State of the Climate Kenya 2022

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1. Introduction

1.1. General weather and climate features of the Country

The climate of Kenya is highly variable both in time and space. Just like the rest of the East African region and other parts of the tropics, Kenya is prone to climate extremes such as floods, landslides, and droughts (Muhindi et al 2001: Liebmann et al., 2014; Philippon et al., 2015; Uhe et al., 2017; Funk et al., 2018; Kilavi et al., 2018). In the last decade alone, the frequency and severity of climate extremes is increasingly evident as global warming and climate change continue to be experienced across many parts of the world (IPCC, 2021: Lott *et al.* 2013; Holden *et al* 2022).

Kenya is located in Eastern Africa between latitudes 5^{o} North and 5^{o} South and between longitudes 34^{o} East and 42^{o} 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 Northwest, Eastern and some parts of the South-east 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.

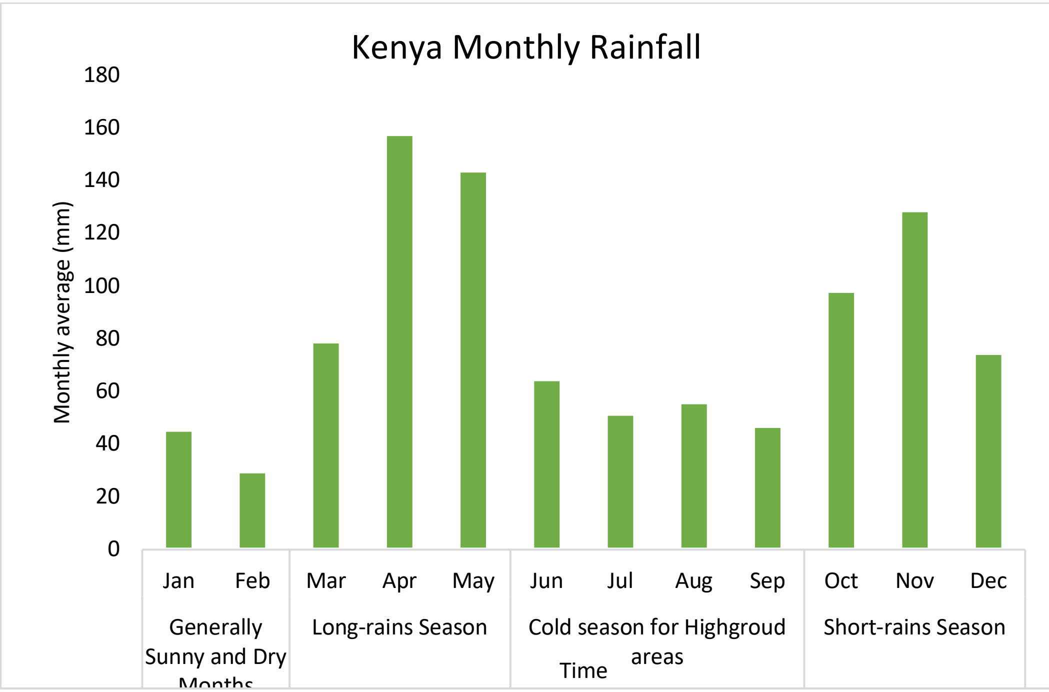


Figure 1.1: *Monthly distribution of average rainfall across Kenya*

The "long rains'' season occurs from March to May (MAM) and the "short rains" season from October to December (OND (Fig 1.1)). However, 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 and contributes to 26% of the Gross Domestic Product (GDP) and an additional 27% of GDP from indirect linkages with other sectors. 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. The performance of the tourism sector, which is a main foreign exchange earner for Kenya, is influenced by rainfall and temperature fluctuations. Health, sanitation, and human settlements are likewise impacted by changes in weather and climate and even more so as climate changes. The energy and transport sectors are directly impacted by weather. For example, temperature fluctuations and severity of extreme weather events – such as heavy rains resulting in floods – damages 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.

The main driver of weather and climate conditions in Kenya is the bi-annual northward and southward movement of the overhead sun across the equator. The movement of the overhead sun influences the position of the Inter-Tropical Convergence Zone (ITCZ) (Muhindi et al 2001). Other important drivers include the El Nino Southern Oscillation, Indian Ocean Dipole and the Congo Basin Air mass among others. According to the annual rainfall distribution patterns, the climatology of Kenya can broadly be defined as indicated in Figure 1.2.

The counties in the highlands west of the Rift Valley receive the highest rainfall amounts annually of more than 1800mm, a few other counties in the central highlands east of the Rift Valley likewise receive high annual rainfall amounts.

Counties that receive the lowest annual rainfall amounts are generally arid or semi-arid ones which include those in Northwest and Northeast Kenya.

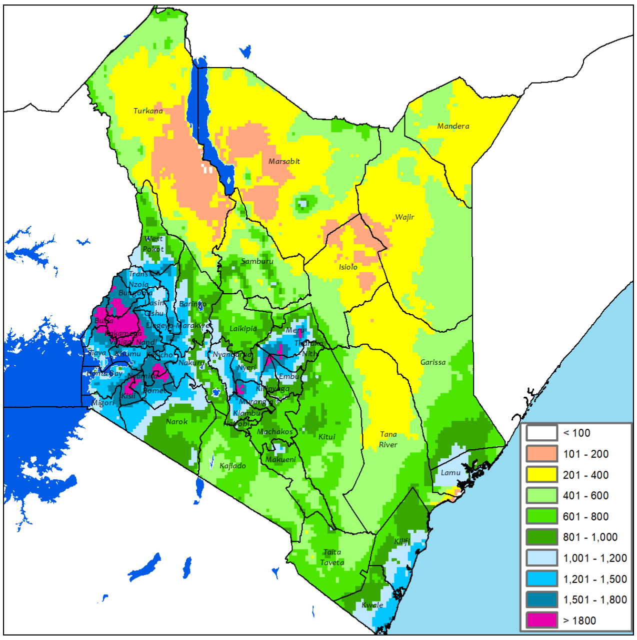


Figure 1.2: *Rainfall climatological zones of Kenya based on annual total rainfall*

The temperature patterns in Kenya are highly variable in time and space, with the highest temperatures ranging from 35^{o}C to 40^{o}C occurring in Northwestern and Northeastern regions during the months of January to March, while the months of June to August are characterized by cooler temperatures in most parts of the country. The lowest temperatures (ranging from 3^{o}C - 6^{o}C) are observed in central regions of Kenya particularly, Nyahururu.

With regard to wind, the Northwest of the country (Marsabit and Turkana counties), the edges of the Rift Valley, as well as the coastal area, enjoy fairly good wind speeds and have the potential to be successfully exploited for energy generation (Kazimierczuk, 2019). Based on analysis of station data, the surface wind patterns in Kenya range from moderate to strong southeasterly winds, especially over the eastern and northern parts of the country during the months of May, June, July and August. The rest of the year experiences relatively calm winds bringing in moisture or dry air, depending on the season.

For the evaluation of the state of the climate for 2022, 32 stations across the country with full rainfall data and 30 stations with full maximum and minimum temperature data were used.

2. Observed Behavior of some key Climatic Parameters in 2023

2.1 Temperature

Figure 2.1(a) shows the spatial temperature anomaly for the year 2022 in reference to the climatological period 1991-2022. Generally, the temperatures during the year 2022 were higher than average. Above normal temperatures prevailed in Northern, northeastern, central highlands and southeast lowlands. Slightly below normal temperatures were experienced along the coastal strip and the inland regions of Garissa, and around the Lake Victoria Basin.

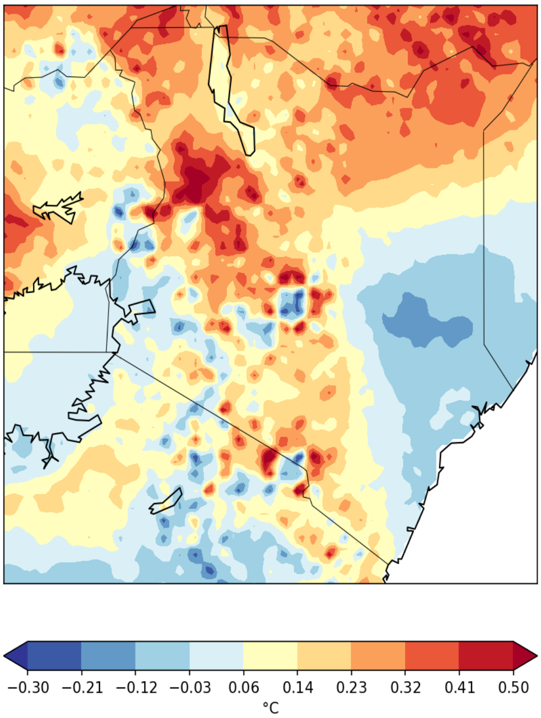


Figure 2.1(a): *Annual average temperature anomaly for 2022 relative to the reference period 1991-2022.*

An analysis of the monthly distribution of temperatures shows that March was the hottest month with an average of 23.3°C while August was the coolest with an average temperature of 19.7°C and July 19.8°C (Figure 2.1(b)).

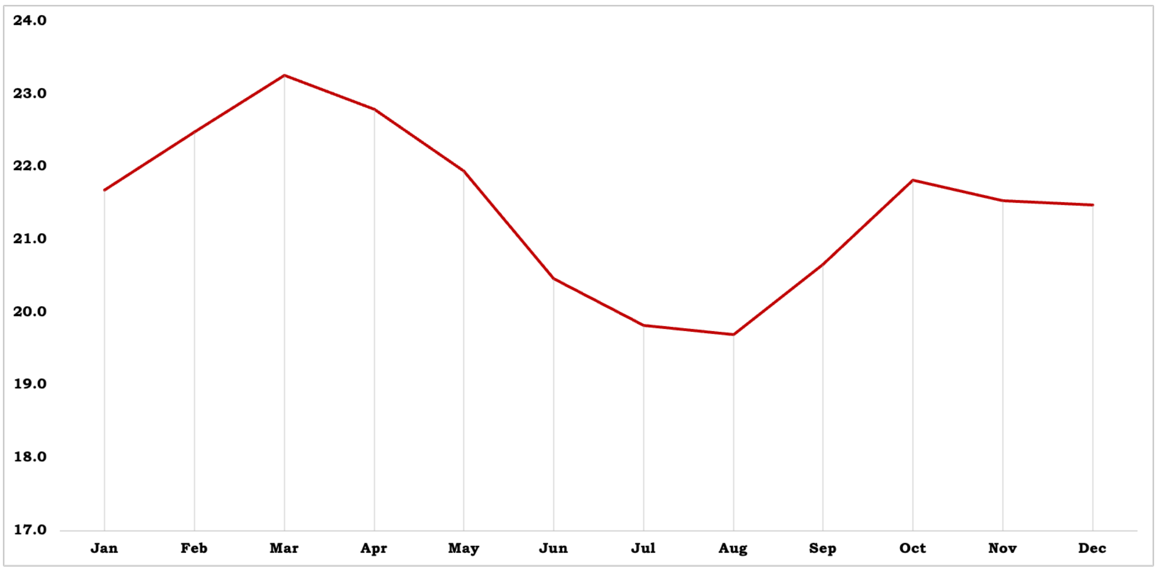


Figure 2.1(b): *Temperature distribution across the year 2022*

2.2 Precipitation

The year 2022 saw most parts of the country experiencing below average rainfall across the country during all seasons (Figure 2.2), more so in the northeastern regions that are still in the throes of a long drought that has ravaged the region from 2020.

