coast.

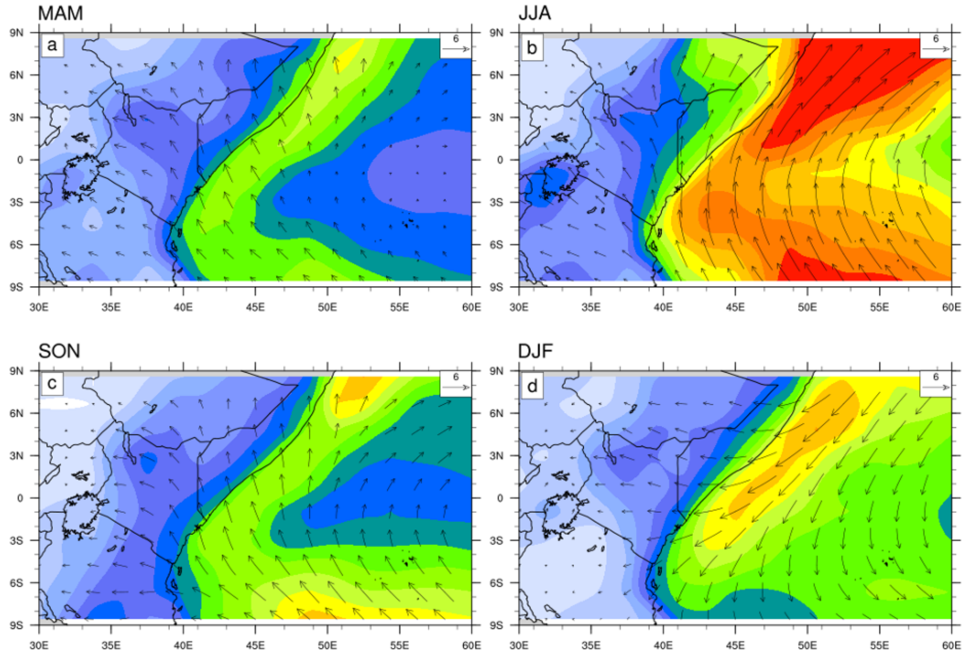


Figure 15: Seasonal distribution of the 10m winds directions (vector) and 10m wind speed (m/s)-shading (a) MAM, (b) JJA, (c) SON, and (d) DJF in 2023.

Water Resources

River levels across most basins had dwindled in 2022 due to the prolonged drought conditions. The situation started improving as the rainfall seasons in 2023 set in.

Heavy rains experienced during the short rains season led to a rise in river levels across the country. The sharp rise in the Tana River caused heavy flooding in the lower parts of the basin in Garissa and Tana River Counties as well as the Tana Delta. The Nyando and the Kuja Migori Rivers in Lake Victoria Basin had the levels rise beyond the flood alarm levels causing flooding in the adjacent low-lying lands in Kisumu and Migori Counties respectively.

Flash floods, occasioned by excessive runoff were experienced in the Upper Tana basin in Meru and Tharaka Nithi Counties as well as the lower Athi Basin at the coastal strip and parts of Ewaso Ng'iro North basin in Wajir, Mandera, Isiolo and Samburu Counties. Several urban areas across the country experienced flash floods as a result.

Lake Victora Basin

Rivers Nyando, Kuja Migori and the shoreline streams of Lake Victoria basin surpassed the flood alarm levels and flooded the adjacent low-lying lands. Water levels at Nyando River reached 3.56m, which is 0.56m above the flood threshold. River Kuja Migori reached 4.53m against a flood alarm level of 3.8m.

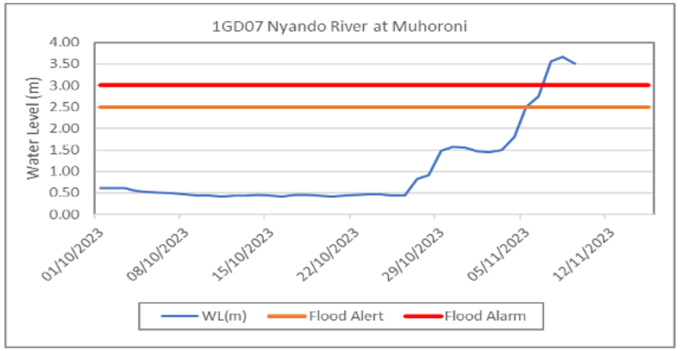


Figure 16: Nyando River water levels from 1 October-12 November 2023.

Rift Valley Basin

The northern and central parts of the basin experienced floods between 4th and 6th November 2023.

Athi River Basin

The Athi river levels remained below the flood alert threshold despite the heavy rains received. However, flash floods were experienced at the coastal strip due to excessive runoff.

Tana River Basin

Tana River at Garissa surpassed the flood alarm level of 4.0m on 2nd November 2023 the highest recorded level was 5.59m on 5th November 2023.

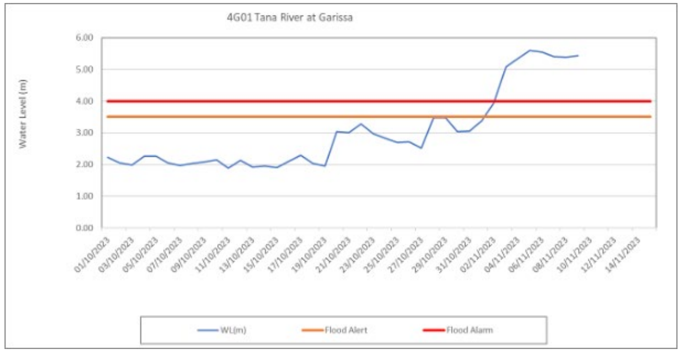


Figure 17: Tana River water levels from 1 October-14 November 2023.

Ewaso Ng'iro North

The basin experienced flash floods between 2nd and 6th November 2023 within Samburu and Marsabit Counties. The river levels however remained normal, with a peak of 1.37m above flood alert threshold on 4th November 2023.

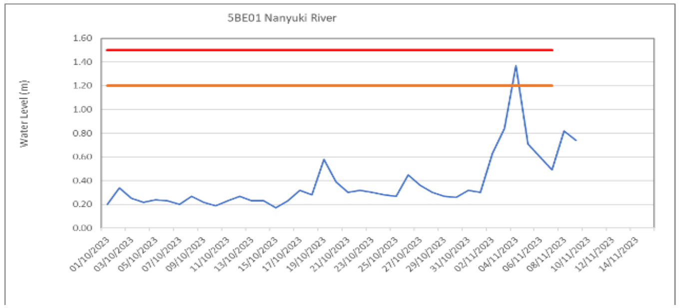


Figure 18: Nanyuki River water levels from 1 October-14 November 2023.

Extreme Events in 2023

In 2023, Kenya experienced a series of extreme weather events, including prolonged droughts and severe flooding, which had widespread impacts on communities and infrastructure across the country.

