



STATE OF MALAWI CLIMATE IN 2022

MINISTRY OF NATURAL RESOURCES AND CLIMATE CHANGE
DEPARTMENT OF CLIMATE CHANGE AND
METEOROLOGICAL SERVICES



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STATE OF MALAWI CLIMATE IN 2022

MINISTRY OF NATURAL RESOURCES AND CLIMATE CHANGE

DEPARTMENT OF CLIMATE CHANGE AND
METEOROLOGICAL SERVICES

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FOREWORD



Like many countries, Malawi continues to experience increased frequency and magnitude of extreme weather and climate events. The year 2022 was no exception as was characterised by tropical cyclones, heavy rainfall and flooding, dry spells and droughts, heat waves, and strong winds. These extreme events had varying degrees of impact on different sectors of the Malawi's economy.

The Department of Climate Change and Meteorological Services (DCCMS) is mandated to monitor, predict and provide information on weather, climate and climate change that would contribute towards the socio-economic development of country. During 2022, the department monitored the weather as well as provided early warning information and advisories.

During the year 2022, temperature observations indicate that the mean, maximum and minimum temperatures were slightly warmer than long-term average for all the months. On average, the temperature anomaly of minimum and maximum temperatures were in the range of 1.0 to 1.5°C and 0.5 to 1.5°C higher respectively.

For rainfall, the total cumulative rainfall amounts were generally normal. Normal to above-normal, with pockets of above-normal rainfall amounts recorded over southern areas of Malawi while generally normal to below-normal rainfall was observed over the northern half, with few pockets of normal to above-normal over northernmost districts of Karonga and Chitipa. Malawi experienced extreme events during 2021/2022 rainfall season. For example, during October to December 2021, the country experienced one of driest sub-season since the 1970s. This was observed through Standardized Precipitation Evapotranspiration Index (SPEI). December contributed highly to moderate drought conditions for the sub season. Regarding rainfall related extreme events for 2022, the country was hit by Tropical Storms Ana and Tropical Cyclone Gombe in January and March, respectively. Most rainfall stations over southern Malawi recorded highest maximum 24-hour rainfall, with some stations recording as high as 350mm. Tropical Storm Ana

resulted in higher 24-hour rainfall amounts compared to Gombe. This resulted into the destruction of infrastructure both public and private as well as loss of lives. Kapichira Hydro Electric Power station for example, was severely damaged resulting in loss of 129.6 Megawatts from the national grid.

Regarding temperature extremes, Malawi experienced very high temperatures during October to December 2022. Areas in the Lower Shire Valley and Lakeshore experienced heat waves that at some point led to the suspension of schools in those areas. For example, in November 2022, Ngabu registered 21 very hot days, with extreme temperatures in the range of 40.5 to 42.5°C.

These extreme weather and climate events had various degrees of impacts on social economic sectors of the country. These sectors include, but not limited to, Disaster Risk Management, Agriculture and Food Security, Water Resources, Transport (Road, Rail, Air, Marine), Energy, Health and Education.

DCCMS appreciates continued collaboration with various stakeholders and partners. The department will continue to fulfil its mandates and furthermore endeavour to continue improving its services to the public and all weather/ climate sensitive sectors in the country and beyond.

Lucy Mtilatila (PhD)

DIRECTOR OF CLIMATE CHANGE AND METEOROLOGICAL SERVICES

TABLE OF CONTENTS

Foreword	i
List of Figures	v
Abbreviations	vii
Chapter One	1
1. Background Information	1
Chapter Two	3
2. Observed weather and climatic parameters Analysis	3
2.1 Temperature	3
2.1.1 Annual Mean, Maximum and Minimum Temperature	3
2.1.2 Monthly Mean Temperature	5
2.1.3 Monthly Maximum Temperature	7
2.1.4 Monthly Minimum Temperature	9
2.2 Rainfall	11
2.2.1 Seasonal Rainfall Distribution	11
2.2.2 Monthly Rainfall Distribution	13
2.2.3 Cumulative Rainfall	15
Chapter Three	17
3.0 Extreme Weather and Climatic Events	17
3.1 Standardized Precipitation Evapotranspiration Index (SPEI)	17
3.2 Extreme Rainfall and Flood Events	18
3.3 Extreme Temperature Events	19
Chapter Four	21
4. Major drivers of weather and climate events in 2022	21
4.1 Observed Rain Bearing Systems and Wind Regimes	21
4.1.1 Inter-tropical convergence zone (ITCZ)	21
4.1.2 Congo Air Mass	21

4.1.3	Easterly Waves	22
4.1.4	Tropical Cyclones	22
4.1.4	Mwera winds and Chiperoone	23
4.2	Observed Climate drivers	24
4.2.1	The Sea Surface Temperatures (SSTs)	24
4.2.1.1	El Niño and Southern oscillations (ENSO)	24
4.2.1.2	Indian Ocean Dipole (IOD)	25
4.2.1.3	Madden-Julian Oscillation (MJO)	26
Chapter Five	28
5.	Social-economic impacts of extreme Weather and climate events	28
5.1	Early Warning and Disaster Risk Reduction	28
5.2	Agriculture and food security	32
5.3	Water Resources	34
5.4	Transport	35
5.5	Energy	39
5.6	Health	40
5.7	Education	43
Chapter Six	46
6.0	Summary and conclusion	46
References	47

LIST OF FIGURES

Figure 1: Observed average temperature anomaly for Malawi in 2022	3
Figure 2: Observed maximum temperature anomaly for Malawi in 2022	4
Figure 3: Observed minimum temperature anomaly for Malawi in 2022	5
Figure 4: Observed monthly average temperature anomaly for Malawi in 2022	6
Figure 5: Observed monthly maximum temperature anomaly for Malawi in 2022 ...	8
Figure 6: Observed monthly minimum temperature anomaly for Malawi in 2022 ..	10
Figure 7: Observed sub-seasons rainfall anomaly for Malawi in 2022	12
Figure 8: Observed Rainfall anomaly for Malawi in 2021/2022 rainfall season	12
Figure 9: Observed monthly rainfall anomaly for Malawi in 2022	14
Figure 10: Cumulative rainfall analysis for Karonga, Makoka, Chitedze, Bolero, Mzimba, Chileka, Mimosa, Ngabu and Salima	16
Figure 11: Observed Monthly SPEI for Malawi in 2022	17
Figure 12: Observed 24-hour rainfall during TS Ana and TC Gombe	19
Figure 13: Southwest Indian Ocean Tropical cyclone tracks in 2022	23
Figure 14: Observed winds over Lake Malawi in 2022	24
Figure 15: Observed Sea Surface Temperature anomaly for Nino 3.4 including the year 2022 (IRI, 2023)	25
Figure 16: Observed Indian Ocean Dipole Index including the year 2022 (Weatherzone, 2022)	26
Figure 17: Observed MJO between January and March, 2022 (Australian , 2022) ...	27
Figure 18: Wash away maize field, Mikalango EPA, southern Malawi	32
Figure 19: Acute food insecurity situation (IPC Malawi, 2022)	34
Figure 20: Increased water levels in Lake Malawi (Malekeza, 2022)	35
Figure 21: The M1 road in Chikwawa district was damaged by the floods	36
Figure 22: Cut off road in East Bank of Shire River	37
Figure 23: Washed away vehicle in Lower Shire	38
Figure 24: Kapichira power station dike, extensively damaged by Tropical storm Ana in January 2022 (EGENCO, 2022)	40

Figure 25: A child undergoing nutritional screening at Matsukambiya in Chikwawa after Tropical Storm Ana (WHO, 2023)	41
Figure 26: Presentation of suspected and confirmed cholera cases (n=36 943) and deaths (n=1210) per day in Malawi, 3 March 2022 to 3 February 2023 (WHO, 2023)	42
Figure 27: Geographical distribution of confirmed and suspected cholera cases (n=36 943) and deaths (n=1210) by District in Malawi, 3 March 2022 to 3 February 2023 (WHO, 2023)	43
Figure 28: Left: Classroom damaged. Right: Families shelter at a local school in Neno District during by cyclone Ana (Partners In Health, 2022)	44
Figure 29: Primary school roof blown by strong wind in Mangochi, November, 2022	45

ABBREVIATIONS

APES	Agriculture Production Estimate Survey
CAB	Congo Air Boundary
DCCMS	Department of Climate Change and Meteorological Services
DMI	Dipole Mode Index
DoDMA	Department of Disaster Management Affairs
EGENCO	Electricity Generation company
ENSO	El Niño and Southern oscillations
FEWS NET	Famine Early Warning Systems Network
IOD	Indian Ocean Dipole
IPC	International Phase Classification
ITCZ	Inter-Tropical Convergence Zone
JFM	January, February, March
MASL	Metres Above Sea Level
MDF	Malawi Defence Force
MJO	Madden-Julian Oscillation
MT	Metric Ton
MW	Mega Watts
NWRA	National Water Resources Authority
OND	October, November, December
SPEI	Standardized Precipitation Evapotranspiration Index
SST	Sea Surface Temperature
TC	Tropical Cyclone
UNICEF	United Nations Children’s Fund
WHO	World Health Organisation

CHAPTER ONE

1. Background Information

Malawi experienced a number of weather and climatic extremes during the year 2022. The extremes included heavy rain, dry spells and droughts, flooding, heat waves, tropical cyclones, strong winds. These had impacted hugely on different sectors of the Malawi economy. In this regard, this document presents scientific data and information that evaluates these climate events and their associated impacts on the different social economic sectors in Malawi.