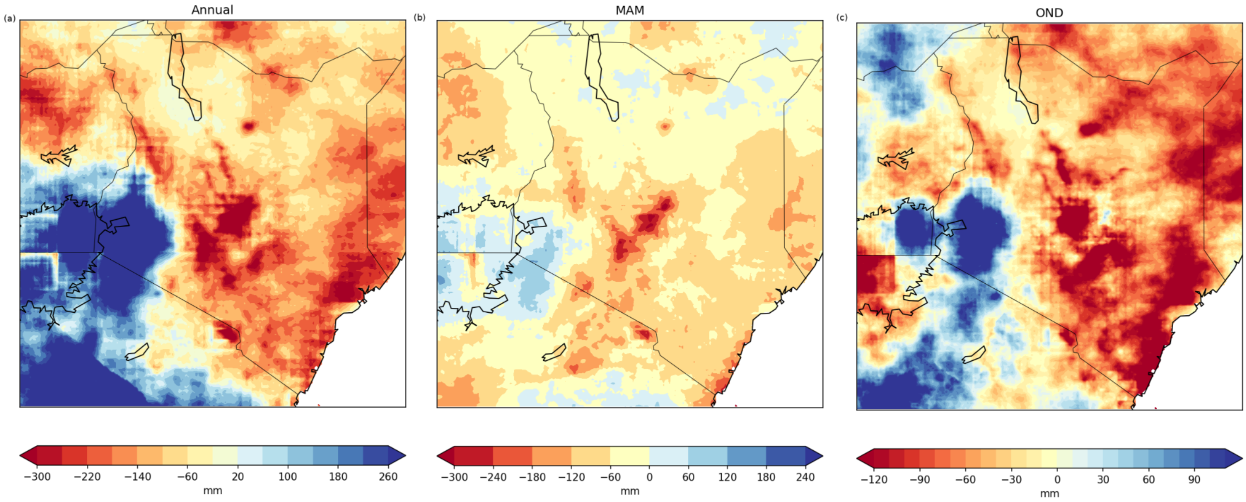


Figure 2.2: *Spatial distribution of rainfall anomalies for 2022 at annual (a), and seasonal; March-April-May (b) and October-November-December (c) time scales.*

2.2.1 Review of rainfall during the Long Rains Season March to May (MAM) 2022

An assessment of the rainfall recorded from 1st March to 31st May 2022 indicates that the rainfall performance was depressed over the country. The distribution, both in time and space, was generally poor over most parts of the country. The rainfall in March was depressed over most parts except Moyale, Kisumu, Voi and Laikipia that recorded near average amounts. In April and May 2022, most parts of the country received near to below average rainfall except Wajir and Nakuru that recorded above average figures in May. The season was characterized by long dry spells due to development of tropical cyclones over the southwest Indian Ocean, which affected the overall distribution in space and time.

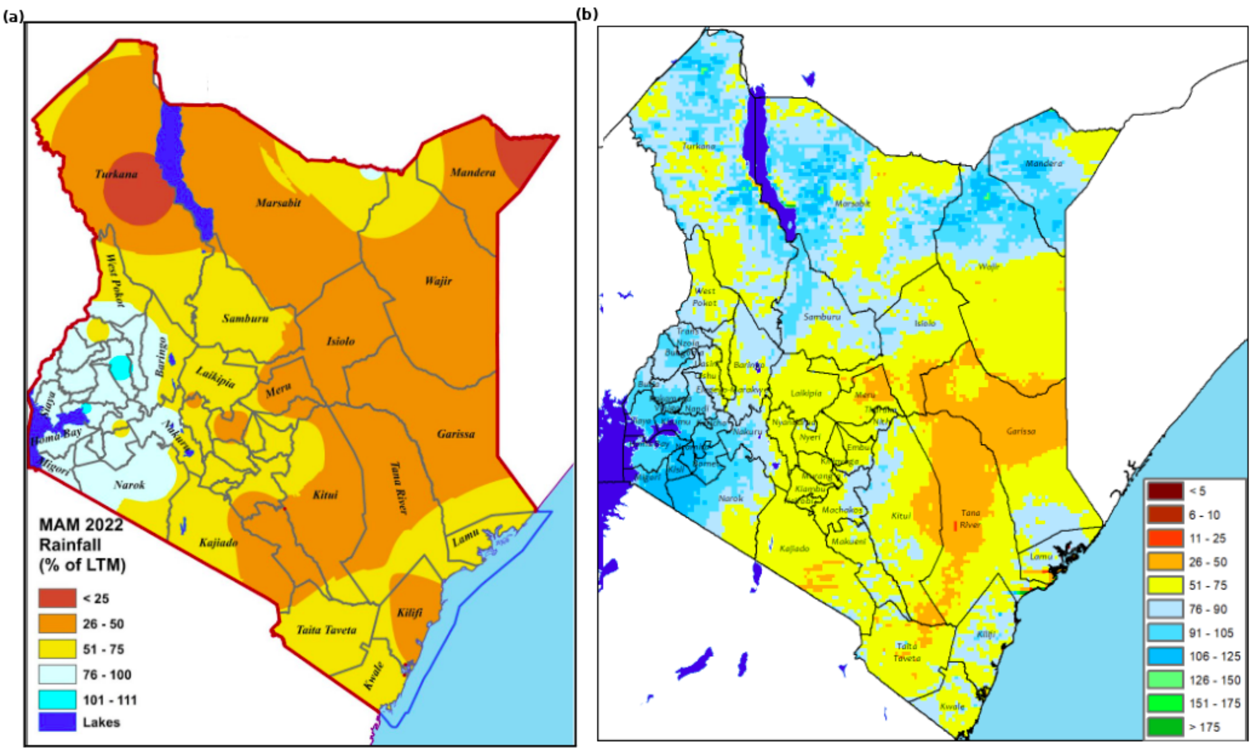


Figure 2.3: *MAM 2022 Rainfall Performance (% of LTM) using (a) station data (b) Chirps data*

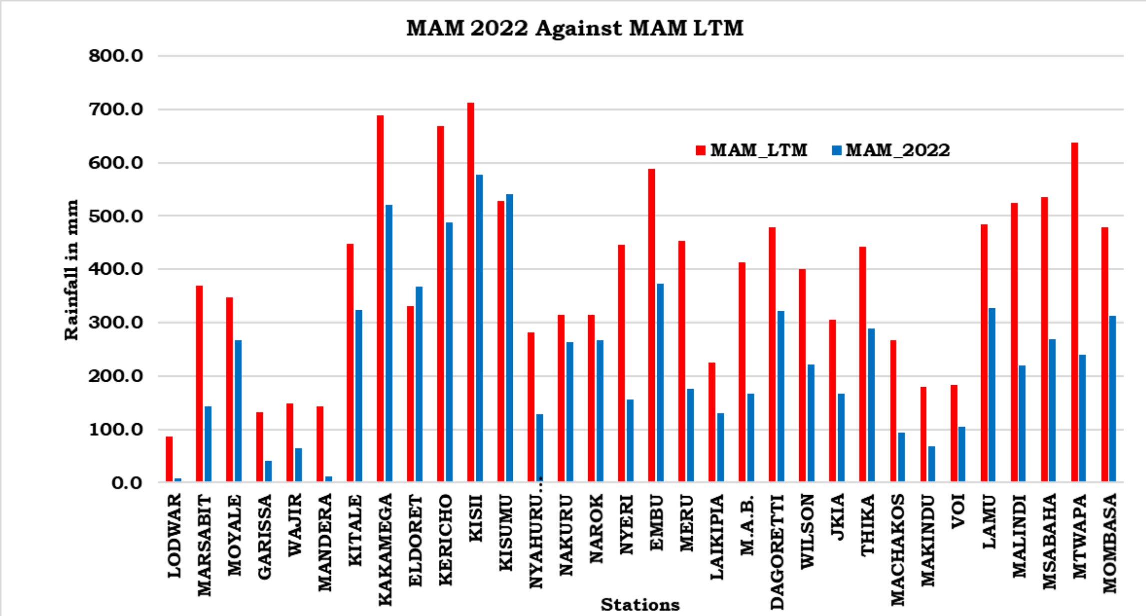


Figure 2.4: *MAM 2022 Rainfall Totals against MAM LTM (1991-2020).*

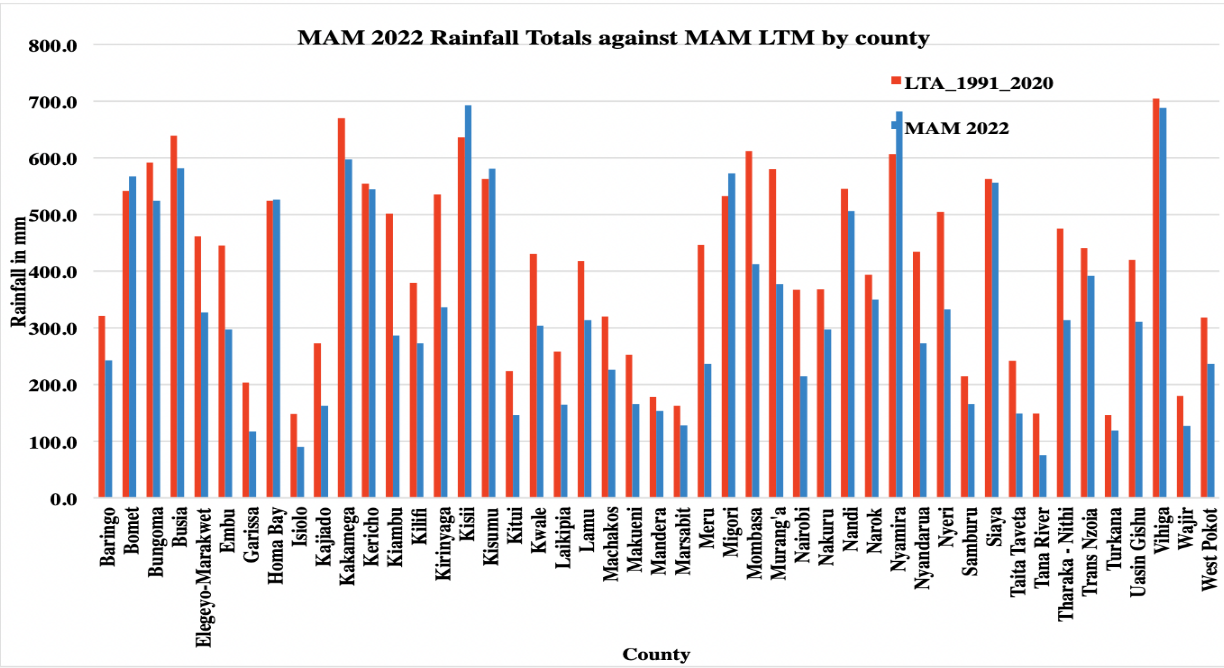


Figure 2.5: *County total rainfall for the MAM season based on KMD stations data*

2.2.2 Review of rainfall during June to August 2022

Several parts of the country experienced dry weather conditions. However, the western sector of the country, the coastal region and a few areas over the Highlands East of the Rift Valley experienced some rainfall during June-July-August (JJA) 2022. Near average to above average rainfall was recorded over several parts of the Highlands West of the Rift Valley, the Lake Victoria Basin, Central and South Rift Valley. Near average rainfall was recorded along the Coastal region, while near to below average rainfall, with cold and cloudy conditions were experienced over the Highlands East of the Rift Valley, including Nairobi County. The Northeast, Northwest and Southeastern lowlands remained generally dry. The JJA temperatures were generally warmer than average over much of the country.

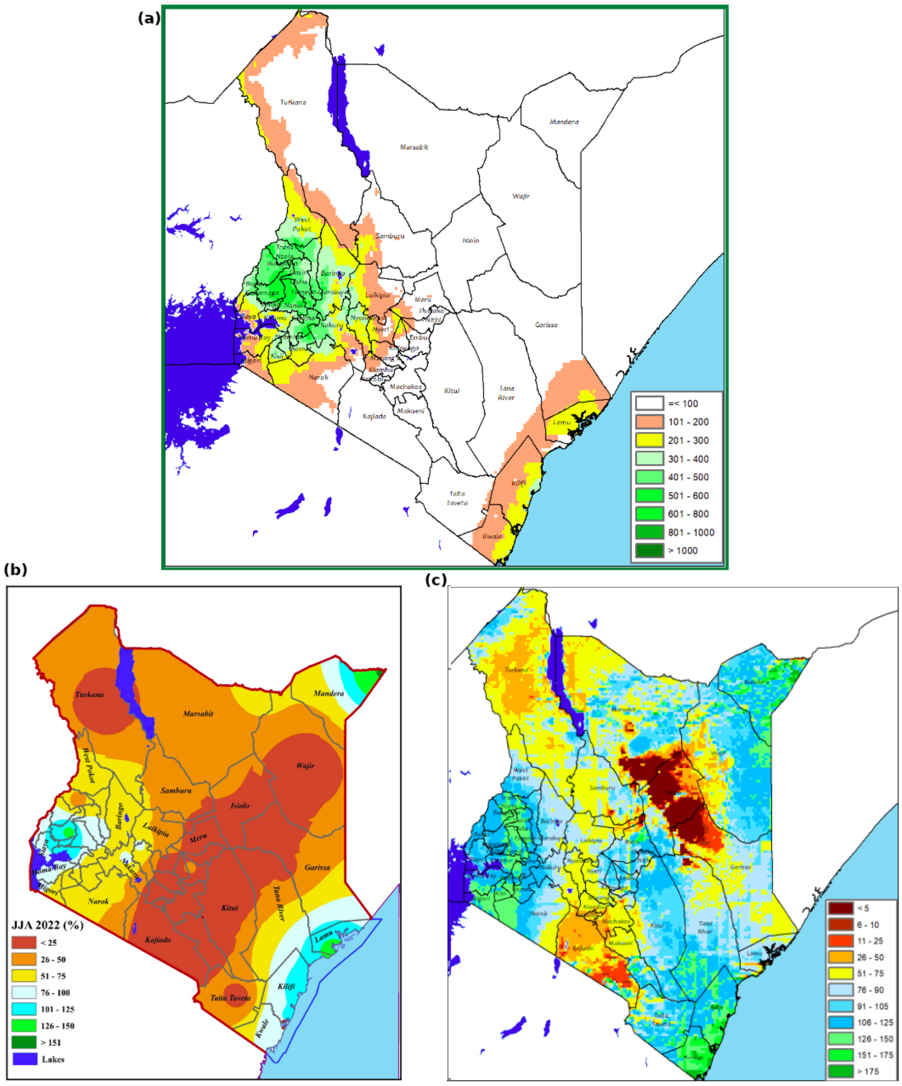


Figure 2.6: *(a) JJA climatological rainfall (1991-2022). JJA rainfall performance (% of normal) based on (b) Station Data and (c) CHIRPS blended data*