Collapsed bridge in Bome

Drought Conditions

The beginning of 2023 was marked by ongoing drought conditions, a result of five consecutive failed rainy seasons since November 2020. This prolonged drought severely affected water availability, agriculture, and livestock, leading to food insecurity and economic hardship for many communities. The lack of sufficient rainfall continued to strain resources and posed significant challenges to the livelihoods of millions of Kenyans.

Extreme Rainfall:

Severe storms marked the MAM season, influenced by Cyclone "Freddy" and the Madden-Julian Oscillation. Later in the year, extreme rainfall was recorded along the coastal regions on November 15 and 16. Notable measurements are shown in the table below. Such heavy rainfall contributed to flooding, particularly in low-lying and poorly drained areas.

Date	Rainfall	Station
16/11/2023	110.7mm	Mtwapa
	49.2mm	Mombasa
	134.3mm	Msabaha
15/11/2023	102.6mm	Mombasa
	63.4mm	Mtwapa

Table 1: Extreme rainfall values recorded in three stations on 15-16 November 2023.

Flooding Events

As the year progressed, the drought was interrupted by episodes of extreme rainfall, leading to devastating floods in various regions.

- March: From March 25-30, heavy rains led to widespread flooding across several counties, including Mombasa, Kwale, Tana River, and others. These floods resulted in 36 fatalities and left 29 people injured, affecting a total of 139,135 individuals. Infrastructure damage, particularly to roads and homes, compounded the impact on affected communities.
- April: Flash floods in Kisumu and Mandera counties in late April caused significant displacement, with approximately 22,500 people affected. The Nyando River in Kisumu was particularly impacted, highlighting the area's vulnerability to sudden and intense rainfall.
- October-November: From late October through November, severe flooding affected Mombasa and Mandera, Marsabit, Meru, Samburu, Isiolo, Turkana and Busia counties, among others. These floods, driven by heavy rains and the influence of the El Niño weather pattern, resulted in more than 400 deaths and 200 injuries. Approximately 695,255 people were impacted, with many requiring urgent humanitarian assistance.

Chapter Three: Socio-economic Impacts

Floods affected 38 counties across Kenya, resulting in loss of lives, injuries, displacements, and destruction of key infrastructure. An increase in contaminated water also led to secondary effects, including vector and waterborne disease outbreaks.

757,173 people (138,560 households) were affected since the onset of the short rains season between October and December 2023. Of these, 64,373 households were displaced in Mandera, Wajir, Garissa, Mombasa, Tana River, Marsabit, Meru, Isiolo, Samburu, Homa Bay, Turkana, Taita Taveta, Kwale, Kilifi, Tharaka Nithi and Makueni, Migori, Kisumu, Busia, West Pokot, Bungoma, Elgeyo Marakwet, Turkana, Narok, Baringo, Kericho, Nyandarua, Nakuru, Kirinyaga, Murang'a, Nyeri, Lamu, Kajiado, Nairobi and Kitui Counties. Additionally, the destruction of over 25,269 acres of farmland, 1,302 businesses, and 17,392 livestock deaths were reported.

The floods exacerbated the humanitarian crisis in the country just as it emerged from the worst drought in four decades, which left millions of people hungry. Some of the hardest hit areas were the semi-arid lands where pastoralism is the economic driver for livelihoods. These areas were still recovering from the worst drought in 40 years, which led to high rates of malnutrition. The drought, coupled with El Niño rains and extreme temperatures, underscored the climate change challenges that Kenya and other countries in the Horn of Africa region are grappling with. (IFRC)

Agriculture and Food Security

The rainfall during the October to December season increased agricultural productivity across most counties, enhanced pasture, forage, and water resources supporting livestock keeping. Flooding affected some pulses due to water logging (FEWS NET, 2023).

At the beginning of the year, 4 counties (Isiolo, Turkana, Marsabit and Mandera) improved from the emergency phase to the crisis phase of food insecurity (Figure 17a)(IPC, 2023). This situation was extending from the previous year. Between July and September 2023—typically dry and cool over most of the northern and coastal regions—about 2.8 million people in the ASALs were classified in IPC Phase 3 or above (Crisis or worse) (Figure 17b). According to the August 2023 update of the Food Security and Nutrition Working Group (FSNWG), by August 946,000 under-five children were estimated to be acutely malnourished(FSNWG1, 2023), with 217,000 of them severely so. Close to 145,000 pregnant and lactating women also required urgent acute malnutrition treatment. This number was lower than the previous assessment at the beginning of the year, in part due to a slight improvement in availability of food after the March to May long rains season.

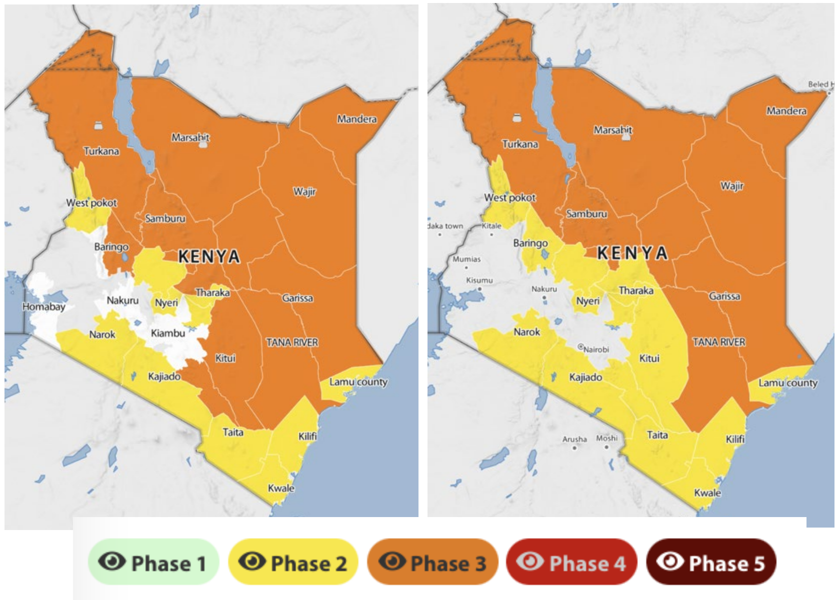


Figure 19: Maps showing counties IPC phases by February 2023 (left) and IPC phase between July and September 2023 (right).

Livestock were swept away in the Northern, Southeastern and Eastern parts of the country, mainly in the counties of Samburu, Meru, Kitui, Mandera, Wajir, Isiolo and Voi. Likewise, crops were destroyed by floods in Nyandarua and Narok county.

In Mwingi constituency of Kitui county, heavy rainfall led to loss of trees including fruit trees such as mango and lemon trees, sugarcane, maize, cowpeas among other farmed produce.

Figure 20: Goats and chicken killed by floods in Voi (top) and destroyed maize crops in Loita, Narok county (bottom).

Early Warning/Disaster Risk Reduction

The floods that occurred in several counties led to loss of lives, displacement of people and destruction of property. These areas include Mandera, Wajir, Isiolo, Garissa, Tana River, Samburu, Meru and Kisumu.