Climate change and variability are affecting many people and economies around the world. Developing countries such as Malawi have high vulnerability to climate change and variability because of their low levels of adaption capacities to climate extremes. Floods and droughts are the most common extreme climatic events. Often times, these extremes result into loss of life and property, reduce agricultural production, damage of public infrastructure, disruption of essential services such as water and electricity, among others.

During the rainfall season of 2021/2022, Malawi experienced a number of weather and climatic extremes including tropical cyclones, heavy rain, flooding, dry spells and droughts, heat waves, strong winds. These impacted hugely on the different sectors of the economy.

The Department of Climate Change and Meteorological Services (DCCMS) monitored the weather and climate and continuously provided information to the public and different stakeholders as one way of minimizing the risks associated with such extreme events.

Using weather and climate observations for the year 2022 and rainfall season of 2021/2022, DCCMS has conducted climate analyses of the different weather and climate parameters. To appreciate the impact of weather during the past season, additional data and information was obtained from relevant sectors and government departments. These include Department of Disaster Management Affairs (DoDMA), Ministry of Health, Ministry of Education, Ministry of agriculture, Ministry of Transport and Electricity Generation Company (EGENCO)

Therefore, this document contains results of the analyses of temperature and rainfall patterns for the year 2021/2022 with respect to 1991-2020 climatological period and how they impacted the different social and economic sectors in Malawi.

This first edition of the “Status of Malawi Climate” has six chapters. Chapter One presents the introductory information; Chapter Two discusses the weather and climatic events observed in 2022 and the rainfall season of 2021/2022. The observed trends of precipitation and temperature are discussed in detail including annual and monthly patterns of precipitation and temperature; Chapter Three presents a discussion on the extreme climatic events such as drought, heat waves and floods; Chapter Four details the behaviour and influence of the major drivers of weather and climate during the year under consideration; Chapter Five discusses the impacts of extreme weather and climate events on the social and economic status of the country.

A detailed discussion on the following social economic sectors; Early Warning and Disaster Risk Reduction, Agriculture and food security, Water Resources, Transport, Energy, Health, and Education is present under this chapter. Chapter Six brings the summary and conclusion.

CHAPTER TWO

2. Observed weather and climatic parameters analysis

2.1 Temperature

Temperature observations for the year 2022 reveal that the mean, maximum and minimum temperatures were slightly warmer than long term average for all months. On average, normal temperatures were observed over most areas with slightly higher than normal minimum and maximum temperatures in the ranges of 1.0 to 1.5°C and 0.5 to 1.5°C respectively.

2.1.1 Annual Mean, Maximum and Minimum Temperature

The annual average temperatures of the season of 2021/2022 across the country did not depart much from the long term annual average temperatures as depicted in Figure 1. The average temperature was generally normal over most areas except for some southern and northern tip areas. It was slightly warmer in the range of 0.5 to 1°C like over Karonga and Chitipa while over the Shire valley areas like in Chikwawa being also slightly warmer in the range of 1.5 to 2°C as compared to their long term annual average temperatures. However, it was 1 to 1.5°C cooler over some areas in the south-eastern parts of the southern highlands of Malawi like in Phalombe and Mulanje.

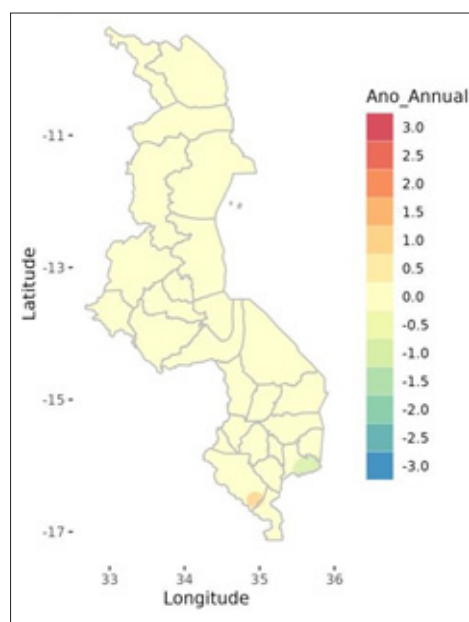


Figure 1: Observed average temperature anomaly for Malawi in 2022

Maximum temperatures are usually high in the summer season. Figure 2 shows no significant change in terms of maximum temperatures in 2022 except the south eastern part of Malawi over Mulanje district. The district was cooler than the normal range by 1°C. Annual maximum temperature anomaly is significantly noticed in monthly spatial distribution than in annual distribution as shown in Figure 5.

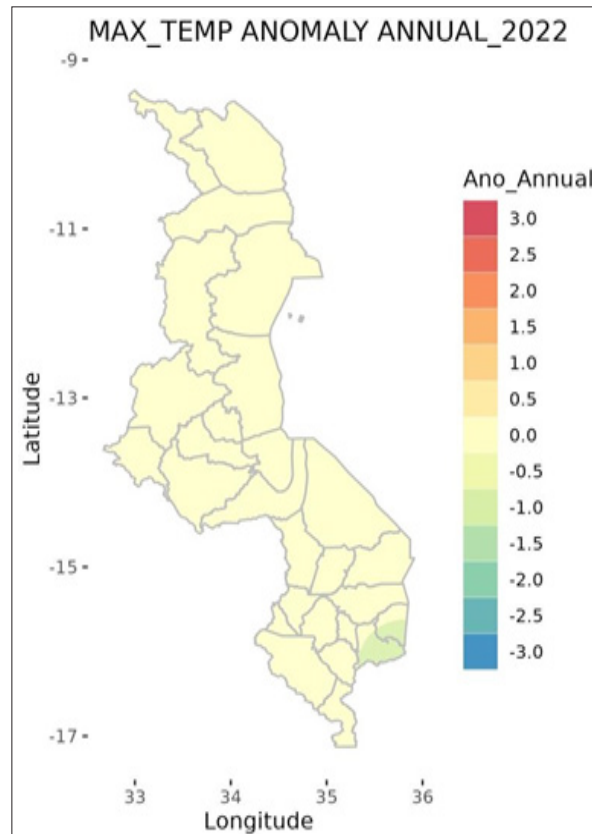


Figure 2: Observed maximum temperature anomaly for Malawi in 2022

The annual minimum temperature anomalies indicate the year 2022 was slightly warmer over most parts of Malawi with part of northern-central area (Mzuzu), Central-western (Lilongwe) and Southern tip of Malawi (lower Shire valley) recording the warmest departure ranging from 1.0°C to 1.5°C as depicted in Figure 3. However, the results further indicates that north eastern part of Malawi (Karonga) was cooler than long term average in the range between 1.0°C and 1.5°C.

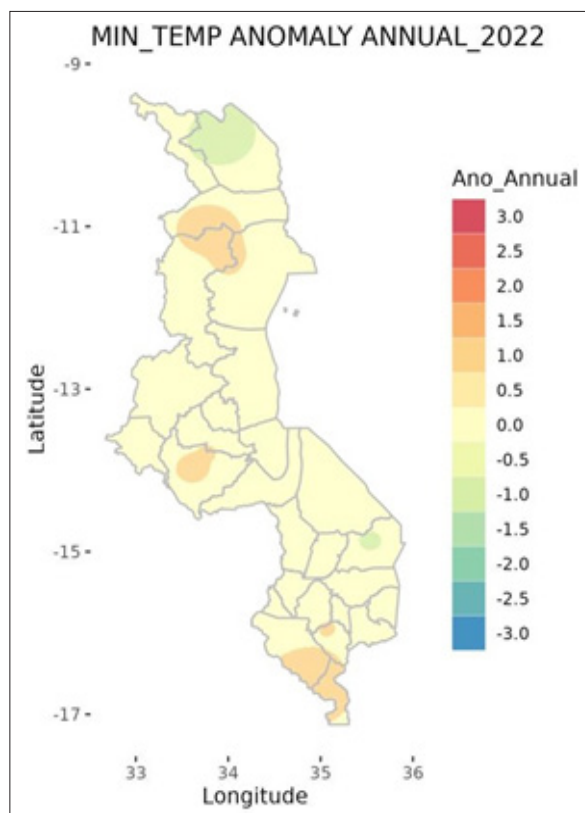


Figure 3: Observed minimum temperature anomaly for Malawi in 2022

2.1.2 Monthly Mean Temperature

The Analysis for monthly mean temperature anomalies across the country indicates generally normal temperatures were observed over most areas except for the southern highlands which experienced below-normal temperatures in the range of 1 to 2°C during the months of January, March and June as shown in the Figure 4. The south-eastern areas like Phalombe and Mulanje experienced below-normal temperatures that were 2.5 to 3°C lower than normal mainly in the month of January as highlighted by the blue colour.