2.2.3 Review of rainfall during October to December (OND) 2022

Depressed rainfall was reported over much of the country as the drought continued its grip on the country. The start of the seasonal rains (onset) was well within the predicted times over several parts of the country. However, the onset was delayed over a few areas in the southeastern lowlands while over the coast and parts of the southern Rift Valley, there was a false onset that was followed by long dry spells. In some stations such as Machakos and Msabaha meteorological stations, the onset criteria were not met. The rainfall distribution both in time and space was poor throughout the country especially in October and December. In November, the distribution was good over several parts of the country except over the northern sector and parts of the southeastern lowlands (Machakos) where distribution was poor. The poor rainfall performance over several parts of the country was mainly as a result of the La Nina conditions owing to the prevailing cooler than average SSTs in the central and eastern Equatorial Pacific Ocean and the warmer than average Sea Surface Temperatures in the Western Equatorial Pacific Ocean. The Indian Ocean dipole (IOD) remained negative in October and November and was neutral in December.

The seasonal rainfall analysis from 1st October to 31st December shows that depressed rainfall was received over North-western, Coast, most stations over the Southeastern lowlands and Northeastern, several stations over the Highlands East of the Rift Valley including Nairobi County and a few stations over the Highlands West of the Rift Valley and Central Rift Valley. Kakamega

Kericho, Garissa, Kisii, Narok, Eastleigh, Thika, Makindu, Nyahururu, Embu, Kisumu, and Kitale are the only stations that recorded near average rainfall. All the other stations recorded less than 75% of their OND long term means (LTMs), with Lodwar recording the lowest percentage at 15.2%

The highest seasonal total rainfall was received at Kericho Meteorological station, which recorded 588.2mm. Other stations that recorded significant amounts of rainfall are Kakamega (532.6mm), Kisii (514.2mm), Meru (457.2mm), Embu (387.7mm), and Thika (319.0mm). The other stations recorded between 100-295mm except Machakos, Mandera, Marsabit, Msabaha, Wajir and Lodwar that reported 75mm, 72.5mm, 55.3mm, 47.1mm, 30.2mm and 8.5mm respectively.

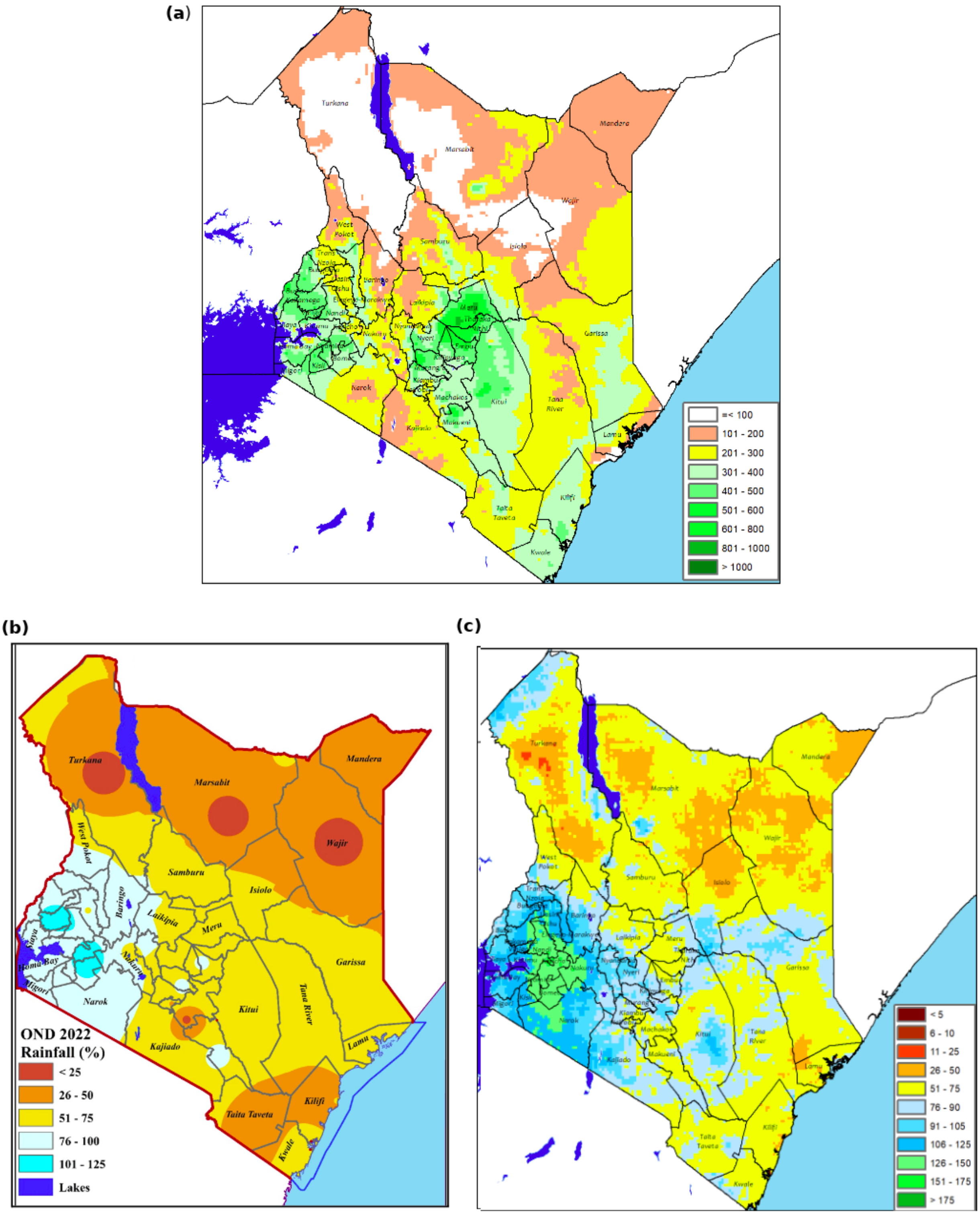


Figure 2.7: *(a) OND climatological rainfall (1991-2022). OND rainfall performance (% of normal) based on (b) Station Data and (c) CHIRPS blended data*

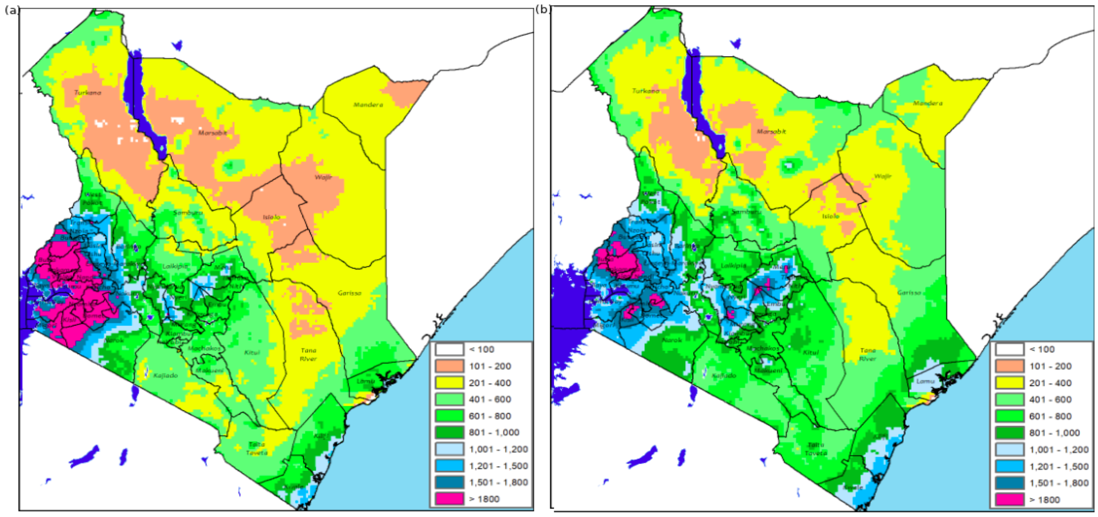


Figure 2.8: *(a) Annual Rainfall Totals for 2022 (b) annual average climatological rainfall (1991 - 2020) period*

2.3 Marine weather

The state of the sea over Western Indian Ocean (WIO), is influenced by the seasonal monsoon winds. Figure 2.9 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 characterized 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 8(d), the wind speeds over the EEA coast are low as compared to the SE monsoon occurring during JJA as shown in Figure 8 (b). The reduction in wind speeds is characterized by the transition period during SON season when the sun is overhead over EEA. From Figure 8 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 characterized by rough seas caused by strong winds of more than 17 knots and high waves of more than 2 meters.

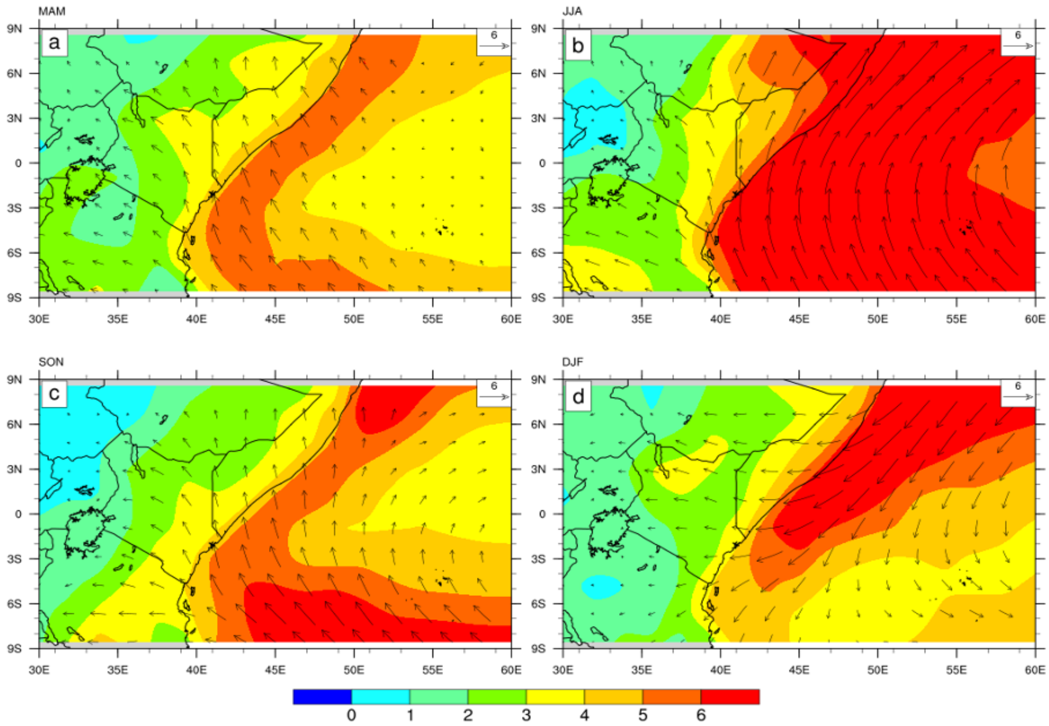


Figure 2.9: *Seasonal distribution of the 10m wind directions (vector) and 10m wind speed m/s shading (a) MAM (a) JJA (c) SON (d) DJF*

The 2021-2022 cyclone season was characterized by near-normal activity in the South-West Indian Ocean cyclone basin. The tropical cyclone season in the southwest Indian Ocean always starts in early November and ends in April of the following year. This season could therefore have 8 to 12 systems (tropical storms and cyclones), with 4 to 6 among them reaching the stage of a tropical cyclone. In a large-scale context similar to that of the previous year, the genesis area was favored 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).
No major impacts associated with tropical cyclones were recorded along the Kenyan coast during the year.