The incidents include people who died as they attempted to cross flooded rivers in Isiolo, Migori, Kwale, Meru and Kitui counties while others were swept by flash floods in Mandera and in Bangala Luanda area in Mombasa where a house caved in due to heavy rains. Lightning strikes also led to loss of life as well as injuries in Sotik.

During the short rains counties in the southeast lowlands including Voi as well as some in the highlands west of the rift valley including Kisumu experienced flooding with damage to infrastructure and homes and leading to displacement of households.

Kenya Red Cross reported on 06 November that floods during the short rains had affected a total of 15,264 households across the country and at least 15 people had lost their lives. Wide areas of crops were damaged, and hundreds of livestock perished.

Health

In the aftermath of prolonged and intense rainfall, health took center stage as communities struggled with the impacts of water-related challenges. The effects of heavy rain significantly influenced public health from waterborne diseases concerns. Waterborne diseases became more prevalent due to contaminated water sources caused by flooding.

Cholera outbreak affected twenty-seven counties: Nairobi, Kiambu, Nakuru, Uasin Gishu, Kajiado, Murang'a, Machakos, Garissa, Meru, Nyeri, Wajir, Tana River, Kitui, Homa Bay, Mandera, West Pokot, Bomet, Samburu, Marsabit, Kirinyaga, Kisumu, Siaya, Isiolo, Mombasa, Kwale, Migori and Busia. Additionally, vector-borne diseases may rise as a result of stagnant water providing breeding grounds for disease-carrying insects. As of 2nd October 2023, a total of twelve thousand, one hundred and twenty-three (12,123) vector-borne disease cases, with six hundred and twenty-seven (627) confirmed by culture, and two hundred and two (202) deaths were reported (MOH, 2023).

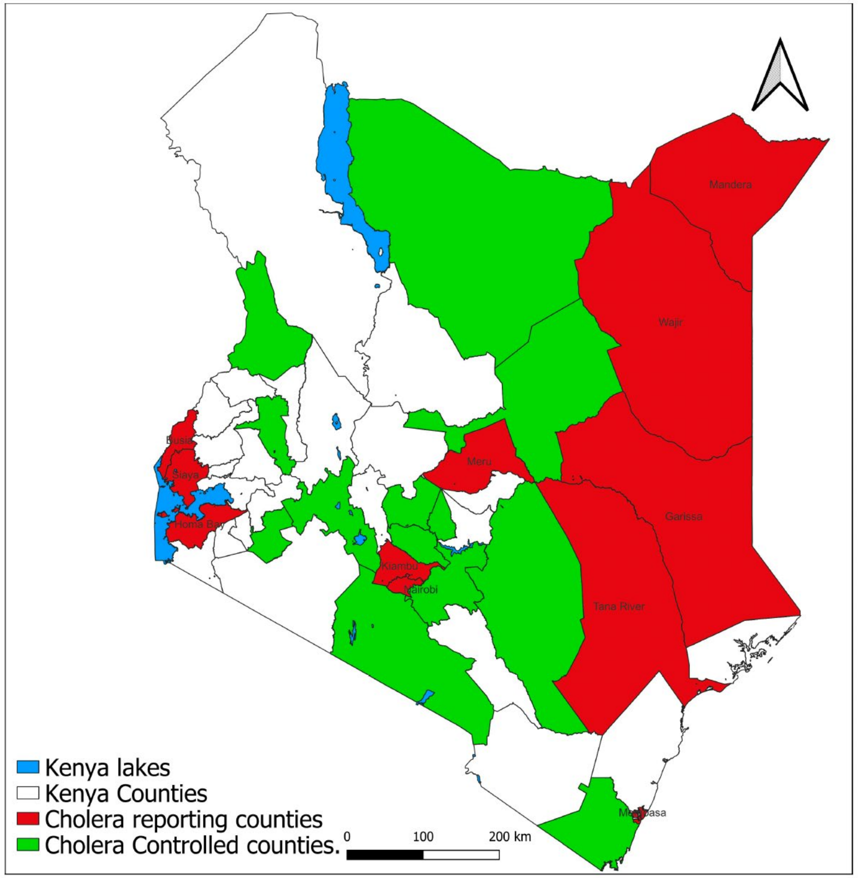


Figure 21: Cholera reporting counties by October 2023

Transportation

The heavy rainfall experienced throughout the year resulted in destruction of roads across different parts of the country. For example, several roads were cut off by flash floods in Tana River, Garissa, Wajir and Mandera. Two bridges were destroyed by floods in Tinderet. In March 2023, Kenya National Highways Authority (KeNHA) reported parts of the Nairobi – Mai Mahiu – Narok Highway were blocked or flooded due to the heavy rains recorded. Flooding toward the end of the year severely affected 80% of the road infrastructure in Mandera County, including the vital A13 road.

Environment

Landslides and mudslides occurred in various counties including Tharaka Nithi, Nandi, Meru, Muranga, Kiambu, Mombasa and Elgeyo Marakwet. In April, during the peak of the long rains season, heavy rains experienced in some parts of Olenguruone in Nakuru county, were accompanied by surging storms and hailstones. Trees were uprooted and rooftops blown.

7 AFFORDABLE AND CLEAN ENERGY

Energy

In 2023, energy generation was impacted by the prolonged drought experienced in 2022 with the catchment areas for the Seven forks dams going very low. However, the situation improved once the short rains in 2023 set in and the flooding experienced led to a recharge of the hydropower dams and improved energy generation. Prior to that, reports indicate that thermal plants were the main source of energy and the country had to import power from both Ethiopia and Uganda according to (KNBS, 2023).

Table 2 provides at a quick glance the comparison of electricity generation by source for Kenya between 2022 and 2023. For hydropower there was a decline across 2022 and into February 2023, it started to pick up in May 2023 at the end of the long rains.

Data from KenGen indicates that the worst electricity generation performance was recorded in the 2022/2023 financial year when hydropower generation reduced to just 2,569 GWh from a high of 4,141GWh recorded in 2020/2021 financial year (Table 3). This reflected hydropower contribution drop in the generation mix from 34.22% in 2020/2021 financial year to 19.33% in 2022/2023 financial year (Table 4).