The Shire valley areas also showed significant mean monthly temperature anomalies, being 1 to 1.5°C warmer in all months except June and September. The months of April and May were the warmest in the year 2022 with December being the coolest as compared to long term mean monthly temperatures of 1990 to 2020 climatological anomalies.

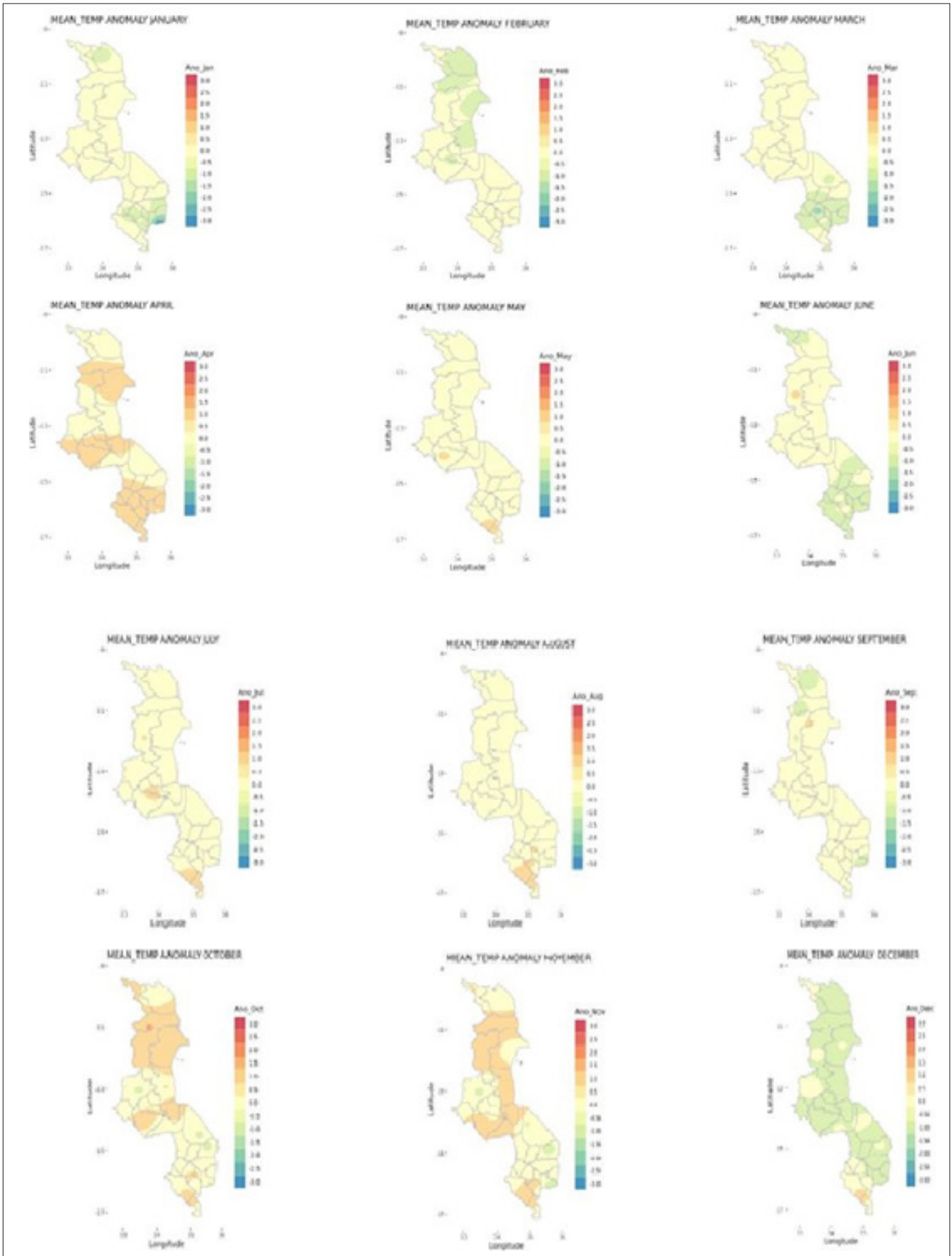


Figure 4: Observed monthly average temperature anomaly for Malawi in 2022

2.1.3 Monthly Maximum Temperature

The monthly maximum temperature anomalies for the country were slightly warmer than the average as shown in Figure 5. The spatial distribution of temperatures in months of April, May, July, October August and November were generally slightly higher by 0.5°C to 1.5°C than the average. However, Chileka in November, Chichiri in October and Ngabu in December were significantly warmer by 3.8°C, 2°C and 1.6°C respectively.

In contrast, maximum temperatures were slightly lower than the average in February, January, March and December with maximum temperature recorded as 4°C below the average. The Figure 5 further shows the months of January and February, most areas in Northern and southern Malawi registered lower maximum temperatures, anomaly range between 0°C and 1°C. Highest drop was recorded at Mimosa with the anomaly of 3.9°C. March and June also depicted negative maximum temperature anomalies, mainly for the southern half of Malawi, and was between 0°C to 1.5°C lower, outstanding cases being Chileka (-4.0°C) and Mimosa (-3.3°C).

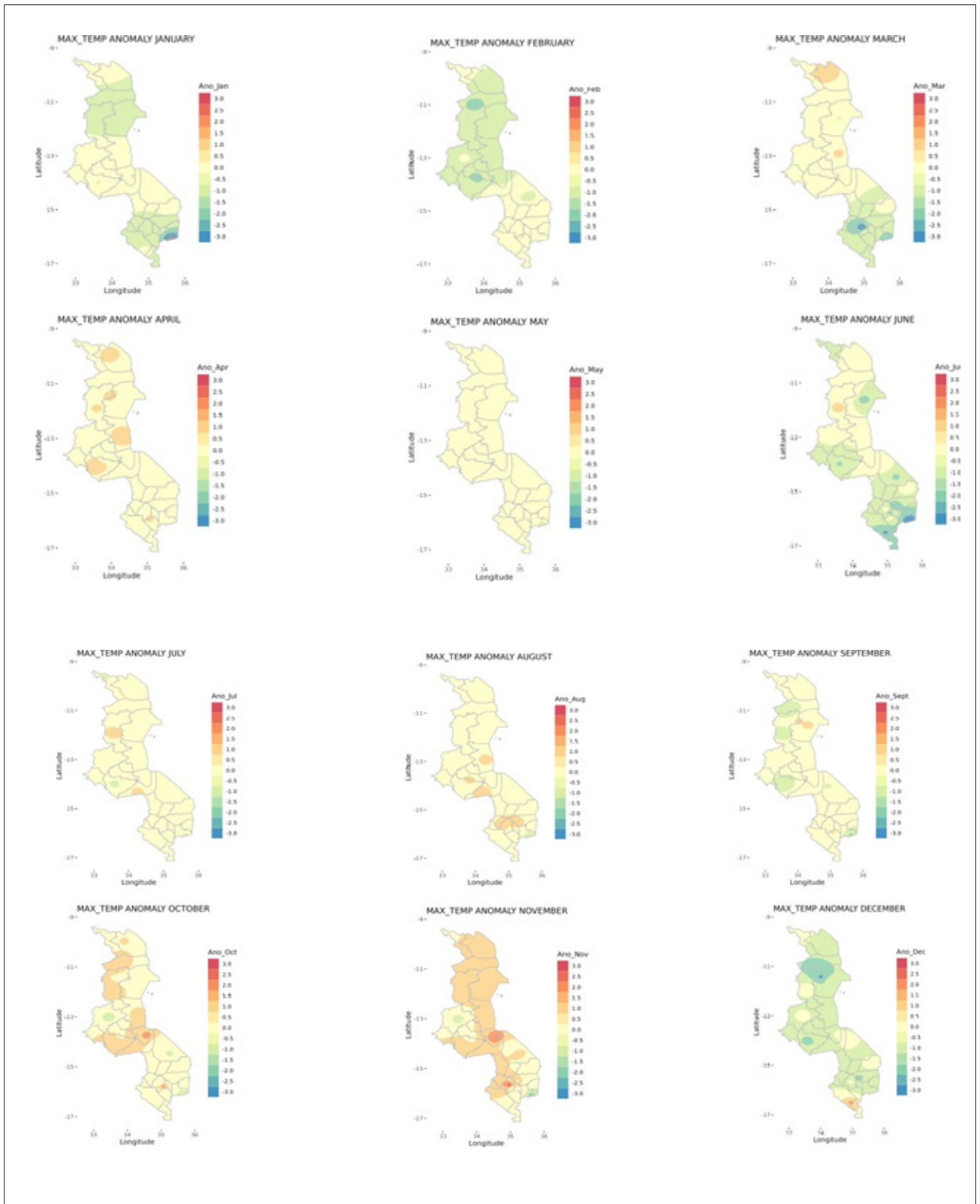


Figure 5: Observed monthly maximum temperature anomaly for Malawi in 2022

2.1.4 Monthly Minimum Temperature

Figure 6 displays the spatial distribution of monthly minimum temperature anomalies across Malawi for the year 2022. Warmer than average minimum temperatures were observed in most parts of the country with the southern tip of the country (lower Shire Valley) recording the highest departure of +2.4°C during the month of April. Central-western Malawi (KIA) and north most parts of Malawi (Chitipa) were also warmer by 2°C during the month of July, and a similar observation was noted for Northern central area (Mzuzu) during the month of October.