3. Trends

This section assesses the trends in rainfall and temperatures for the 1991-2022 and highlights the trend behavior for the year 2022.

3.1 Precipitation Trends

Total annual and seasonal (MAM and OND) climatological trends in precipitation are analyzed for selected representative stations (Figures 3.1 and 3.2) and across the country (Figure 3.3). The stations are representative of four homogeneous climatological zones. The analysis is based on KMD station (for the selected station) and CHIRPS gridded (country-wide) data. Lodwar, Mombasa, Dagoretti, and Kakamega stations are representative of Northwestern, Coast, central highlands, and western highlands respectively. Results show high variability of rainfall in time with no consistent trend. The highest rainfall amounts were recorded in 1998 and 2018, both country-wide and over the stations. High seasonal variability also characterizes the rainfall in MAM and OND seasons. Lodwar station shows an upward trend in rainfall till the end of the first decade of the 21st century after which a decline is observed. In 2022, annual rainfall is near-equivalent to the climatology. For Mombasa station, a general decline in rainfall from late 1990s is observed. The highest rainfall amounts were recorded in 1997, while 2021 was the driest year. Rainfall in 2022 was somewhat equal to the long term mean. Upward rainfall trends are observed in Kakamega station while no consistent pattern is seen in Dagoretti station. There is a general upward trend in total annual rainfall. The years 1997, 2018 and 2022 were the wettest, while 2005 was the driest. Below-normal rainfall was recorded in 2022. For MAM, a downward trend in rainfall from the early 2000s to mid-2015 dominates the pattern. Spikes are recorded in 2018 and 2020. The driest seasons in the climatological period remain the years 2000 and 2011. There is no significant trend in OND total rainfall. The OND seasons of 1997 and 2019 were the wettest on record while 2005 and 1998 were the driest. The 2022 annual and seasonal totals were below the climatological mean.

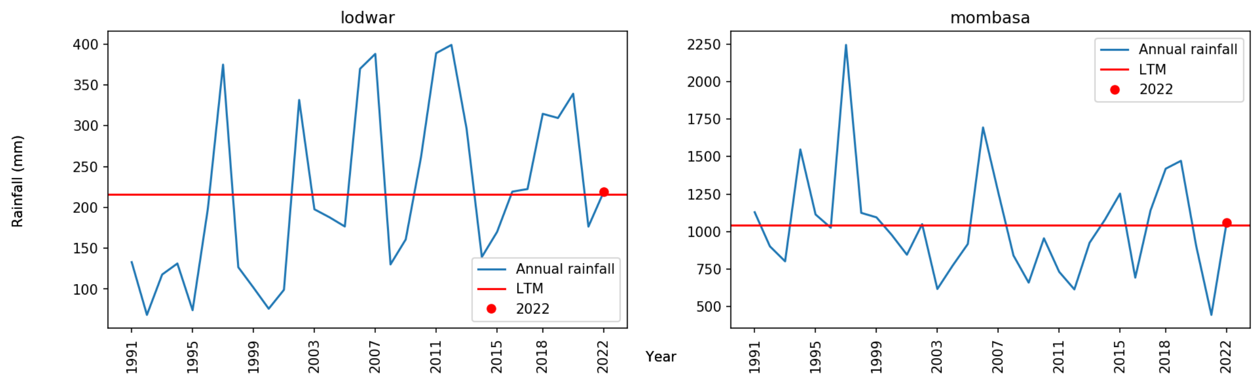


Figure 3.1: *Trends in annual rainfall for Lodwar and Mombasa stations in northern and coastal regions of Kenya, respectively.*

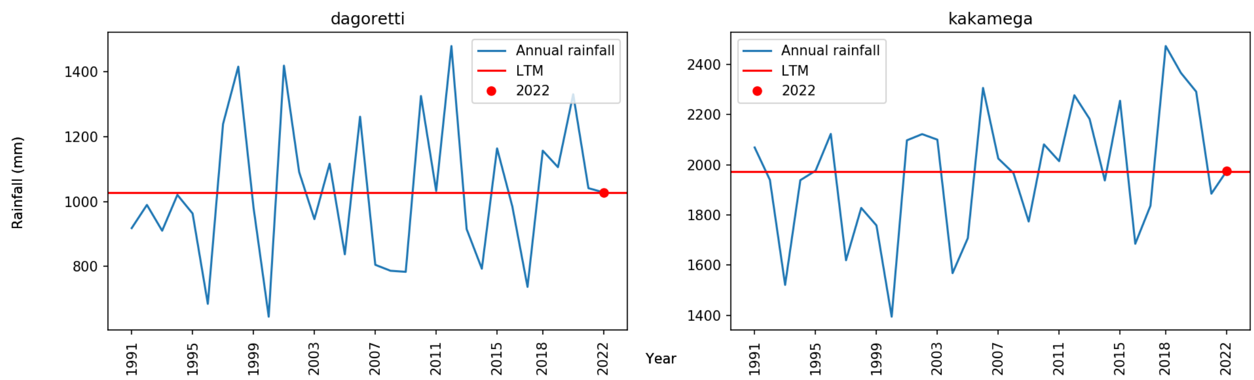


Figure 3.2: *Trends in annual rainfall for Dagoretti and Kakamega stations in central and western highlands of Kenya, respectively.*

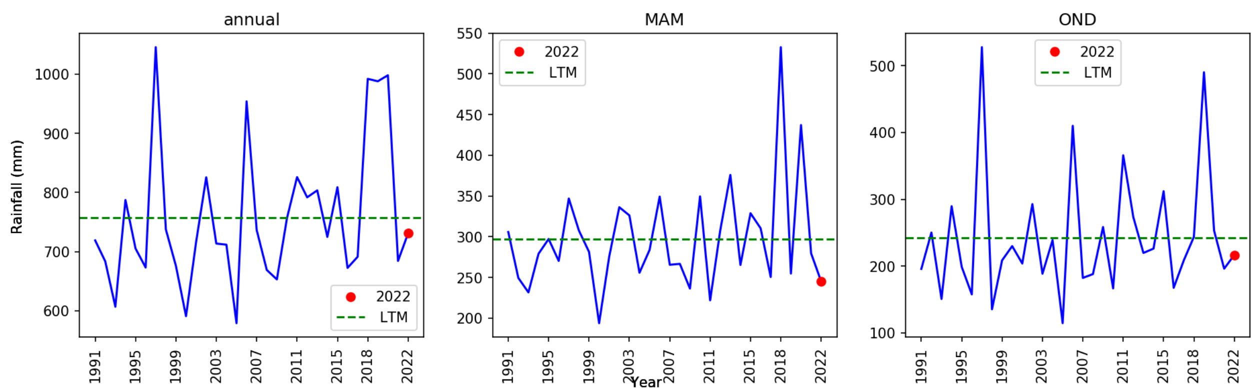


Figure 3.3: *Trends in total annual (a), seasonal MAM (b), OND (c) rainfall. The red marker indicates the 2022 value*

3.2 Temperature Trends

This section presents annual trends of temperature in selected stations (maximum, average and minimum) and country-wide (average). The stations are representative of four homogeneous climatological zones (see Section 3.1 for description). Similar to rainfall trends, the station analysis is based on KMD data. The gridded analysis is based on ECMWF ERA5. For Mandera and Lodwar stations, the year 2022 was warmer than normal in terms of maximum, minimum and average temperatures. Since 1991, there has been a general upward trend in temperature, more pronounced in Mandera. In Kakamega, a considerable increasing trend in maximum, minimum and average temperature is seen throughout the climatological period. The year 2022 was warmer than normal, and the warmest year based on minimum temperature. Kisii, on the other hand, registered average temperature conditions in 2022. Despite recording warmer than normal conditions in 2022, stations in the central highlands such as Nyeri and Dagoretti do not exhibit consistent trends in maximum and minimum temperatures. Minimum temperatures show a consistent upward trend while maximum temperatures exhibit less consistency. For Lamu and Mombasa in the coastal strip, 2022 was warmer than climatology and trends in temperature (max, min and average) have been on the rise since 1991. The average annual change throughout the country shows that the temperature rise was 0.5°C above average during the year, using all the available station data (not shown). The year 2021 had a similar rise of 0.5°C compared to the same period??? (complete this statement). Based on analysis of data from 1975, the year 2022 was the 3rd warmest year on record tying with 2021 and following closely behind 2019 and 2020 as first and second warmest respectively.

Maximum temperature analysis shows that for most parts of the country, the temperature experienced in 2022 falls within the top five of the available records, which in most cases is based on data records dating back to 1975. Kisumu was the only station that recorded lowest maximum temperature values compared to all the years on record at 28.8°C. Minimum temperature analysis shows that 2022 had some of the warmest temperatures, falling generally within the top five of the available records.

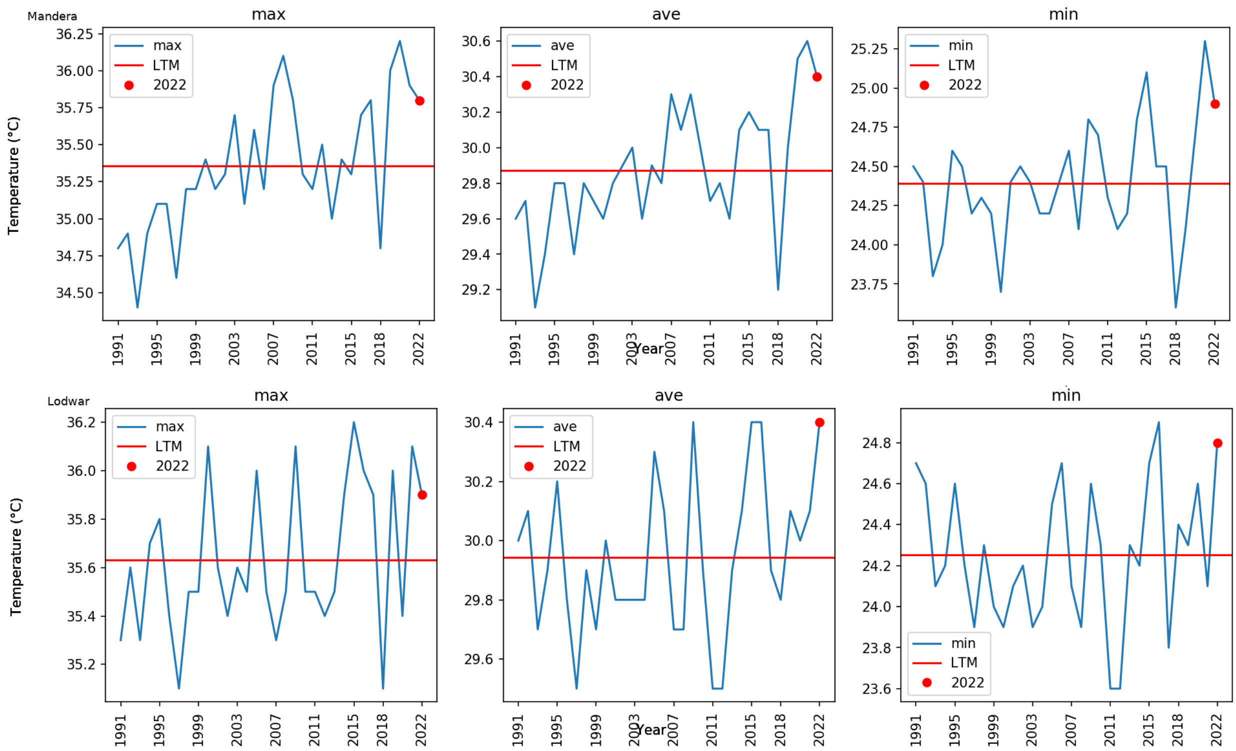


Figure 3.5: *Trends in Maximum, Minimum and Average temperatures in the Northern Kenya stations of Mandera and Lodwar. The red marker shows the 2022 temperature record.*