KWh Million

Month	Hydro	Geo - Thermal	Thermal[1]	Wind	Solar	Co-Generation	Total
2022							
January	320.30	310.79	206.26	156.28	32.41	0.00	**1,026.03**
February	244.23	304.77	223.97	123.29	30.09	0.05	**926.40**
March	243.20	410.35	170.16	201.76	35.14	0.01	**1,060.62**
April	228.86	441.39	125.82	179.24	31.04	0.04	**1,006.39**
May	284.04	521.44	79.71	152.76	33.21	0.03	**1,071.19**
June	264.86	493.85	83.10	181.07	28.20	0.02	**1,051.10**
July	252.39	520.69	104.36	208.40	24.71	0.02	**1,110.57**
August	256.76	513.48	120.54	185.70	22.43	0.02	**1,098.92**
September	243.89	487.63	118.11	200.56	26.32	0.01	**1,076.52**
October	247.42	478.09	96.53	237.49	38.77	-	**1,098.30**
November	233.02	494.27	123.62	177.13	38.81	0.04	**1,066.89**
December	220.92	540.80	132.92	139.35	42.41	0.02	**1,076.42**
2023*							
January	185.20	524.82	107.32	203.31	46.69	0.02	**1,067.36**
February	112.91	472.15	142.35	190.65	42.85	-	**960.91**
March	125.98	509.36	166.86	152.35	40.59	-	**995.14**
April	190.85	476.33	119.53	157.00	39.41	-	**983.12**
May	237.88	510.83	95.38	181.72	44.28	-	**1,070.09**
June	257.94	504.57	68.13	168.06	36.66	-	**1,035.36**
July	279.48	494.81	108.29	198.46	37.90	0.04	**1,118.98**
August	258.71	522.92	89.58	186.66	40.85	0.02	**1,098.74**
September	247.20	511.88	130.18	141.30	39.25	0.03	**1,069.84**
October	205.28	509.54	140.57	183.36	42.87	0.01	**1,081.62**

Source: Kenya Power

Table 2: Local electricity generation by source. Source: Kenya Power

Since it is only hydropower and thermal plants which are suitable for peaking and load following, more thermal generation was enhanced to cover for the loss of hydropower leading to high cost of generation as well as increased electricity tariffs. During the same period, diversification into wind, solar and additional geothermal capacity helped in managing these rising costs even though they could not do peaking and load following.

With the onset of the short rains in October 2023, the water inflows into the hydropower reservoirs improved leading to more hydropower generation and displacing the expensive thermal plants. Hydropower is expected to perform well in the 2023/2024 financial year based on the enhanced rainfall experienced during the short rainfall season of October to December 2023 and the forecasted enhanced rainfall during the long rainfall season of March to May 2024.

	2018/19	2019/20	2020/21	2021/22	2022/23
Hydro	3,741	3,693	4,141	3,349	2,569
Geothermal	5,033	5,352	5,034	4,953	6,035
Thermal	1,298	882	940	1,648	1,396
Cogeneration	0.27	0.29	0.33	0.38	0.21
Solar	60	91	88	313	444
Wind	1,192	1,284	1,700	2,052	2,202
Imports	170	161	197	338	644
Total	**11,493**	**11,462**	**12,101**	**12,653**	**13,290**

Table 3: Energy generated (GWh) by source and financial year from 2018-2023.

	2018/19	2019/20	2020/21	2021/22	2022/23
Hydro	32.55%	32.22%	34.22%	26.47%	19.33%
Geothermal	43.79%	46.69%	41.60%	39.15%	45.41%
Thermal	11.29%	7.69%	7.77%	13.02%	10.50%
Cogeneration	0.00%	0.00%	0.00%	0.00%	0.00%
Solar	0.52%	0.79%	0.73%	2.47%	3.34%
Wind	10.37%	11.21%	14.05%	16.22%	16.57%
Imports	1.48%	1.40%	1.63%	2.67%	4.85%

Table 4: Energy generated in percentage by source and financial year from 2018-2023.

Chapter Four: Projected Climate Patterns in 2024

During 2024, Kenya is projected to experience climate patterns marked by higher temperatures, erratic rainfall, and water scarcity due to climate change. These changes are likely to result in socio-economic impacts such as food insecurity, health risks, displacement of communities, economic disruptions, and damage to infrastructure. Below are the major drivers that influence the climate in Kenya.

El Nino Southern Oscillation (ENSO)

As of mid-February 2024, moderate to strong El Niño conditions persist in the central-eastern equatorial Pacific. Key oceanic and atmospheric indicators support this ongoing El Niño event, although it is gradually weakening. The Climate Prediction Center (CPC) continues to issue an El Niño advisory for February 2024, while also monitoring for a potential La Niña event from June to August 2024.

Most of the models in the International Research Institute for Climate and Society (IRI) ENSO prediction plume predict that the El Niño event will continue through the remainder of the boreal winter and into the spring of 2024 but will then rapidly weaken. ENSO-neutral conditions are expected to become the most likely scenario in April to June, and May to July of 2024. For June to August 2024, no single category is predicted to dominate, with ENSO-neutral and La Niña conditions being almost equally probable.

By July to September 2024, La Niña is forecasted to become the most likely scenario.

The graph below displays forecasts from both dynamical and statistical models for sea surface temperatures (SST) in the Nino 3.4 region across nine overlapping 3-month periods. It's important to note that these models have varying levels of expected skill, which are based on historical performance. Generally, the skill of the models decreases as the lead time increases. Additionally, forecasts made during certain times of the year tend to have higher skill than others; specifically, forecasts between June and December are typically more accurate compared to those made between February and May.

The differences observed among the forecasts of the models can be attributed to variations in model design as well as the inherent uncertainty in predicting future SST scenarios.

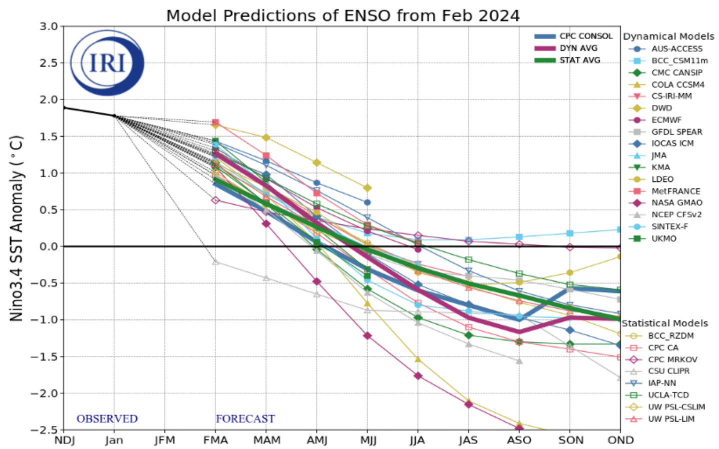


Figure 22: Model predictions of ENSO from February 2024.

Indian Ocean Dipole (IOD)

The Indian Ocean Dipole (IOD) is characterised by differences in sea surface temperatures between the eastern and western tropical Indian Ocean. A negative phase usually correlates with above-average winter-spring rainfall in Australia, while a positive phase tends to bring drier than average seasons.

In 2023, the Indian Ocean Dipole (IOD) is in a neutral phase, with the IOD index recorded at -0.42 °C for the week ending March 3, 2024. Typically, IOD events fail to develop between December and April due to the southward shift of the monsoon trough over the tropical Indian Ocean, altering wind patterns and inhibiting the formation of the IOD pattern.