Cooler-than-normal minimum temperatures were also observed at some stations. For instance, part of north eastern Malawi (Karonga) recorded below-normal minimum temperature departures in the range between 1.0°C and 1.5°C throughout the year except during March, July and August. In December, parts of Central-eastern Malawi (Salima) and few areas in south-east also recorded notably below average anomalies, whereas Chileka in the south was cooler by 2°C in November 2022.

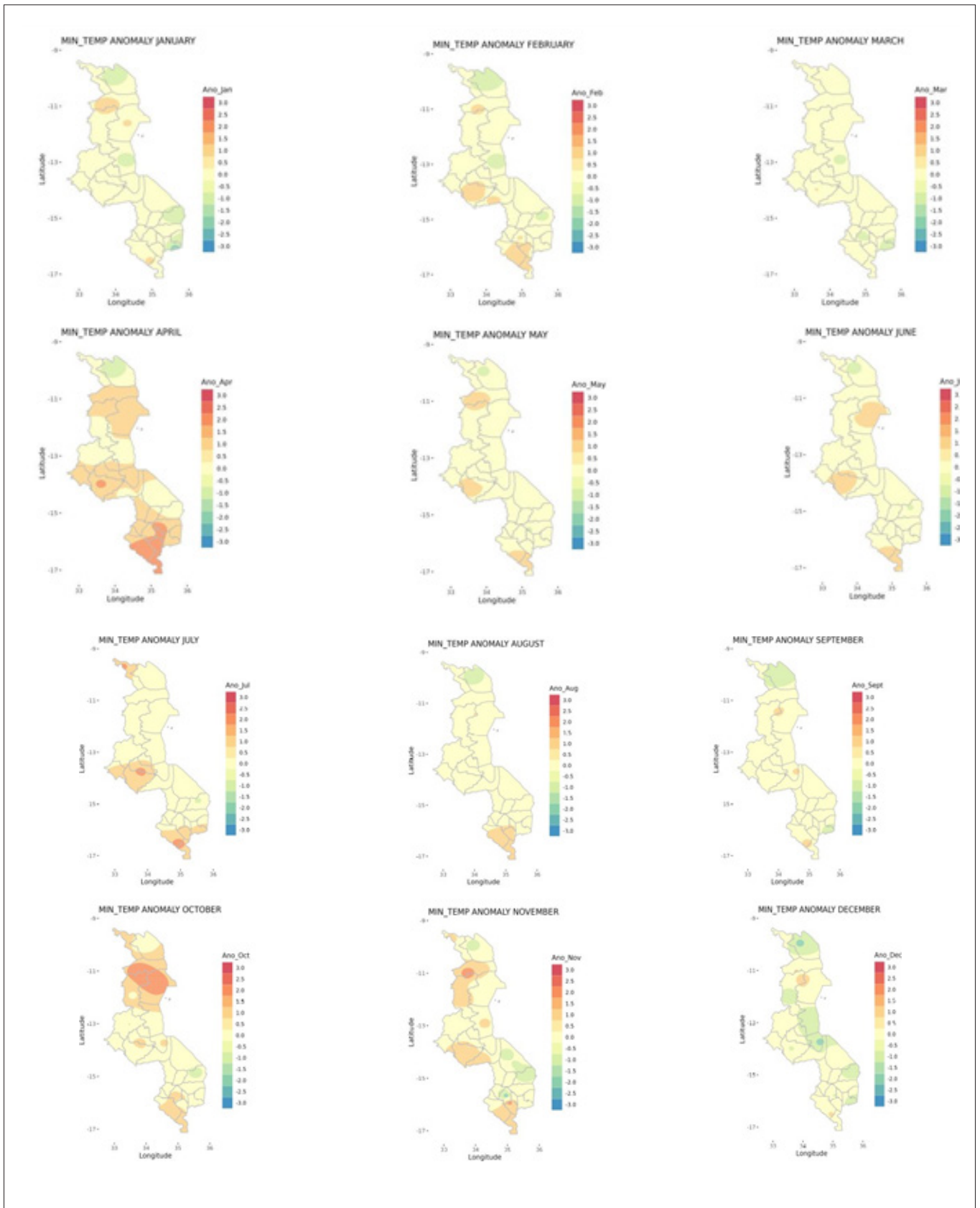


Figure 6: Observed monthly minimum temperature anomaly for Malawi in 2022

2.2 Rainfall

The rainfall season monitoring in Malawi officially starts from October to April. The season characteristics have been changing in recent years in terms of experienced rainfall intensity, spatial and temporal distribution, as well as the extreme events that come with the rains. During the 2022 period, total rainfall amounts were generally normal. Normal to above-normal, with spots of above-normal rainfall amounts were recorded over southern areas of Malawi while for the northern half, normal to below-normal was observed with few spots of normal to above-normal over Karonga and Chitipa. The rainfall season was influenced by La Nina conditions and the main rain bearing systems were Inter-Tropical Convergence Zone (ITCZ), Congo air mass, convergence and tropical depressions. Onset of the season was late and erratic, and this affected the rainfall amounts accumulated for the October- December (OND) 2021 sub-season.

The rains normally start from the south progressing northwards. Planting rains started late during the 2021/2022 rainfall season, in December and January. During the January to March (JFM) sub-season, the two cyclones, Ana and Gombe which affected Malawi in January and March respectively brought more rains in the southern parts of the country.

2.2.1 Seasonal Rainfall Distribution

According to the rainfall seasonal forecast released in September 2021, during the October to December (OND) 2021, most of the southern and central areas were expected to receive normal to below-normal rainfall amounts while for most of the northern areas normal to above-normal rainfall amounts were expected. The performance wasn't good because there was a delayed onset over the whole country. The OND sub-season experienced below-normal rainfall amounts due to delayed onset across the country, and December of 2021 happened to be the hottest and driest month since 1960. Below-normal rainfall distribution for OND 2021 is shown in Figure 7.