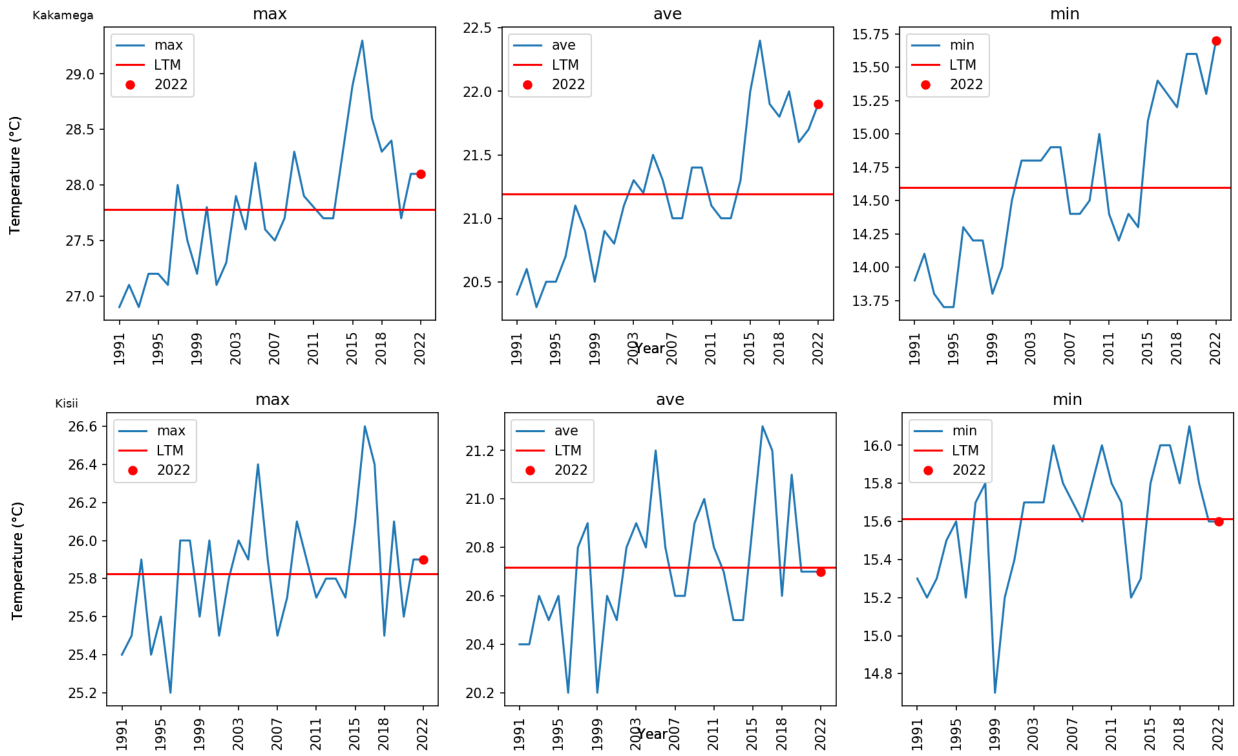


Figure 3.6: *Trends in Maximum, Minimum and Average temperatures in the western highlands of Kenya stations of Kakamega and Kisii. The red marker shows the 2022 temperature record.*

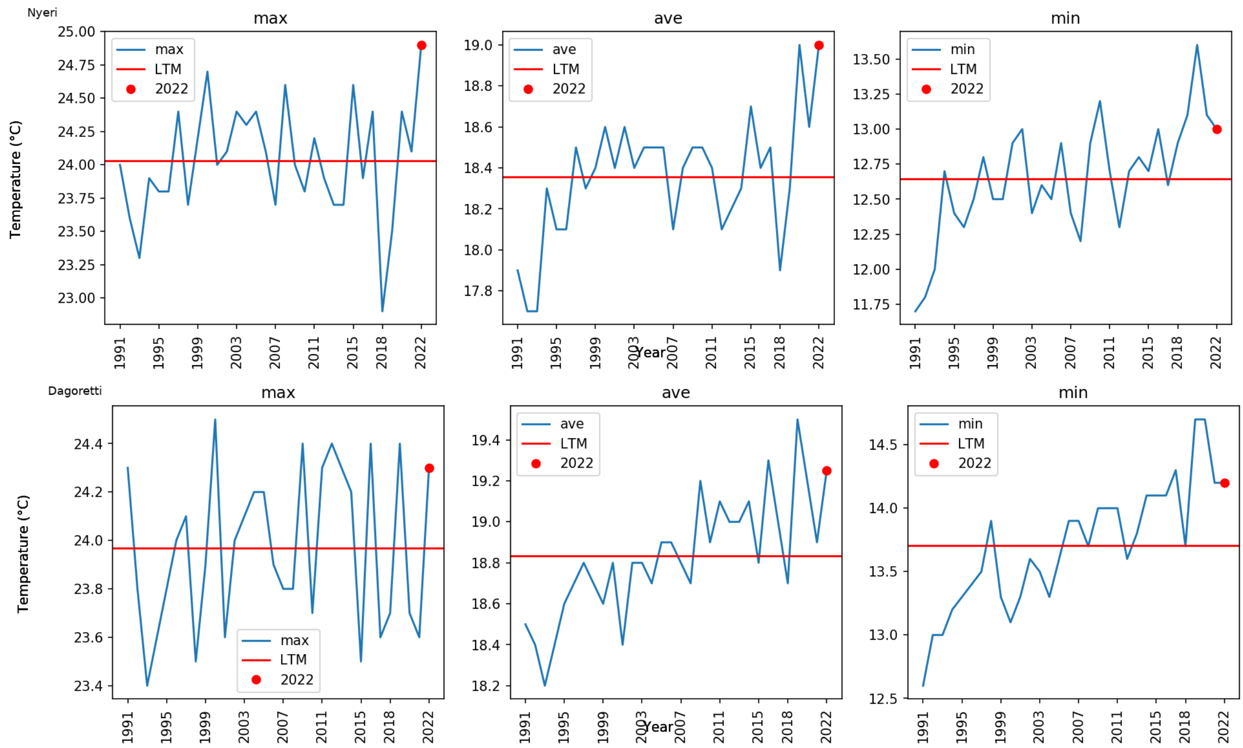


Figure 3.7: *Trends in Maximum, Minimum and Average temperatures in the central highlands of Kenya stations of Nyeri and Dagoretti. The red marker shows the 2022 temperature record.*

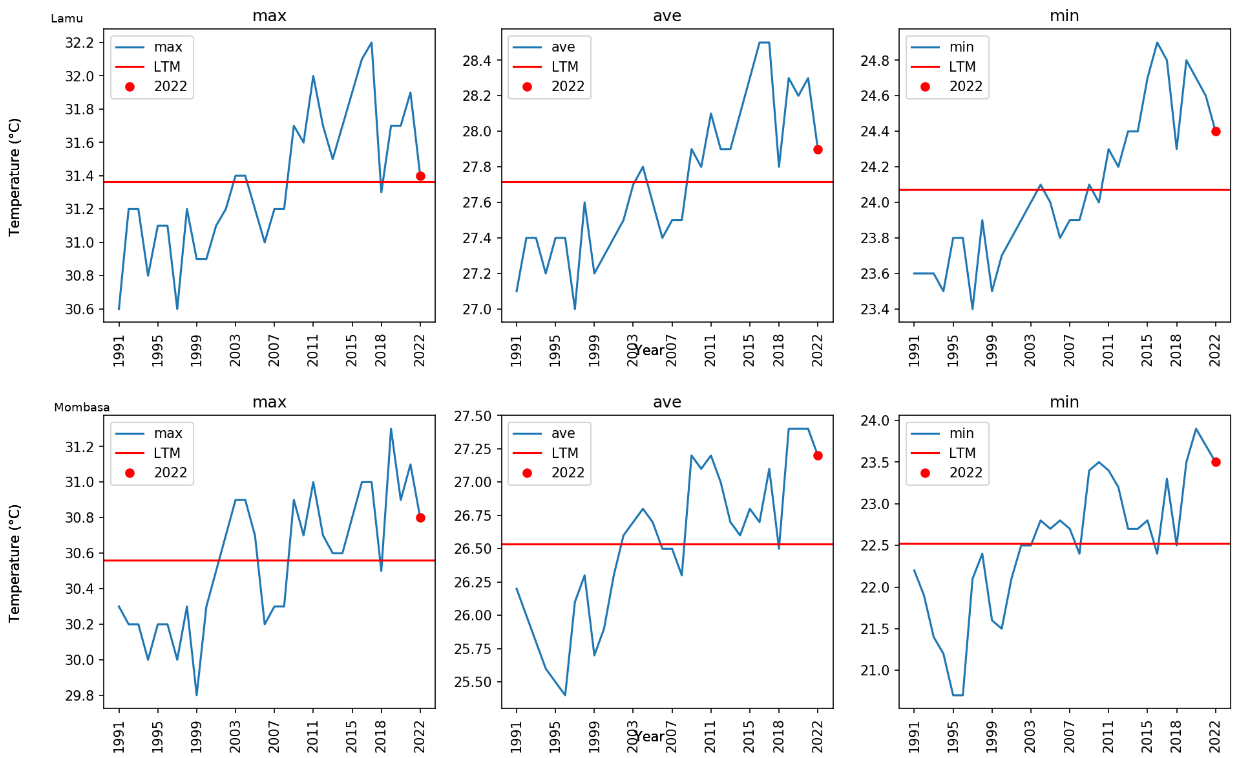


Figure 3.8: *Trends in Maximum, Minimum and Average temperatures in the coastal stations of Lamu and Mombasa. The red marker shows the 2022 temperature record.*

4. Observed Climate Drivers

Climate drivers like Southern Oscillation Index, Indian Ocean Dipole (IOD), Tropical cyclones and other sea surface temperature differences influence the Year-to-Year differences in rainfall for a given season/region although they do not fully determine the seasonal outcome.
Research conducted over recent decades has shed considerable light on the important role played by interactions between the atmosphere and ocean in the tropical belt of the Pacific Ocean in altering global weather and climate patterns including across the East Africa region. During El Niño events, for example, sea temperatures at the surface in the central and eastern tropical Pacific Ocean become substantially higher than normal. In contrast, during La Niña events, the sea surface temperatures in these regions become lower than normal. These temperature changes are strongly linked to major climate fluctuations around the globe and once initiated, such events can last for 12 months or more.

Rainfall seasons in Kenya are mainly influenced by the prevailing and the expected evolution of Sea Surface Temperature Anomalies (SSTAs) over the Pacific, Indian and Atlantic Oceans as well as the synoptic, mesoscale and local factors that typically affect the climate of Kenya.

During 2022 these factors were assessed using various tools including ocean-atmosphere models, statistical models, satellite derived information and expert interpretation. The global drivers considered included the Neutral Indian Ocean Dipole (IOD), negative El Niño Southern Oscillation (ENSO), Quasi Biennial Oscillation (QBO) and Madden-Julian Oscillation (MJO).

4.1 El Niño/La Niña Southern Oscillation (ENSO)

The El Niño/La Niña Southern Oscillation (ENSO) has a major influence on climate patterns in various parts of the world. This naturally occurring phenomenon involves fluctuating ocean temperatures in the central and eastern equatorial Pacific, coupled with changes in the atmosphere. Scientific progress on the understanding and modeling of this phenomenon has improved prediction skills to within a range of one to nine months in advance, giving society the opportunity to prepare for associated hazards such as heavy rains, floods and drought.

During the year 2022, ENSO was negative (La Niña was present) for most of the year. This has been persistent with slight interruptions in 2020 and has had an influence over the rainfall received in Kenya, especially in the OND season where depressed rainfall was recorded.

Table 1 indicates the varied ENSO indices in 2022. Below average sea surface temperatures were recorded across most of the Pacific Ocean.

Table 1: ENSO indices 2021 - 2022

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.5	0.5	0.4	0.2	-0.1	-0.3	-0.4	**-0.6**	**-0.9**	**-1.2**	**-1.3**	**-1.2**
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**

4.2 Indian Ocean Dipole

The Indian Ocean Dipole (IOD) is the irregular, though sustained oscillations of sea surface temperatures of the tropical western and eastern Indian Ocean. The IOD is one of the key drivers of Kenya's climate and can have a significant impact on agriculture and food security among other sectors. The IOD 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 OND season. In 2022, the IOD was largely negative to neutral and thus had an impact on the depressed rainfall experienced in Kenya, especially during the OND season.