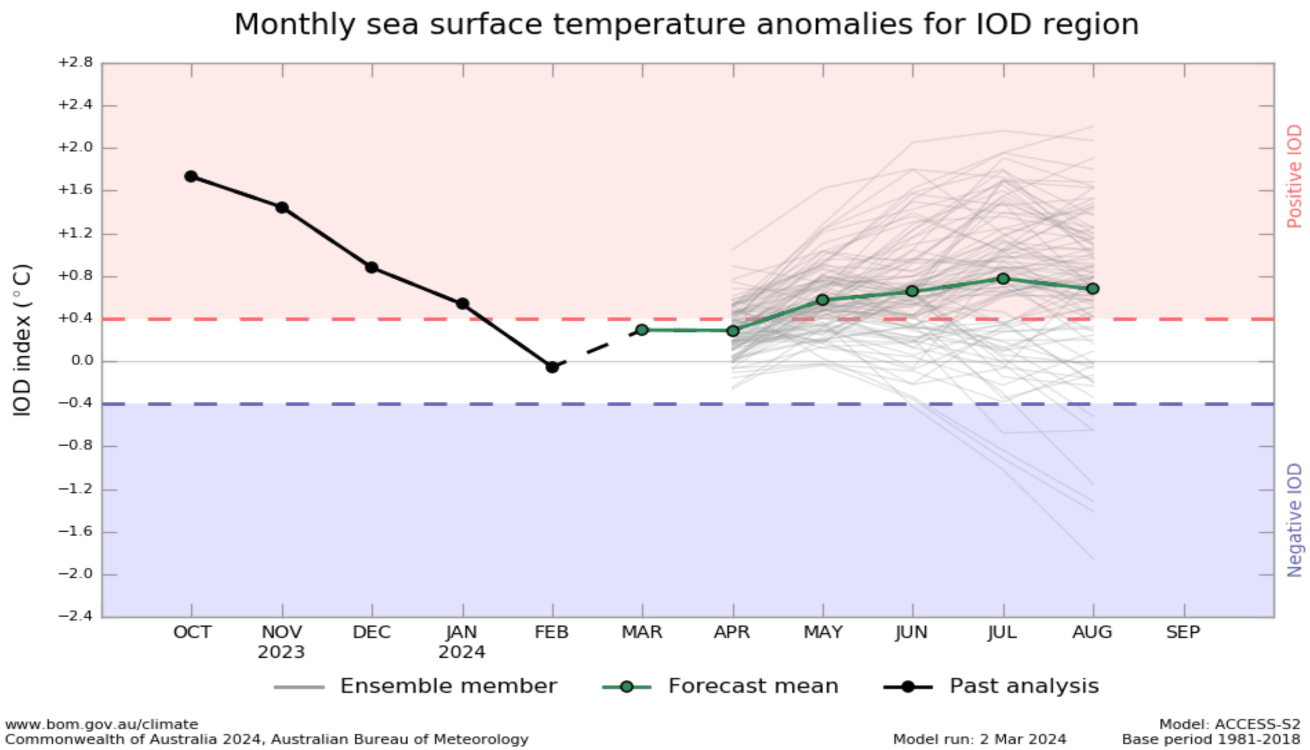


Figure 23: Monthly sea surface temperature observed and projected anomalies for the IOD region from October 2023-September 2024.

Based on assessments from international climate models surveyed by the Bureau, it is anticipated that IOD values will remain neutral at least until April 2024.

Rainfall projections

Kenya typically experiences two major rainfall seasons throughout the year. Global climate drivers such as ENSO, IOD, PDO, WNP, as well as other short-range climate drivers such as Tropical cyclones and ITCZ, influence our rainfall patterns.

Research has shown that historically, ENSO and the IOD have no effect on MAM rainfall in East Africa. However, they do impact the JJA and OND seasons. Forecasts starting in DJF do not effectively predict El Niño/La Niña beyond MAM, providing early predictions with poor skill to ascertain the likely phases of global drivers for the rest of the year. Therefore, meteorological services, GPCs, and the WMO will continue issuing updates.

In February, the Kenya Meteorological Department (KMD) released the MAM seasonal forecast for 2024, indicating above-average rainfall is expected over the Lake Victoria Basin, Highlands West of the Rift Valley, Central, Northern and Southern Rift Valley, Highlands East of the Rift Valley (including Nairobi County), Northeastern, Southeastern Lowlands, and Northwestern regions. Generally, near-average rainfall with a tendency towards above-average rainfall was expected over the Coastal region and parts of the Southeastern lowlands. Additionally, occasional storms are likely to occur in some parts of the country.

The released October-November-December (OND) 2024 'Short Rains' season indicates that the western sector of the country is expected to receive near to slightly above average rainfall while the central parts of the country and isolated areas over northeast and southeastern lowlands are predicted to receive near to below average rainfall. The Coastal region, most of the Southeastern lowlands and Northeastern Kenya are expected to receive below average rainfall. This will be driven by weak La Nina conditions which are likely to develop during September to November and persist into early 2025 and a neutral Indian Ocean Dipole. The distribution is expected to be poor over most parts of the country with prolonged dry spells and cases of isolated storms.

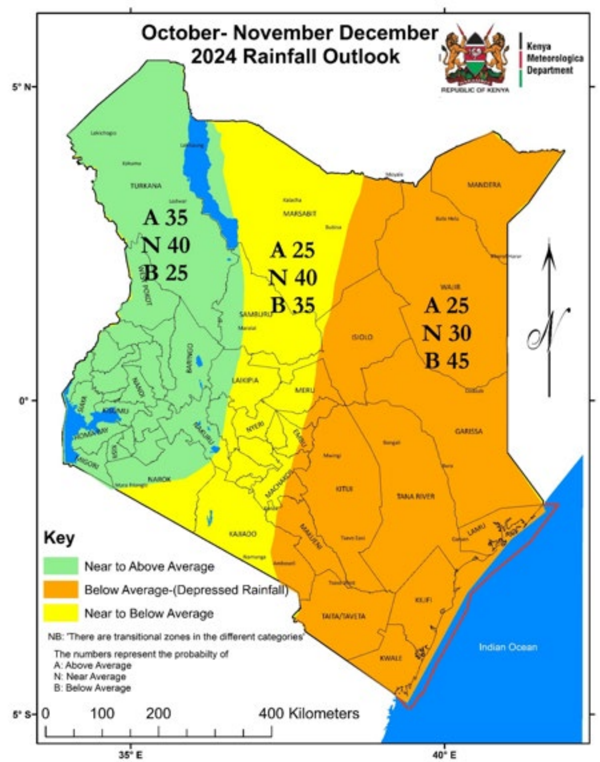


Figure 24: October-November-December 2024 Rainfall Outlook

Temperature projections

For the past couple of seasons, global temperatures have consistently risen above the average. Similarly, this year, due to El Niño conditions and other anthropogenic factors, global temperatures are forecasted to be warmer than average. In 2023, which was the warmest year on record, the presence of El Niño released oceanic heat into the atmosphere, contributing to increased global temperatures and exacerbating anthropogenic global warming.

It is anticipated that 2024 will likely match or exceed the temperatures observed in 2023.

The Kenya Meteorological Department (KMD) seasonal temperature forecast for the MAM season also indicated above-average temperatures. The OND forecast likewise indicated that temperature is expected to be warmer than average over most parts of the country, except over a few areas in the western sector where temperature is expected to be near normal. Higher probabilities for warmer than average temperatures are expected over central and eastern sectors of the country.