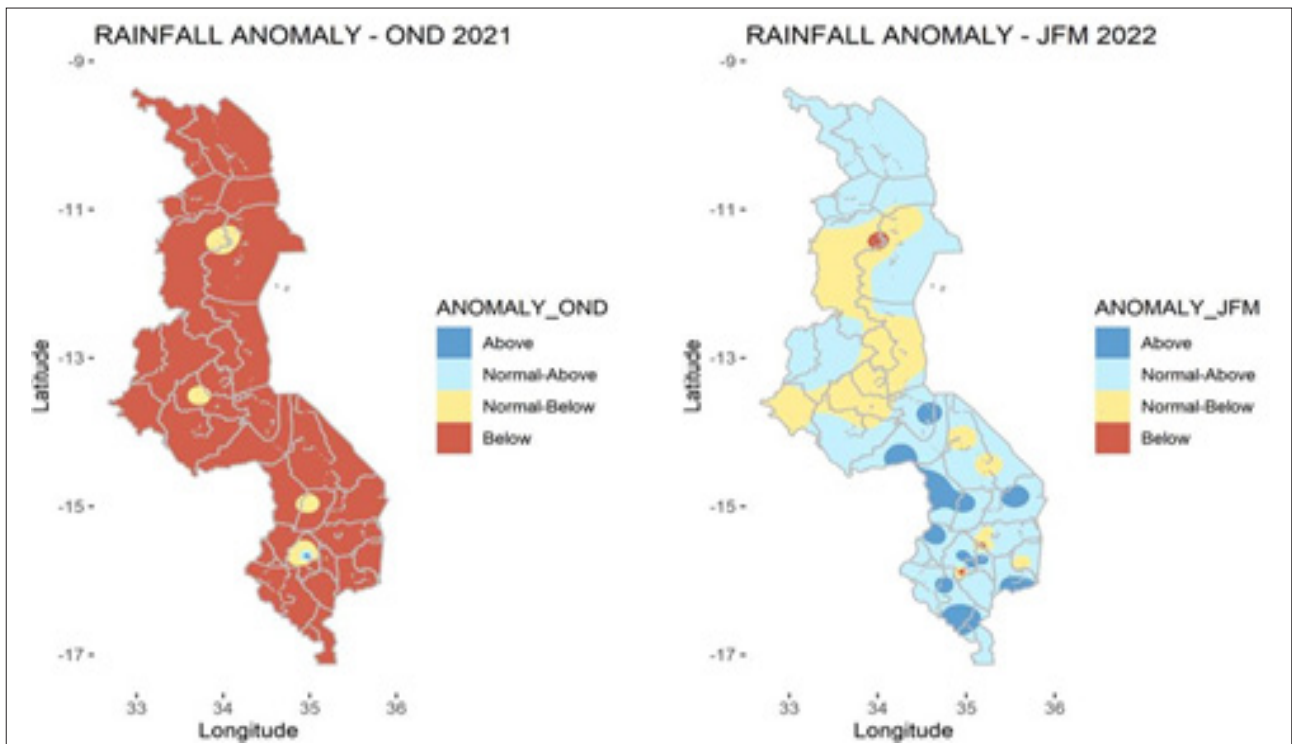


Figure 7: Observed sub-seasons rainfall anomaly for Malawi in 2022

The Figure 7 shows improved rainfall performance during the JFM 2022 (January to March) sub-season. The northern half of the country received normal to below-normal rainfall amounts, while the southern half received normal to above-normal rainfall. Cyclone Ana influenced the pick in rainfall amounts over the south where some rainfall stations recorded the highest ever 24-hour rainfall amounts. For instance, Chileka Meteorological station reported 352.1mm in one day, with other some stations' records in the range of 100-300mm.

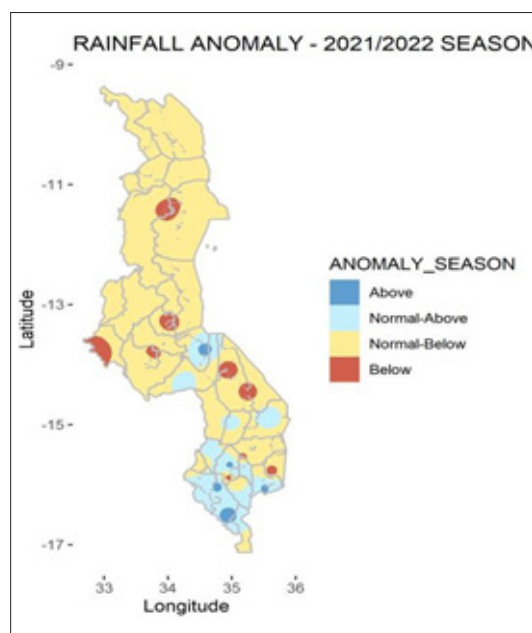


Figure 8: Observed Rainfall anomaly for Malawi in 2021/2022 rainfall season

Overall, the 2021/2022 rainfall season was not good as most areas received normal to below-normal rainfall amounts with only few areas over the south receiving normal to above-normal rainfall as depicted in Figure 8. December 2021 was the worst month within the season which affected rainfall amounts and also the planting season in Malawi. Despite this, southern areas performed well in terms of seasonal total rainfall amounts. This was due to other rain bearing systems that were well established by January 2022, including the influence of two cyclones Ana and Gombe.

2.2.2 Monthly Rainfall Distribution

Figure 9 shows the monthly rainfall anomaly for the whole rainfall season spanning from October 2021 to April 2022. In January although the northern half of the country especially in Mzimba and Nkhatabay continued to receive below-normal rainfall, there was a significant change mainly over the south where all the districts received normal to above-normal rainfall, with districts like Nsanje, Chikwawa, Mwanza and Neno receiving above-normal rainfall. The situation improved in the country during the month of February where most areas received normal to above-normal rainfall but some districts like Zomba, Phalombe, Nsanje, Blantyre and Neno received normal to below-normal. March experienced normal to below-normal conditions throughout the country except for some southern areas which benefited from cyclone Gombe, for example, Nsanje which recorded 24-hour rainfall of 150.1mm.

In April 2022, the north was also wet and some areas like Nkhatabay, Mzimba and Rumphi received above-normal rainfall but for the south there was a reduction in rainfall amounts as many districts received below-normal conditions. During the month of May, the whole country experienced below-normal conditions though by this time the northern part of Malawi gets more rains.

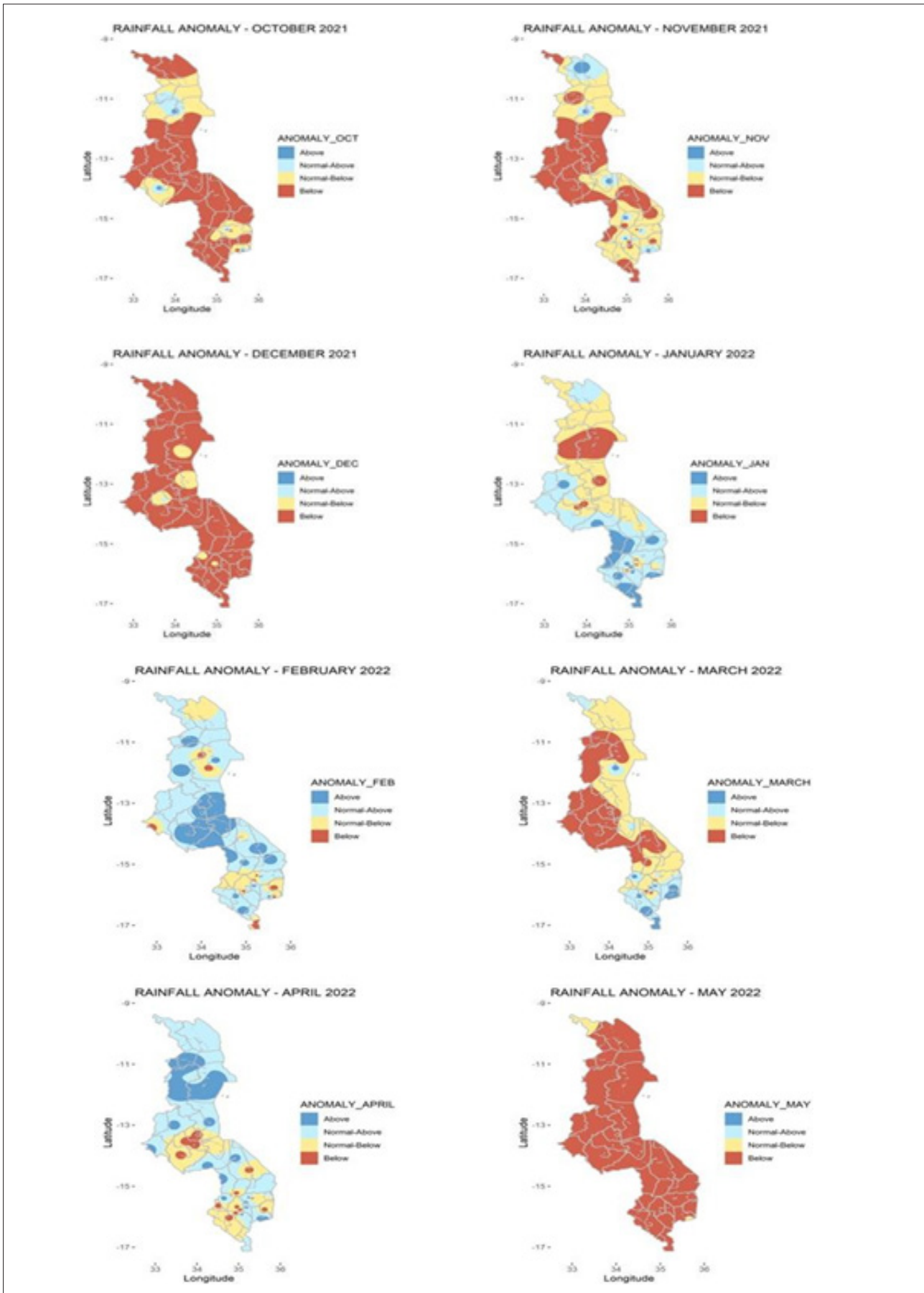


Figure 9: Observed monthly rainfall anomaly for Malawi in 2022

2.2.3 Cumulative Rainfall

Cumulative rainfall analysis is used to characterize observed rainfall performance and trends for different areas in the country. The cumulative rainfall departure from long-term average provides an indication of either insufficient or abundant rainfall during the season. Overall, the cumulative rainfall plots for 2021-2022 indicate that most parts of the country received normal to above-normal total rainfall amounts although the 2021/2022 plots for most of the stations appear to be below that of the long term mean 1991-2020, as shown in Figure 10. The stations used for analysis and comparison are; Karonga, Makoka, Chitedze, Bolero, Mzimba, Chileka, Mimoso, Ngabu and Salima.