4.3 Tropical cyclones in 2022

The South-West Indian Ocean cyclone season of 2021–22 recorded a first-ever late start for a system to develop. Despite the slow start, the season had 12 named storms, five of which developed into tropical cyclones. With the exception of Mauritius and the Seychelles, where it ended on 15 May 2022, the season started on 15 November 2021 and ended on 30 April 2022.

The tropical cyclones in the SWIO affect the weather in EA by either influencing the influx or deficit of moisture into the region depending on the path and direction. Notable cyclones reported during the 2021 - 2022 season were Ana, Batsirai, Cliff, Dumako, Emnati, Fezile, Vernon, Gombe and Halima.

5. Extreme Events in 2022

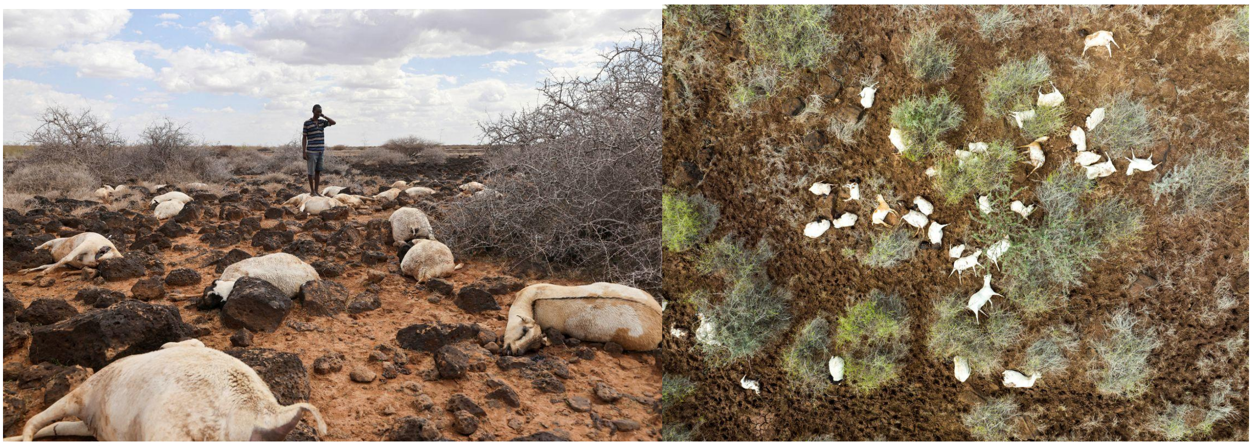
This section outlines extreme events that happened during 2022

5.1 Flood events

During 2022 some isolated flooding incidents were reported. For example, on 17th January 2022 Marsabit received heavy rainfall (89.9mm) that led to flooding that swept away 1,500 sheep and goats, destroying the livelihoods of local farmers. The drastic change from hot weather to heavy rainfall and cold weather also led to further losses of livestock. In September, heavy rainfall in Kisumu led to bursting of the banks of rivers draining into Lake Victoria; the flash flooding led to loss of property but no deaths.

Between November 16th and 18th 2022, the Taveta Sub County experienced heavy rains, primarily within the national park, where the storm water caused flash floods in the neighboring Mata

Ward, affecting 41 acres of crop production and rendering roads to the main health facility, schools, and main shopping center impassable, as well as hampering ferrying of farm produce from the irrigated zone.



REUTERS/Baz Ratner

Figure 5.1: *Carcasses of goats and sheep which died due to cold weather brought about by heavy rains, near Huri Hills, Marsabit County.*

5.2 Drought

The prevailing extreme event has been drought during 2022 that extended from 2021. By the end of 2022, 4.5 million people (Source: NDMA) were in dire need of food. It is estimated that over 2 million livestock were lost in 2022 alone due to the prevailing drought. By December 2022, the drought situation was still critical in 22 of the 23 arid and semi-arid (ASAL) counties due to the late onset and poor performance of October to December 2022 short rains, coupled with four previous consecutive failed rainfall seasons. Nine of these counties: Kilifi, Mandera, Marsabit, Samburu, Turkana, Wajir, Isiolo, Kitui and Kajiado were in *Alarm* drought phase while 13 counties were in *Alert* drought phase. These include Garissa, Lamu, Narok, Tana River, Makueni, Tharaka Nithi, Baringo, Laikipia, Meru, Taita Taveta, West Pokot, Nyeri and Kwale. Embu county was the only ASAL county that was classified in the *Normal* drought phase by the end of the year. Many pastoral communities inhabiting these regions lost their livestock and livelihood. The drought significantly hampered crop production and affected livestock farming, leaving many in the region struggling to put food on their table every day.

Wildlife deaths were reported across most parks due to this prolonged drought condition. (Fig 5.2)

Luis Tato/AFP/Getty Images

Figure 5.2: *Carcass of an adult elephant, which died during the drought, is seen in Namunyak Wildlife Conservancy, Samburu, Kenya on October 12, 2022.*

REUTERS/Thomas Mukoya

Figure 5.3: *Goats drinking water from an open well dug on a dry river bed in Loyoro village of Kalokol in Turkana, Kenya September 28, 2022.*

6. Socio-economic Impacts of extreme events in various sectors of the economy

6.1 Agriculture and Food Security

Food production was greatly impacted by the prolonged rainfall deficits and aggravated by other circumstances such as the Russia Ukraine war. According to the Food Security and Nutrition Working Group (FSNWG) there was an upsurge in food commodity prices due to depressed crop production. Wholesale maize prices in April in the urban reference markets were 41%– 46% above the five-year average linked to lower production. In addition, the Ukraine/Russia conflict negatively affected fuel prices and as well as the prices of essential food commodities such as oil and wheat products.

In terms of vegetation cover, large-scale deterioration in vegetation condition was recorded across the ASALs counties, with varying deficit levels ranging from severe to moderate.

Many farmers had to uproot failed crops due to prolonged drought conditions. By March 2022, the Kenya government announced the removal of duty on imported maize in a bid to boost food security in the light of a prolonged dry spell and household inflationary pressure. The government also put in place plans to distribute subsidized fertilizers and other farm input in a bid to boost crop yield, food security, and rural incomes.

REUTERS/Baz Ratner

Figure 6.1: *Farmers in Kilifi county uprooting maize fields with a failed crop due to the drought. February 16, 2022.*

6.2 Water Resources

Throughout the year water levels in most rivers across the country diminished, leading to rationing of irrigation in parts of central Kenya as well as impacting availability of drinking water in Kiambu, Nyeri, Meru and nearby counties. Analysis of flow in all the basins across the country showed a declining trend leading to significant recession in river flows and in some cases rivers completely drying up. This led to widespread restrictions in abstraction of water from the affected rivers.

Lake Victoria North Basin Area (LVNBA) - The basin received moderate rainfall in the short rains season of October to December 2022 leading to a notable decline in river flows across the basin but still within the 'satisfactory' status depicting normal ranges by the end of the year.
Lake Victoria South Basin Area (LVSBA) - The basin received moderate rainfall in the short rains season of October to December 2022 leading to a notable decline in river flows across the basin. By the end of the year water levels were tending towards alert levels.
Rift Valley Basin Area (RVBA) - Most parts of the basin received very little or no rains at all in the last two seasons of the year 2022. This led to significant reduction in river flows with many drying up. The situation was exacerbated by increased human activities (irrigation) in the upstream areas. By the end of the year water levels were at alert and alarm levels in different rivers.
Athi Basin Area (ABA) - The upper parts of the basin received moderate rainfall during the OND short rains season that maintained flow in the perennial rivers. However, by the end of the year some rivers were tending towards alert levels.
Tana Basin Area (TBA) - The basin did not receive sufficient rains during the year. This led to the basin experiencing a decline in river flows leading to heightened competition for limited available water resources, spurring water use conflicts as the dry spell extended. By the end of the year water levels were at alert and alarm levels in different rivers.
Ewaso Ng'iro North Basin Area (ENNBA) - Like the rest of the basins, insufficient rainfall was recorded throughout the year but mainly during OND. The water resources situation in this basin was at *Alarm* state by the end of the year leading to water resource conflicts among users in various sub basins. The situation was exacerbated by the predominant livelihood which is pastoralism in the middle and lower catchment areas and farmers in the upper catchment area who depend on water from these river systems for domestic, irrigation and other uses such as industrial consumption.

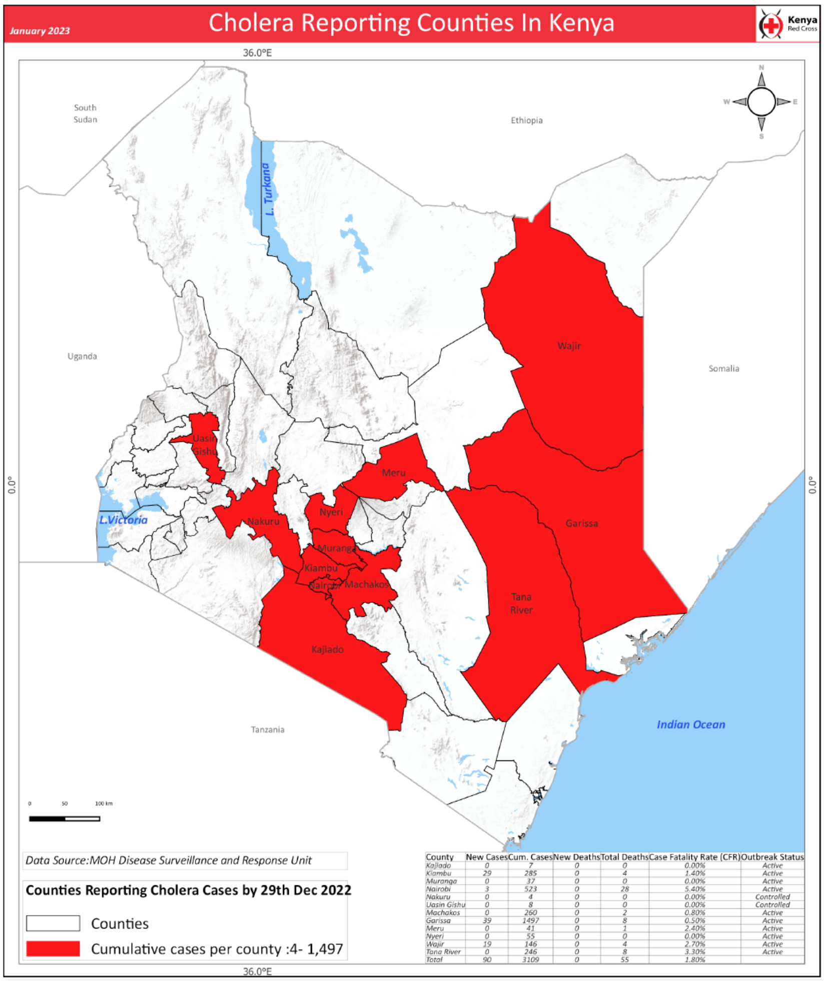
Tine Frank/USAID
Figure 6.2: *Ewaso Nyiro River in Kenya, with low water levels towards the end of 2022.*
KEY
Satisfactory (GREEN) - Water resource is sufficient in quantity and quality for intended uses and users. Abstractors are free to abstract to the limit of their permits;
Alert (ORANGE) - Water resources availability is tending towards scarcity and over-abstraction. Some uses including irrigation are restricted or banned
Alarm (RED) - Water Resource availability is periodically scarce and/or environmental flow/reserve threatened. Most uses, including domestic water abstraction are restricted or stopped all together.

6.3 Health

Once again, the drought was the main driver of major health concerns throughout the year driving malnutrition, especially among children and pregnant women. In addition, poor hygiene practices characterized by poor handwashing at critical times due to water shortage and poor water treatment, especially in the rural areas, contributed to high disease burden (IPC, June 2022). The intensification of drought conditions meant less and less people seeking healthcare in health centers because of insecurity and migration in search of pasture and water. Reports from humanitarian agencies show that there has been an increased need for mobile health outreach programs to address malnutrition and other disease outbreaks most of which were reported in the northeastern counties.

Communicable diseases occasioned by the drought conditions and reduced water prevailed for much of 2022. Kenyan health authorities reported elevated cholera activity with 1,409 suspected cases reported nationwide between 5th and 18th December. This contributed to the total case count of 2,959 between October and December 2022. This includes at least 105 laboratory-confirmed cases. Most suspected cases were reported in Garissa (654 cases), followed by Nairobi (384 cases), Machakos (231 cases), and Kiambu (164 cases) counties. At least 55 cholera associated deaths were reported by 5th December.