Chapter Five: Summaries of other KMD Branches' work

INSTITUTE FOR METEOROLOGICAL TRAINING AND RESEARCH

Training at the Kenya Meteorological Department is carried out at the Institute for Meteorological Training and Research (IMTR) which is a branch of the Kenya Meteorological Department (KMD) under the Ministry of Environment, Climate Change and Forestry (MECC&F). The Institute is charged with the responsibility of training personnel in Meteorology, Operational Hydrology and related geo-sciences in the country and the English-speaking countries in Africa and parts of Asia

IMTR has the capacity and ability to organise and host specialised training courses, workshops and seminars in various fields of meteorology, hydrology, environmental science, disaster management and related geo-sciences due to its existing infrastructure, manpower and collaboration with other institutions both locally, regionally and internationally. The Institute offers regular courses as prescribed by WMO and tailor-made courses depending on the training needs. The courses currently offered at the centre cover the following fields: Meteorology, Meteorological instruments and Calibration, Aeronautical Meteorology, Operational Hydrology and Water Resources, Remote Sensing and Satellite Meteorology, Geographical Information Systems (GIS), Data Processing and Management, Media, Information and Communication, Environmental Science, Disaster Management, Climate Risk Management, Climate Change and Information and Communication Technology (ICT).

In 2023, IMTR was able to train:

- Thirty-Two (32) Meteorological Technicians on Middle Meteorological Technicians Course (MMTC) comprised of 27 Kenyans and 5 participants from Botswana.
- Twelve (12) Meteorologists from Kenya in Operational Training Course (OTC)
- Twelve (12) Meteorological Technicians from Somali in Basic Meteorological Operations Course (BMOC)

Figure 24: Basic Meteorological Operation Course (BMOC) students during field training at Thika Meteorological Station.

Figure 25: BMOC Student during a practical session making weather observations.

Figure 26: Some of IMTR's students listening to a lecture on Meteorological Observations at Nakuru Meteorological Office.

Institute for Meteorological Training and Research (IMTR) - Centre of Excellence (CoE)

IMTR is part of the WMO Virtual Laboratory for Meteorological Satellite Education and Training (VLab) and, as such, has a mandate as a Centre of Excellence (CoE) to conduct training activities and support one or more Regional Focus Groups, representing the NMHSs in the region. IMTR/WMO-RTC is a designated "Centre of Excellence" for training Satellite Meteorology. It is one of the implementers of African Satellite Meteorology Education and Training (ASMET).

1. WMO Satellite Course on MTG

In 2023, the Centre of Excellence played a key role in being the 1st WMO Regional Training Centre (RTC) in Africa (WMO RA I) to provide training on the newly launched Meteosat Third Generation (MTG) satellite that was launched in December. The Meteosat Third Generation (MTG) system will provide weather forecasters with new, more precise and more frequent data to assist them in meeting one of their most significant challenges; providing timely and accurate forecasts of rapidly developing, high impact weather events. As such, it is imperative that the Forecasters in RA I continue strengthening their knowledge and skills in the utilization of satellite data in weather forecasting and climate services.

The "WMO Satellite Course on MTG" was supported by WMO and EUMETSAT in collaboration with IMTR and was carried out on 20 - 24 November, 2023 and was held at IMTR WMO RTC Nairobi, Kenya. The in-person course was organized to introduce MTG to users, specifically Meteorologists, Meteorological Trainers and Remote Sensing Experts in the African Region (RA I). The course allowed participants to familiarize themselves with the new channels and products in addition to the existing and available MSG products, and how to utilize them into training environment for the benefit of their organisations. The participants not only learnt the relevant background on MTG mission, MTG new products, MTG data interpretation and applications but they also obtained the skills and knowledge that support the WMO Competencies that relate to the use of satellite data by operational meteorologists.

Figure 27: Group Photo taken during the WMO Satellite Course on MTG at IMTR

The course was attended by 25 participants from 19 countries as follows: Cote d'Ivoire, Egypt, Eswatini, Ethiopia, Gambia, Kenya, Madagascar, Mauritius, Morocco, Mozambique, Uganda, Rwanda, Seychelles, Sierra Leone, South Africa, South Sudan, Sudan, Tanzania, Zambia

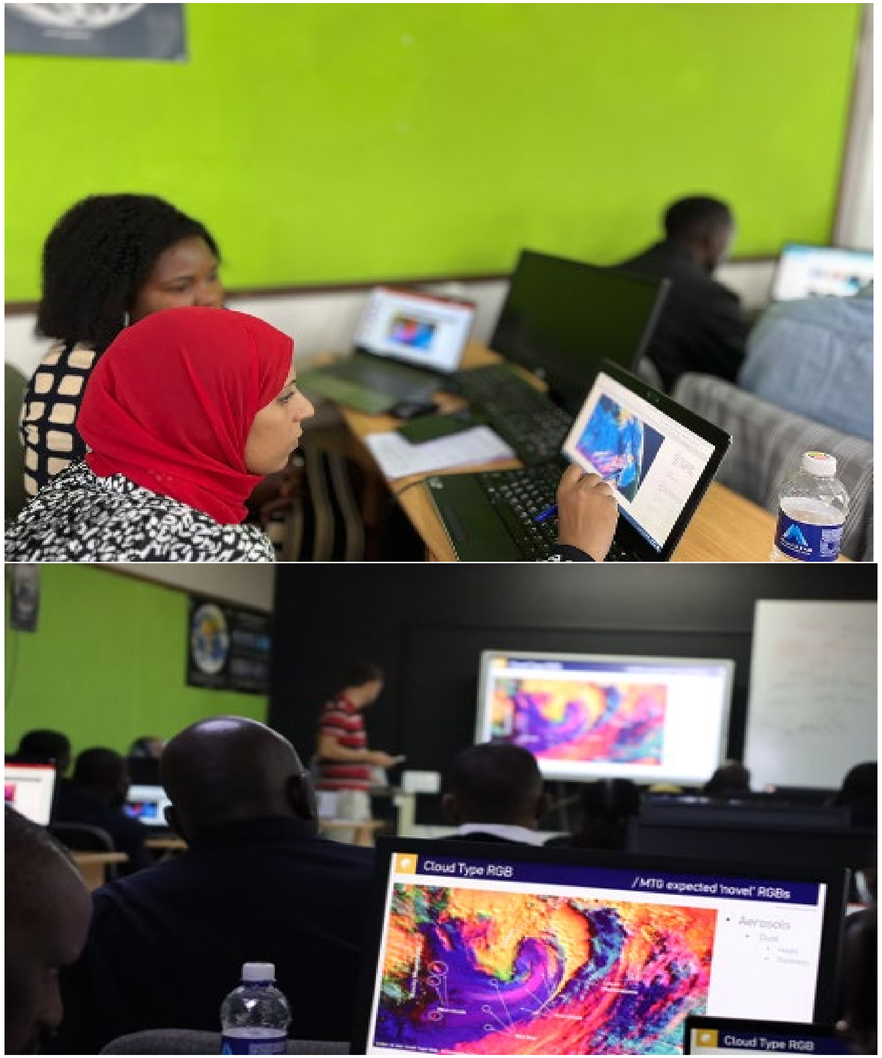


Figure 28: Participants during the WMO Satellite Course on MTG

Figure 29: EUMETSAT Trainer Ivan Smiljanic elaborating to a few Members of Parliament the importance of Satellite data and products during their visit to the Kenya Meteorological Department.