The JFM season most of the stations during the 2021-2022 season accumulated rainfall as compared to the long-term mean cumulated rainfall. The following stations Salima, Chileka, Mimoso and Ngabu received normal to above-normal rainfall amounts. However, other stations received normal to below-normal rainfall amounts as compared with long term mean; stations like Makoka, Chitedze, Dedza, Bolero, Mzimba, and Karonga.

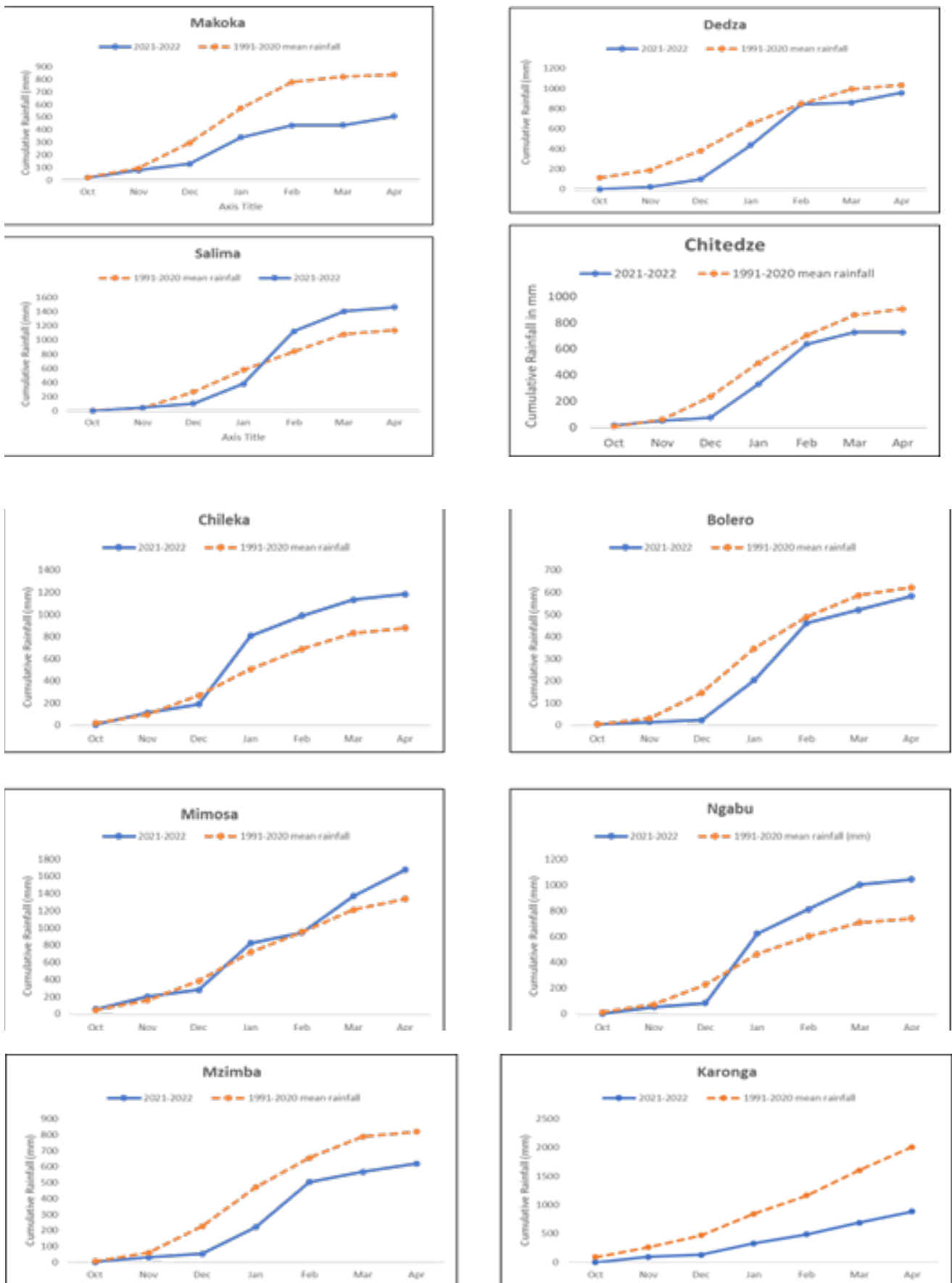


Figure 10: Cumulative rainfall analysis for Karonga, Makoka, Chitedze, Bolero, Mzimba, Chileka, Mimosa, Ngabu and Salima

CHAPTER THREE

3.0 Extreme Weather and Climatic Events

3.1 Standardized Precipitation Evapotranspiration Index (SPEI)

The monthly standardized precipitation evapotranspiration index (SPEI) can be used to monitor and assess drought characteristics with 1-month or longer drought duration. Based on precipitation and air temperature data from 1991 to 2022 at 21 meteorological stations across Malawi, drought indices (1-month SPEI) were computed and are presented in Figure 11 for the year 2022.

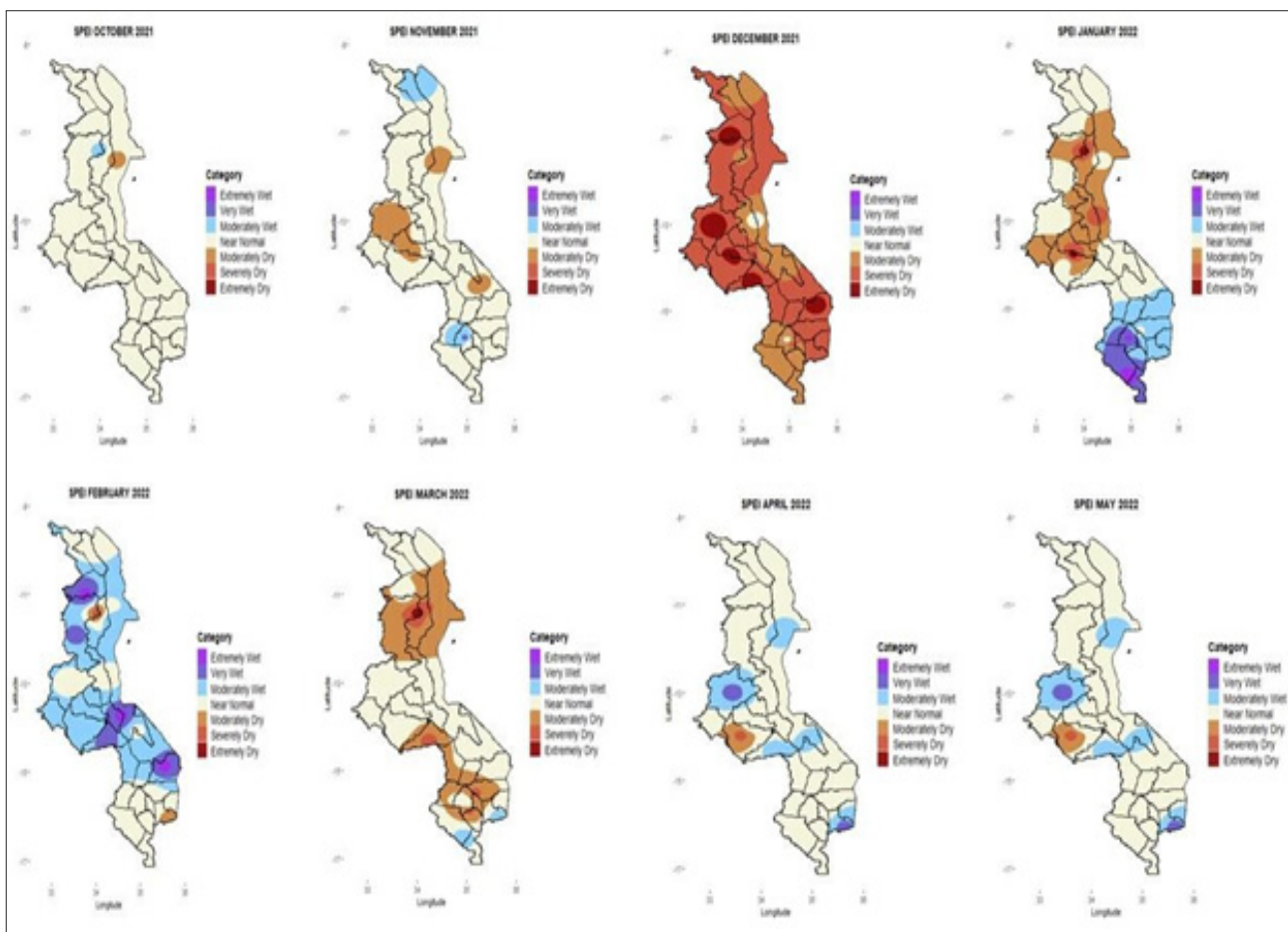


Figure 11: Observed Monthly SPEI for Malawi in 2022

During the October, November and December (OND) period, normal rainfall conditions prevailed in most areas. However, drought conditions of moderate magnitude were experienced in parts of Kasungu, Dowa and Mangochi. The month of December was extremely dry across Malawi.