The Kenya Red Cross Red Crescent society (IFRC, 2022) reported that increased cases were reported mainly within Nairobi and in counties that were reporting persistent drought; communities utilizing unsafe water sources and limited access to sanitation and hygiene services and corresponding poor WASH practices. In particular, Nairobi, Tana River, Garissa and Wajir counties have recently reported increased caseloads with highest mortalities in Nairobi, Garissa, Tana River and Wajir counties.



County	New Cases	Cum. Cases	New Deaths	Total Deaths	Case Fatality Rate (CFR)	Outbreak Status
Kajiado	0	7	0	0	0.00%	Active
Kiambu	29	285	0	4	1.40%	Active
Muranga	0	37	0	0	0.00%	Active
Nairobi	3	523	0	28	5.40%	Active
Nakuru	0	4	0	0	0.00%	Controlled
Uasin Gishu	0	8	0	0	0.00%	Controlled
Machakos	0	260	0	2	0.80%	Active
Garissa	39	1497	0	8	0.50%	Active
Meru	0	41	0	1	2.40%	Active
Nyeri	0	55	0	0	0.00%	Active
Wajir	19	146	0	4	2.70%	Active
Tana River	0	246	0	8	3.30%	Active
Total	90	3109	0	55	1.80%	

Figure 6.3: *Cholera reporting counties towards the end of the year. Source IFRC Kenya DREF Application*

6.4 Pastoral Livelihoods

As indicated above, a late MAM onset was experienced throughout the country with most rainfall being received in late April. Amounts received across most livelihood zones was below the long-term seasonal averages and the spatial distribution was generally poor. Pasture regeneration in ASAL areas was negatively impacted; hence livestock body condition continued to worsen, and some endemic livestock diseases were reported especially in parts of eastern Kenya. Trekking long distances for grazing and in search of water contributed to the deterioration of livestock body condition. Cold weather in January after heavy rainfall resulted in the death of livestock in Marsabit county. Livestock body condition ranged between fair to poor across ASAL counties for much of the year, as result of poor regeneration of pasture and browse.

6.5 Conflict and Insecurity

Water sources for human consumption and livestock dried up in the Northern parts of the country, forcing families to walk longer distances and worsening existing tensions among communities, which led to increased inter-communal conflicts. Dwindling resources compelled pastoralist communities to travel further in search of food and water, leading to intercommunal clashes (OCHA, 2022). According to the Kenya Food Security Steering Group (KFSSG) incidences of insecurity and resource-based conflicts were reported in Baringo, Nyeri, Meru, Lamu, Mandera, Turkana and Marsabit Counties. This led to loss of lives and livestock thefts. Resource-based conflicts, instigated by competition for scare pasture and water resources coupled with long-standing rivalries between communities, were experienced in most of the counties. The number of deaths reported in Marsabit County from March to June 2022 were 44 and 12 injuries. Some cross-border conflicts were also recorded in Ethiopia and Uganda. In Kajiado County, there were warnings of human-wildlife conflict as livestock and wild animals competed for limited pasture and as livestock traversed through private land along migratory routes.

6.6 Energy Sector

Impacts of the slow onset drought conditions on the energy sector were evident at the beginning of 2023. Throughout 2022 low rainfall amounts led to the catchment areas for the Seven Forks Dam particularly going very low. Rivers Tana, Sagana, Mathioya, Maragua and Chania had low water levels due to the prolonged below average rainfall. According to the Kenyan hydroelectric power generation company, KenGen, the water levels in these dams dwindled to the lowest levels in history. The western dams were relatively safer. There was increased generation from thermal power plants leading to a rise in energy tariffs.

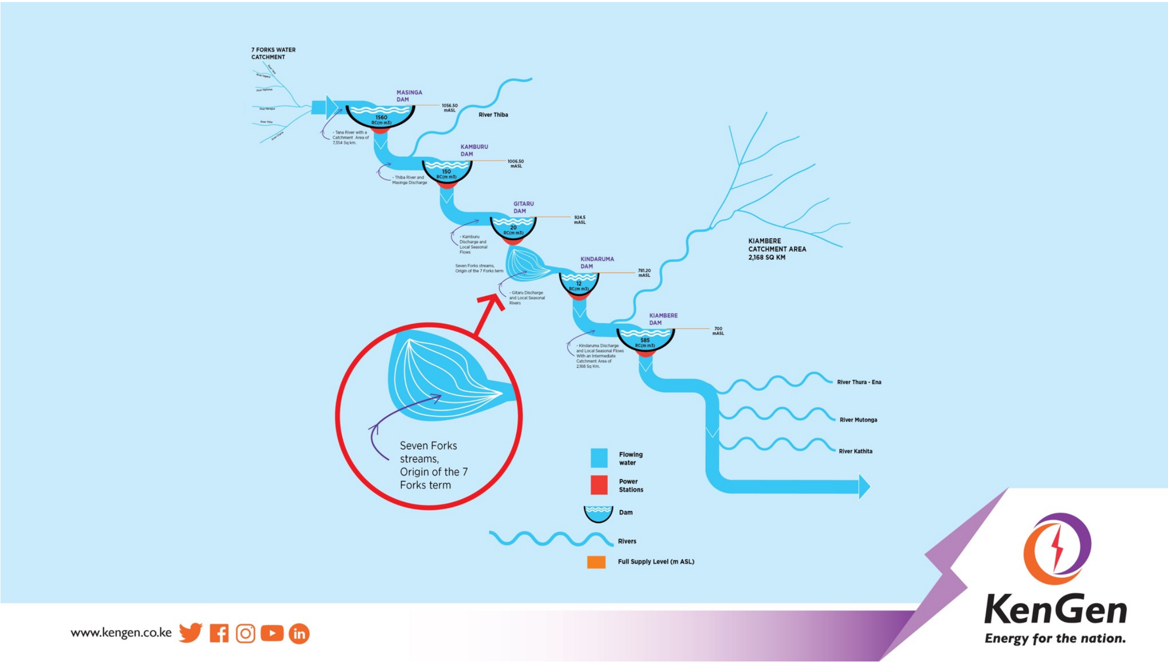


Figure 6.5: *The Seven Forks dam system and catchment areas that have been impacted by low river levels.* **Source:** KenGen

7. Projected Climate patterns for 2023 and possible socio-economic impacts

This section gives a brief outlook of two major general circulation features and large-scale Oceanic anomalies that influence the climate of East Africa (e.g., El Niño/Southern Oscillation (ENSO), and the Indian Ocean Dipole (IOD), and the possible socio-economic impacts.

During October-December 2022, the Pacific Niño 3.4 sea-surface temperature (SST) in the central Pacific was below normal, indicating La Niña conditions associated with drier conditions or below normal rainfall in Kenya. La Niña conditions were still present at the beginning of 2023 in the tropical Pacific atmosphere (Figure 7.1), with all models forecasting a weakening towards neutral (Neither La Nina nor El Nino) values during the February-April 2023 period, with a probability of 72% (Figure 7.2 and Figure 7.3). Neutral conditions are expected to continue into MAM, AMJ, MJJ, JJA with probabilities of 82%, 75%, 62%, and 50% respectively.

There is a 50% chance of transition from Neutral to El Niño conditions in August-October (Figure 7.2). Even so, El Niño and La Niña events tend to develop during April-June and reach their maximum strength during October-February, thus impacting the short rains season. The short rains season this year may not be impacted since El Niño conditions are forecasted to form late in the year (i.e., in August-October). ENSO conditions will however be continuously monitored, and the likely impacts updated.

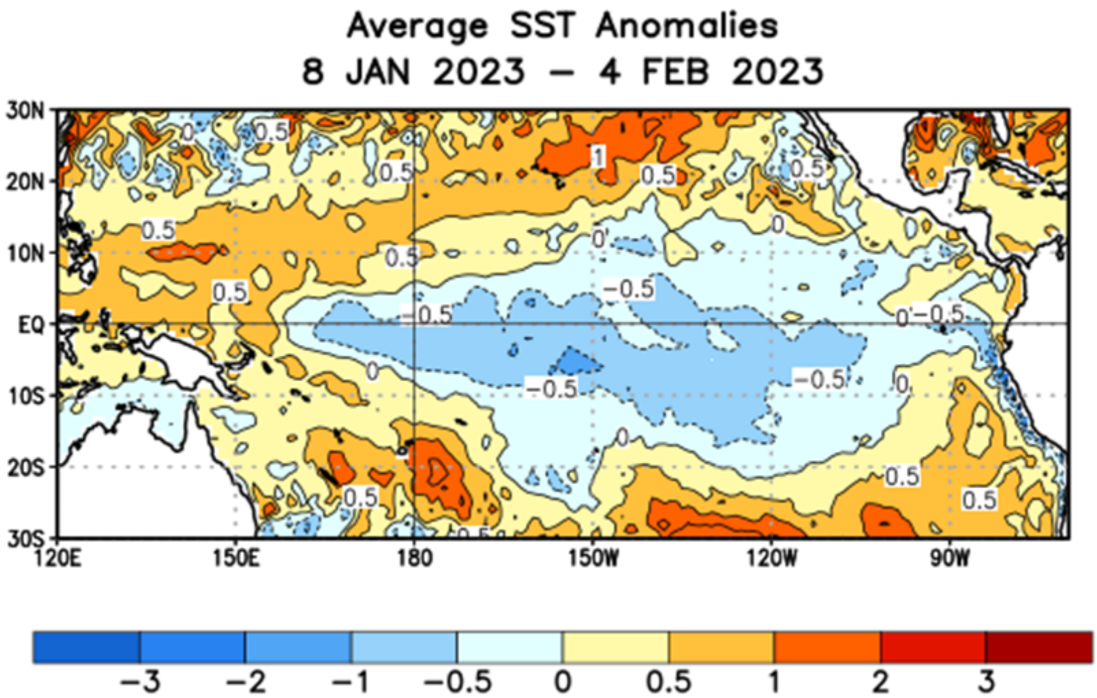


Figure 7.1: *Average equatorial SST anomalies from 8 January 2023 - 4 February 2023*

Source NOAA Climate Prediction Center

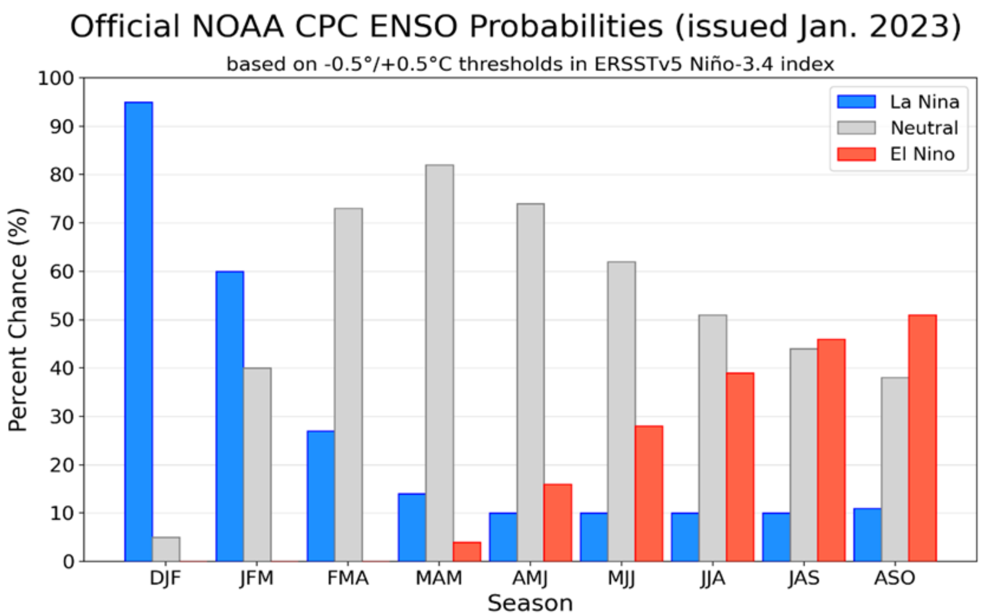


Figure 7.2: *Probabilities of La Nina, Neutral, and El Nino (Nino 3.4 index) conditions for the remainder of 2023 (Courtesy NOAA CPC)*