2. Satellite Applications Course (EI-SAC)

The Satellite Application Course (SAC) was offered by IMTR as part of the ASMET (African Satellite Meteorology Education and Training) activities thus was in collaboration with Instructors from South African Weather Service (SAWS Pretoria), EAMAC/ASECNA (Niger), Morocco National Meteorology Department or DNM (Morocco), This online course took place in May 2023 and was designed for operational forecasters, who were early in their career or who needed to refresh their knowledge of the basics of how to use satellite imagery.

The course covered two main areas in satellite skills:

- Skills in understanding the standard satellite products used in operational meteorology.
- Skills in identifying and interpreting atmospheric phenomena.
- Skills in identifying surface features.

The online was attended by approximately 80 participants from across Africa (WMO RA I)

3. Space Weather Forecasting in Aviation Course

The Space Weather Forecasting in Aviation Course took place at Institute for Meteorological Training and Research (IMTR) from 21st August 2023 for a duration of 3 weeks. The Course was attended by seven (7) Aviation forecasters from Rwanda Airport Company. The course aimed at enabling the students understand space weather and the impacts on aviation.

Figure 30: Group photo of the participants and trainers with the Director Kenya Meteorological Services and the Director, IMTR

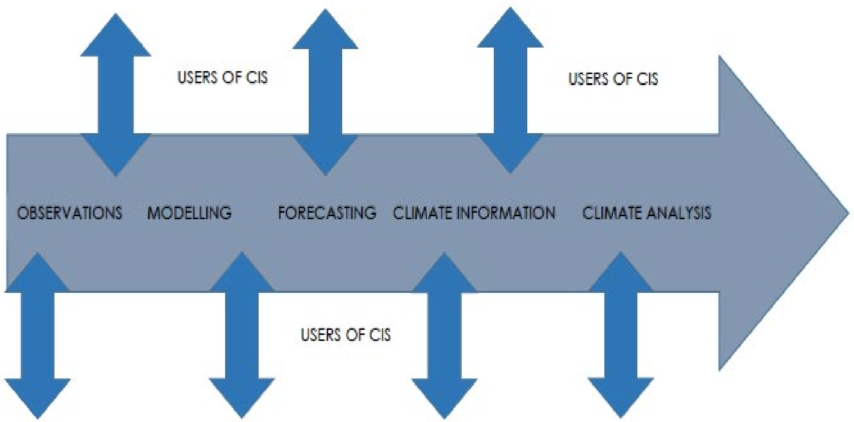
METEOROLOGICAL DATA SERVICES

Every year weather related hazards such as floods, heat waves, droughts, cyclones and hurricanes cause millions of dollars of damage and affect millions worldwide in both developed and developing countries. Effects of weather are nor restricted to large scale hazards. Day to day events that affect virtually everyone have an even larger aggregate impact on the society e.g paralyzed transport or road accidents due to heavy rains. While not all-weather impacts can be avoided or mitigated, there are undoubtedly significant economic and social benefits as a result of timely information on weather and climate.

The Kenya Meteorological Department is mandated with provision of weather and climate information for the safety of life, protection of property and conservation of the natural environment. KMD can achieve this role through effective observation of the atmosphere's parameters, modelling and forecasting, production of climate information services and dissemination of the same, processing and finally production of long-term climate analysis.

Observed meteorological data are unique in the instant and point of observation and have value for weather and climate information as well as historical reference. Operationally data resources are important for forecasting and production of climate information as well as trend analyses that are key in the detection of climate change and variability. On a larger scale meteorological data contributes to national planning, policy formulation and strategic decision making and is also useful for research in meteorology, hydrology and related sciences.

KMD has a rich database of meteorological data collected from both manual and automatic stations. This data is received from the observing stations, digitized, subjected to quality control and finally archived. The Meteorological Consultancy office is mandated with the task of sharing this data with various users of climate data, in accordance with the Data policy. One of the challenges that has been observed over the years is the gap in skills of analysing meteorological data for either research or to inform policy. To improve ease and uptake of meteorological information in a structured and user friendlier manner, KMD has introduced an online platform that affords users access to analyses of rainfall and temperature data for any grid point or ward, sub county and count level of the country.



THE KMD MAPROOM

Climate Data Library is a powerful and freely accessible online data repository and analysis tool that allows a user to view, analyze, and download climate-related data through maproom web portal using a standard web browser.

It is a powerful tool that offers the following capabilities at no cost to the user:

- monitor past, present and future climate conditions with maps and analyses in the Maproom
- create analyses of data ranging from simple averaging to more advanced analyses.
- create visual representations of data, including animations.
- access any number of datasets.
- download data in a variety of commonly-used formats, including GIS-compatible formats.

The data library is built by combining station data and proxy data (satellite and reanalysis dataset) at each grid point. The portal is organised to enable the user navigate through use of administrative boundaries ranging from county to ward level. To support research, the portal, (http://kmddl.meteo.go.ke:8081/maproom/index.html) provides tabs to web pages for historical, current and future climate conditions of a particular location.

Some of the key analysis include:

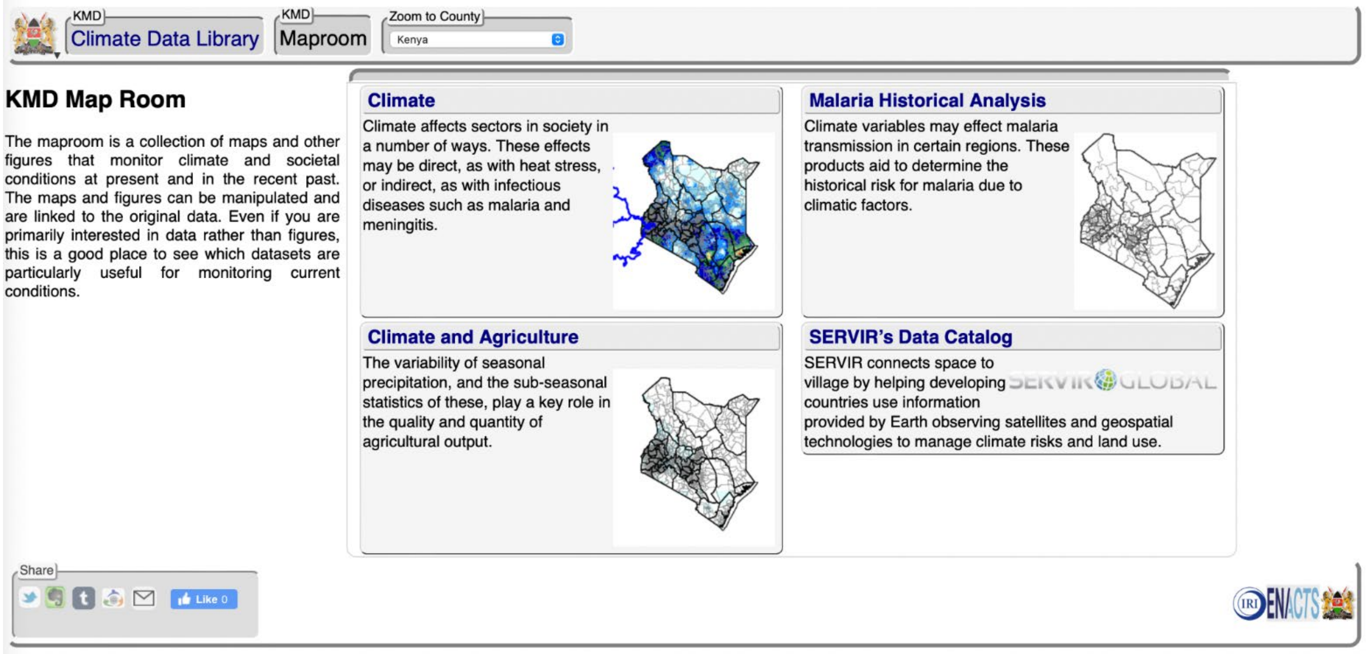
Climate analysis: The maproom explores historical data by calculating simple seasonal statistics such as mean, standard deviation, total cumulative rainfall, no. of wet days, rainfall intensity, no. of dry spells as well as rainfall performance based on the main teleconnections affecting our region e.g Indian Ocean Dipole (IOD) and ENSO (El Nino Southern Oscillation) etc