In the month of January, there was rainfall improvement in the southern areas, where many areas experienced very wet conditions. Extremely wet conditions were observed in the districts of Nsanje, Chikwawa, Blantyre and Mwanza. These wet conditions are attributed to tropical cyclone Ana which enhanced rainfall over southern areas. On the contrast, drought conditions extended into January over central and northern areas.

During February, moderately wet conditions were experienced over many areas of central and northern Malawi while moderate drought was experienced in some areas such as Mzuzu and east of Mulanje.

For the month of April, normal rainfall conditions prevailed over central and southern areas. In the northern region, dry conditions prevailed mainly in Mzimba and Nkhatabay. There were also severe dry conditions in Dedza and some parts of Phalombe and Thyolo.

3.2 Extreme Rainfall and Flood Events

The extreme episodes of rains and floods were experienced during Tropical Storms Ana and Gombe. Tropical Storm Ana had its strongest influence over Malawi from 22 to 26 January 2022. Most rainfall stations over southern Malawi had new records set for maximum 24-hour rainfall, with some stations recording as high as 350mm. In terms of weather, Intense Tropical Cyclone Gombe had its strongest influence over Malawi weather from 11th to 14th March 2022. Rainfall records show that amounts during TS Ana were higher than those recorded during TC Gombe, this is in terms of spatial influence as well as highest recorded 24-hour rainfall values. A comparison of 24-hour highest rainfall amounts during Tropical Storm Ana and Tropical Cyclone Gombe is given in Figure 12.

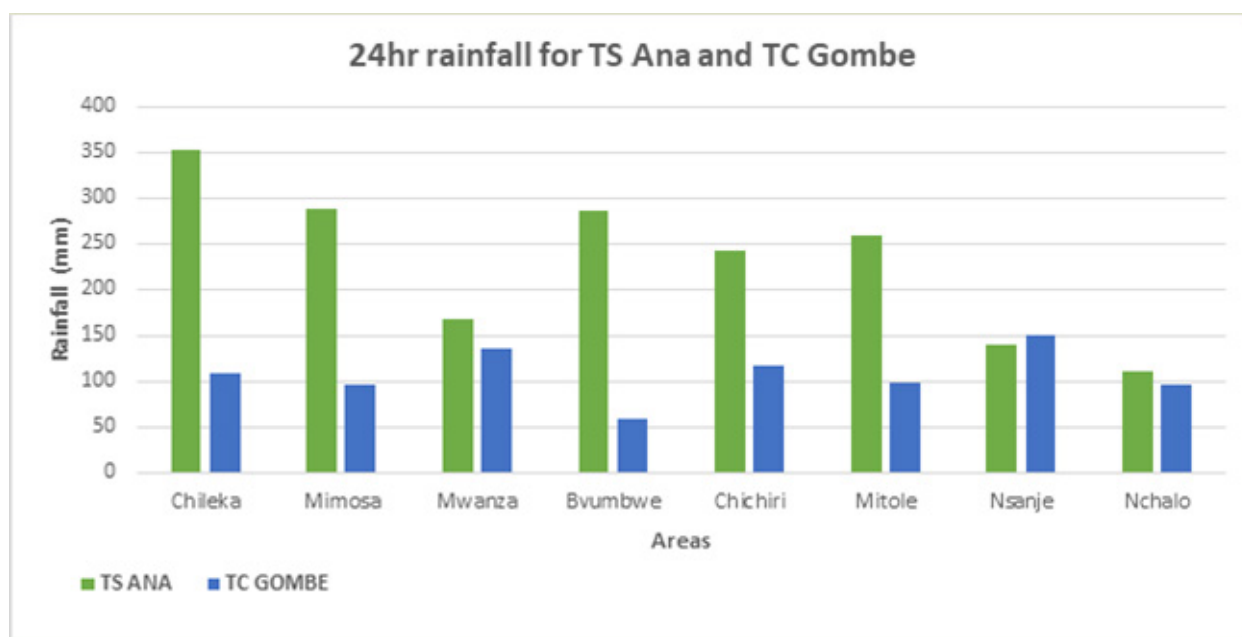


Figure 12: Observed 24-hour rainfall during TS Ana and TC Gombe

3.3 Extreme Temperature Events

The year 2022 was characterised by several events of higher daily maximum temperatures exceeding 36°C. Very high temperatures are expected in summer in the months of October, November, December and January.

During October, Lakeshore districts such as Karonga, Salima and Mangochi together with parts of central areas such as Kasungu and parts of Lower Shire Valley such as Ngabu in southern Malawi, recorded maximum temperatures above 36°C in this month. The highest number of days with extremely high temperatures was 29, and these were observed at Ngabu station in Southern Malawi. This was hot to very hot as the temperatures rose as high 42.5°C. With reference to 1991-2020 climatological period, the highest recorded maximum temperature for Ngabu station is 45°C, recorded in November 2020. These extreme temperature events are exacerbated by the topography of the area as it is a low lying area with altitude of 102m above sea level. Salima registered 14 very hot days with highest temperatures of 37.3°C on 20th October, 2022. Mangochi experienced 12 days of extreme hot weather with the maximum temperature reaching 40°C on 28th October, 2022.

In November 2022, hot weather conditions were experienced over most parts of Malawi. The lakeshore (Karonga, Salima, Nkhatabay, Mangochi and Nkhotakota) and the lower Shire experienced hot to very hot conditions with temperatures exceeding 36.5°C. Among these stations Ngabu had 21 very hot days, with extreme temperatures in the range of 40.5 to 42.5°C. Temperatures above 40.0°C were experienced from

18th to 20th November and 27th to 28th November, 2022 in the lake shore areas and lower shire valley. Salima had registered 14 days of temperatures exceeding 36°C with the highest temperature recorded 37.3°C on 20th November, 2022. Similarly Mangochi recorded 12 days, Karonga 4 days and Nkhatabay 2 days. Based on the timely weather warning issued by DCCMS, the Ministry responsible for Education suspended schools in the areas affected.

During December most areas observed warm to hot conditions with isolated events of maximum temperatures exceeding 36°C. Ngabu in Chikwawa registered 42.5°C on 6th December 2022 as the hottest day, with 20 days of maximum temperature exceeding 36°C. Mangochi also had 2 days with extremely high temperatures, one of which was 37.2°C on 6th December, 2022.

On the other hand, Malawi winter runs from May to August and this is the period when extreme cold temperatures are usually recorded. During the year 2022, very cold weather conditions with minimum temperature below 11°C were experienced over some parts of Malawi including northern-central areas which recorded up to 20 cold nights over Mzuzu in the month of August. In addition, Mzuzu recorded the coldest night temperature on 3rd July 2022 and this was as low as 6°C. The 2022 monthly average for the area was 8.5°C. The next extreme low temperature event in Northern Malawi occurred at Mzimba station which reported 7.4°C on 6th August, 2022.

The coldest night event in central Malawi occurred at Kamuzu International Airport Meteorological station which is located in the central western part of Malawi. This station reported a minimum temperature as low as 6.1°C on 13th June, 2022 which is 4°C lower than its monthly average. Relatively fewer days with extremely cold nights were reported over the south. Notably, Mimosa station in the Southern highlands reported 8.9°C on 1st August, 2022

CHAPTER FOUR

4. Major drivers of weather and climate events in 2022

The Malawi weather and climate events are influenced by local, regional, and global factors. These factors induce the rain-bearing systems that influence rainfall over Malawi which include the Inter-tropical convergence zone (ITCZ), Congo air mass, easterly waves, and tropical cyclones. Winter season is characterised by Mwera winds and Chiperone conditions.

4.1 Observed Rain Bearing Systems and Wind Regimes

4.1.1 Inter-tropical convergence zone (ITCZ)

The ITCZ exists due to the convergence of the trade winds along regions of maximum solar heating. In these regions, north-easterly trade winds from the northern hemisphere converge with south-easterly winds from the southern hemisphere, leading to convective clouds formation as the air is forced up into the warm atmosphere. The ITCZ is formed as a collection of these zones, and is characterised by frequent thunderstorms and heavy rains.