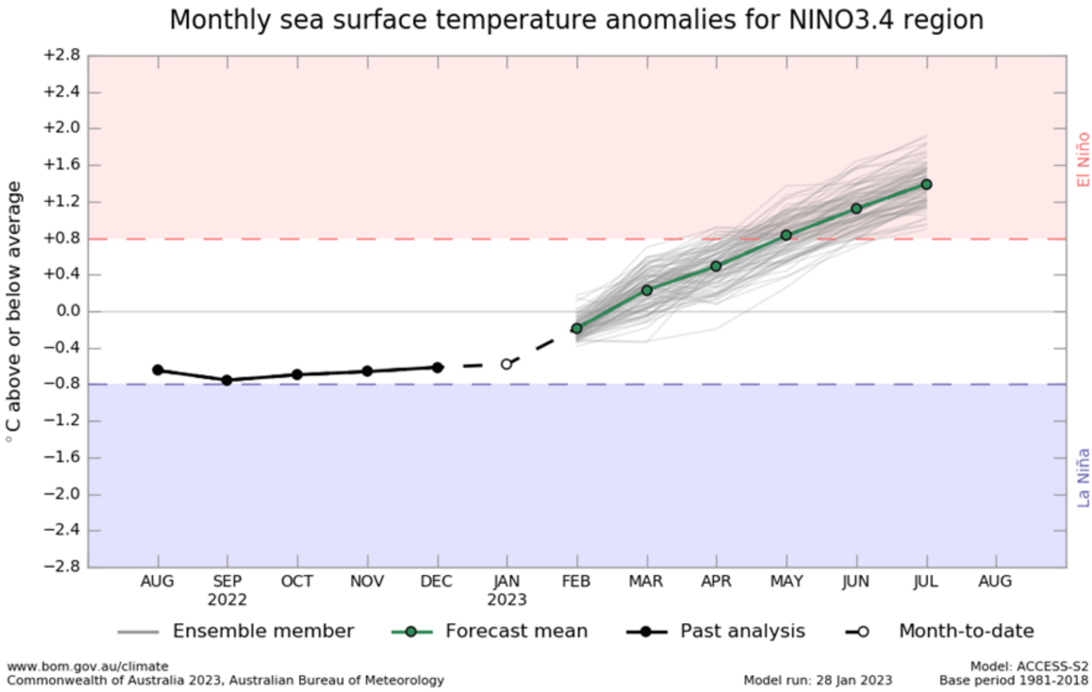


Figure 7.3: *Monthly Sea Surface Temperature (SST) anomalies for NINO3.4 region.*

Indian Ocean Dipole (IOD)

Another driver of Kenyan weather is the Indian Ocean Dipole (IOD), defined as the difference in sea-surface temperature between two areas (poles) i.e., Western Indian Ocean, and the Eastern Indian Ocean south of Indonesia. A positive IOD enhances rainfall intensity over East Africa especially the short rains season but has little influence from December to April.

The IOD is currently neutral. Model forecasts indicate that the neutral IOD index will continue through to May-2023 and transition to a positive phase in June-July-2023 (Figure 7.4). The probabilities of forecasted IOD being either in Neutral, Positive or Negative phases are shown in Table-2.

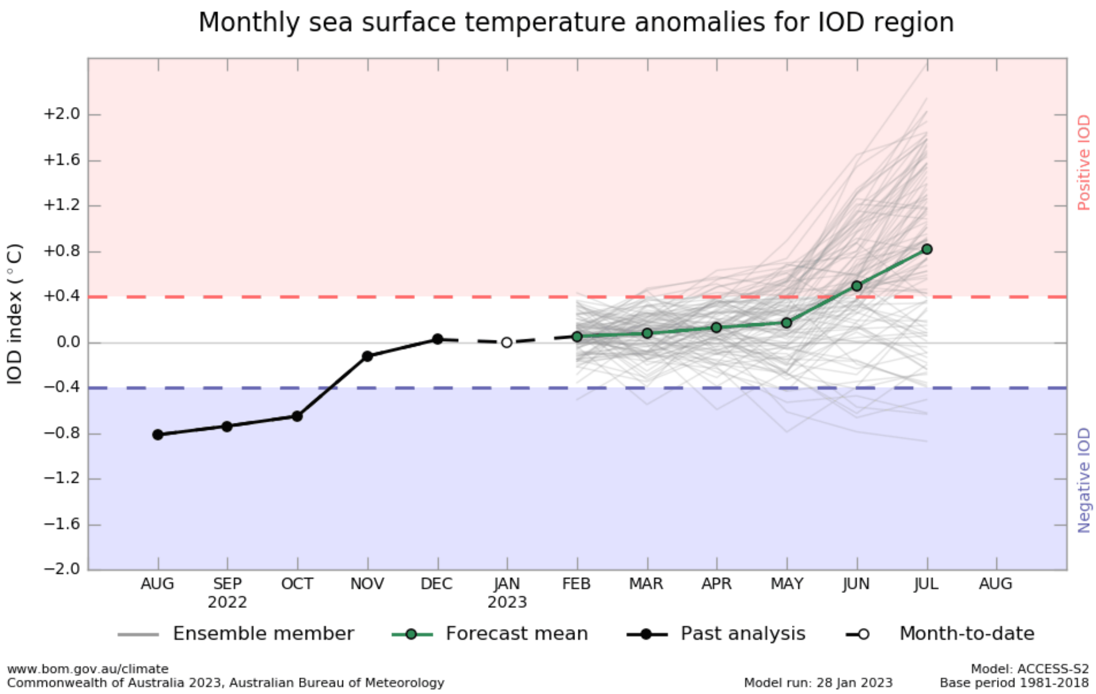


Figure 7.4: *Monthly SST anomalies for IOD region.*

Table 2: Monthly IOD outlook up to July 2023

Month	Feb 2023	Mar 2023	Apr 2023	May 2023	Jun 2023	Jul 2023
IOD	**0.1℃**	**0.1℃**	**0.1℃**	**0.2℃**	**0.5℃**	**0.8℃**
below −0.4℃	1.0%	1.0%	1.0%	3.0%	5.1%	4.0%
neutral	96.0%	90.9%	80.8%	64.6%	30.3%	25.3%
above 0.4℃	3.0%	8.1%	18.2%	32.3%	64.6%	70.7%

Possible socio-economic impacts

With La-Niña conditions transiting to neutral conditions in MAM, people in the arid and semi-arid lands of Kenya will likely continue facing high levels of food insecurity because of the ongoing drought. The food insecurity conditions can however be reversed depending on the performance of MAM rains.

Should the MAM rains be Normal to Above-Normal, then the food security situation in the pastoral areas will improve from April-2023, and in July 2023 in agro-pastoral areas. However, according to previous experiences after the 2011 and 2017 drought emergencies, the Food security and Nutrition Working Group foresees the food insecurity lasting through September 2023 (FSNWG, 2022).

Declining forage and water resources in arid and semi-arid areas will continue until after the long rains of 2023. This will intensify livestock migration as herders search for better rangeland resulting in resource-based conflicts and spread in livestock diseases.

In marginal agricultural areas, the 2023 MAM forecasts could result in below average crop production, reducing on farm casual wage labor opportunities and crop sales thus reducing household income. This would increase reliance on market purchases to fill food gaps, leading to increases in food prices (FEWSNET, 2022).

8. Key achievements by sections

This section briefly highlights the work done by various branches of the Kenya Meteorological Department and raises awareness of the work of KMD.

8.1 Climate services

KMD successfully developed the 4th State of the Climate Kenya document despite various challenges including budgetary ones. This work was led by the climate services branch and was done in collaboration with other branches including the Forecasting branch. There are plans to work on new normal values based on data from 1991 to 2020 incorporating homogenization of station data.

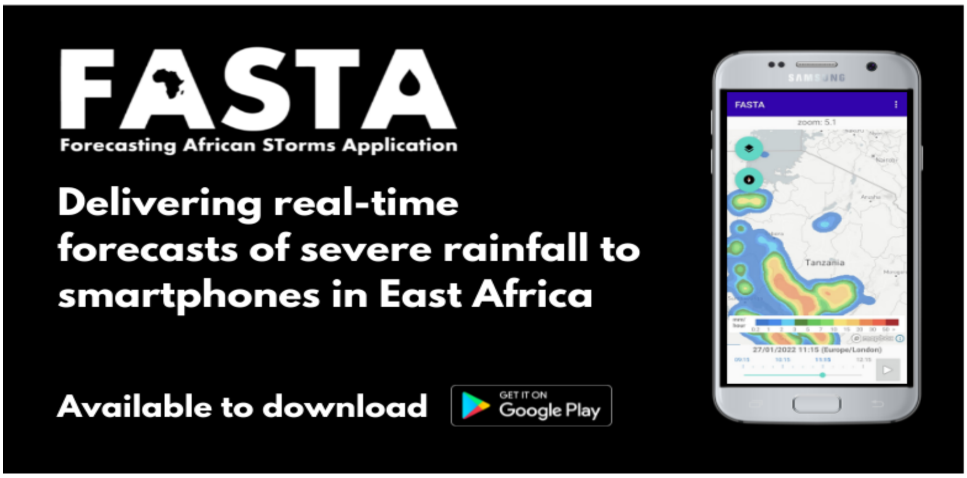
Scientists from the Department under the climate services branch successfully led negotiations at the National and Global level on matters of climate change science as well as research and observation networks. These include participation in IPCC approval sessions, UNFCCC negotiations and other programs.

8.2 Forecasting

The Kenya Meteorological Department in collaboration with the University of Leeds began developing various products, including the FASTA: Forecasting African STorms Application. This project, led by the University of Leeds is part of the GCRF, African Science for Weather Information and Forecasting Techniques (SWIFT) project, a larger initiative that aims to deliver a step-change in African weather forecasting capability.

The FASTA project utilizes satellite data from EUMETSAT, the European operational satellite agency for monitoring weather, climate, and the environment from space, to offer users the current weather situation in their vicinity and highlights of hazardous conditions, enabling people to respond to risks on time. It also allows prediction of accurate weather conditions in areas where very few ground-based observations exist.

The project team developed the Application to display nowcasting (observations of ongoing storm activity and predicted evolution over the coming hours) information. The app is linked to an Application Programming Interface (API) that can be easily integrated with other mobile or online applications and services. It is the culmination of research carried out by scientists involved in the GCRF African SWIFT project to develop techniques for better and more accurate forecasting of severe weather in the Great Lakes region of Africa. This project is intended to deliver critical weather information and better decision support to various economic sectors to pre-empt disruptions due to weather hazards by providing users with a snapshot of current storm activity in their area(s) and enabling them to track extreme weather.



The app is accessible via the link https://play.google.com/store/apps/details?id=uk.ac.ncas.sci.apps.fasta or by searching for the app on google play store. The app has so far garnered 1500 users and plans are underway to scaleup usage of the app especially during the rainy seasons.

Feedback https://docs.google.com/forms/d/e/1FAIpQLSempE1R6TnrsFLTqUyhHLosA-OFZiw3dNTgk63DmCdY_mVSQQ/viewform

8.3 Institute for Meteorological Training and Research (IMTR)

A World Meteorological Organization Regional Training Centre (WMO - RTC), Nairobi. The Institute for Meteorological Training and Research (IMTR) is a branch of the Kenya Meteorological Department. The IMTR 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. IMTR is also part of the WMO Virtual Laboratory for Meteorological Satellite Education and Training (VLab) and as such has 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. In 2022, IMTR carried out the following training activities:

I. Training of 28 Meteorological Technicians in the Middle Meteorological Technicians Course in three different groups of whom two groups are continuing with their training while one group is waiting to graduate.
II. Trained five Aeronautical Observers from Rwanda in the Specialised Aeronautical Meteorological Observers Course (SAMOC)
III. Trained seven Forecasters from Somali in the Specialised Course on Application of Meteorology in Climate Change Mitigation and Adaptation
IV. In collaboration with South African Weather Service (SAWS), Morroco (DGM), EAMAC (Niger) and with the support of EUMETSAT, implemented and delivered a 5 week online course for Forecasters “RA I Meteorological Satellite Application for Nowcasting”. The course had approximately 40 participants from Sudan, Togo, Nigeria, Morocco, Zimbabwe, Djibouti, South Africa, Liberia, Somali, Gambia, Rwanda, Mauritius, Kenya, Cameroon, Burundi, Lesotho, Eswatini, Egypt and Tanzania

8.4 Meteorological Consultancy Services

The state of the climate documents for previous years have been sent out to a wide range of stakeholders who contact the office. Researchers have benefited from information contained therein with respect to climatology as well as events and trends. There’s growing demand for products as opposed to raw data and the State of the Climate document is filling this need currently. Government officers working with project planning such as engineers have also benefited from the document.

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