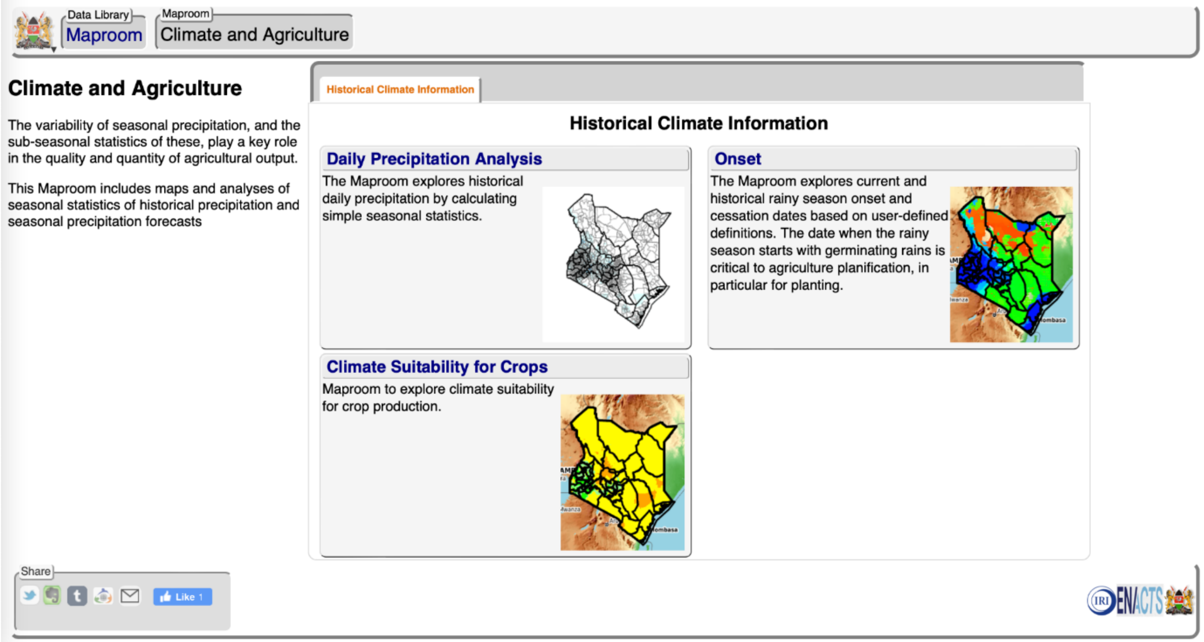
Climate monitoring: Accessing recent/past climate which can be analysed as either dekadal or through monthly rainfall extremes i.e. standard precipitation index (SPIs)

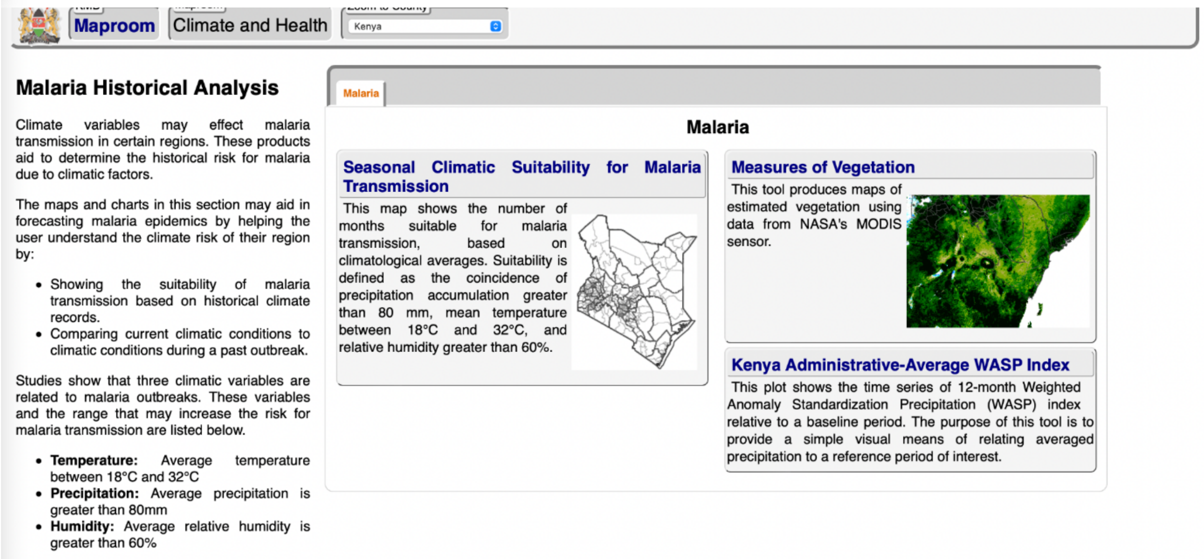
Climate forecast: Users can access Seasonal forecasts rolling monthly. The flexible seasonal forecasts are displayed in full probability distribution.

Climate change: Using the maproom one can access past and future changes in seasonal climate with reference to a historical climatological period

Sector specific climate valuation: Under Climate and Agriculture, one is able to explore crop climate suitability, historical rainy season onset dates based on user-defined thresholds, total cumulative rainfall in a season, onset and cessation dates, probability of exceeding certain thresholds etc







Under Malaria Historical Analysis, one is able to explore the suitability of malaria transmission based on historical climate records and compare current climatic conditions to climatic conditions during a past outbreak.

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