In the year 2022, ITCZ started influencing Malawi weather on 31st December, 2021. The weather System caused thunderstorms and rains which were heavy over some places in southern Malawi. The Inter-Tropical Convergence Zone (ITCZ) continued its influence on the weather in Malawi's region up to late March 2022.

4.1.2 Congo Air Mass

Congo air mass comprises of westerly air mass originating from Atlantic Ocean passing through a tropical forest of Congo basin brings rainfall over most countries in the southern Africa including Malawi. The air mass is characterised by occasional thunderstorms and persistent rainfall covering a wider area and over a long period of time. The region where the low level westerlies from Congo basin converge with easterlies from Indian Ocean trade winds at the surface is called Congo Air Boundary (CAB).

Congo air mass first influenced Malawi weather on 15th January, 2022 which caused widespread rains mainly over central and northern areas. The weather system stopped influencing the weather over the country in late March 2022.

4.1.3 Easterly Waves

The Malawi rainfall season cessation is signified by Easterly waves originating from the eastern part of tropical oceans and moving westward at speeds ranging from 10 to 20 knots. The waves bring about rainfall associated with a wave-like disturbance of the normal isobaric pressure pattern.

By early April, 2022, easterly waves became a dominant weather system. This marked the end of the rainfall season over most areas in Malawi. Rainfall ceased in early April in most southern and central areas while the rains continued over most northern areas until late April and early May.

4.1.4 Tropical Cyclones

The summer season is affected by Tropical Cyclones originating from the Southwest Indian Ocean which brings dry spells or wet spells over the country depending on its position and trajectory in the basin. Some of the Tropical cyclones make a landfall over Mozambique and proceed to hit Malawi directly which leads to loss of life and property, and damage to infrastructure due to devastating floods and strong winds.

In 2022, Southwest Indian Ocean recorded and named 9 Tropical cyclones and storms of which 4 of them were fully grown as shown in Figure 14. Malawi as a country was directly affected by two of these cyclones. Tropical Cyclone Ana impacted the southern half of Malawi from 24th to 27th January 2022 bringing strong winds and heavy rains which led to significant floods affecting 16 districts, hundreds of thousands of people, and causing damage to infrastructure such as Hydro-power station and supply lines. Tropical Cyclone Gombe also hit southern Malawi from 12th to 13th March 2022, affecting 11 district councils. The two Tropical Cyclones resulted in the Malawi government declaring a state of emergency in the southern half of the country.

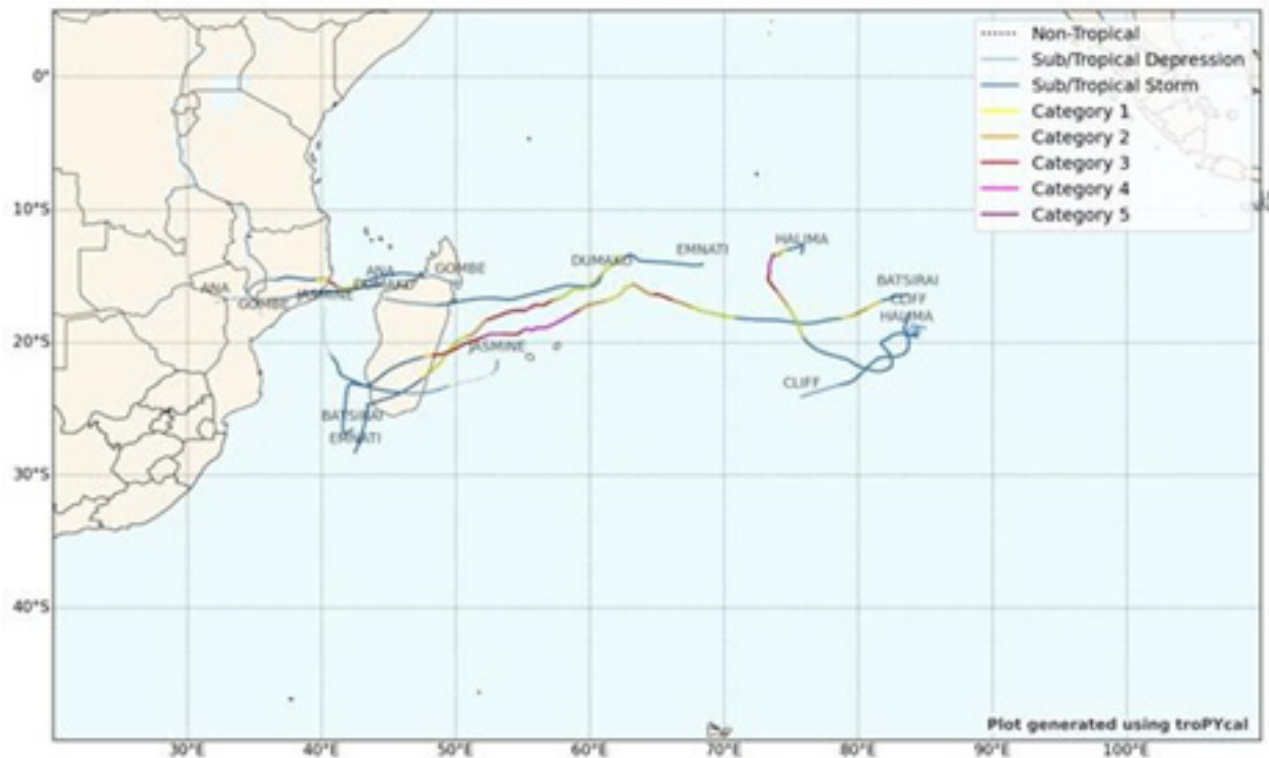


Figure 13: Southwest Indian Ocean Tropical cyclone tracks in 2022

4.1.4 Mwera winds and Chiperone

Malawi winter weather and climate events are influenced by cool and moist air mass from the Indian Ocean due to the dominance of high-pressure systems moving from Azore Island to St Helena Island. The strong high-pressure systems lying over the Southern East Coast of South Africa draw a cool and moist south easterly air mass into the country causing overcast conditions with rain drizzles locally known as “Chiperone” over highlands and Mwera (south-easterly) winds over Lake Malawi.

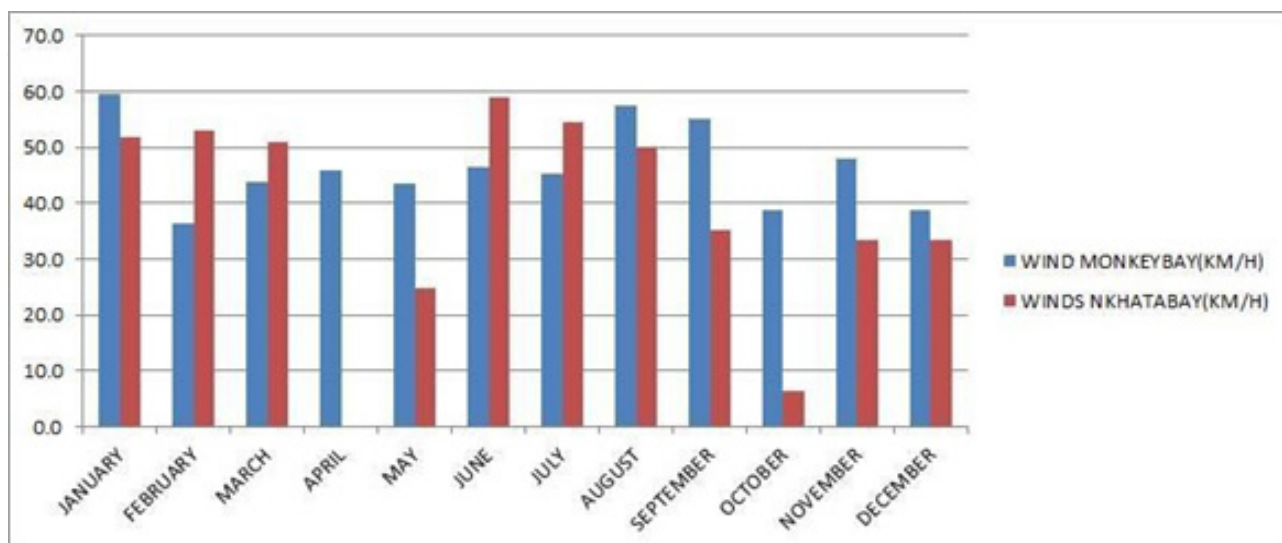


Figure 14: Observed winds over Lake Malawi in 2022

The frequency of winds throughout the year 2022 is presented in Figure 15. For the months from April to September Mwera winds and episodes of chiperone are depicted in the graph where June to August has the highest wind speed in the range of 50 to 60km/h. However, during October, November, December, January, February, and March the winds are from different directions.

4.2 Observed Climate drivers

The dominating and key driving factors of the weather and climate events over Malawi are global factors that include mean sea level pressure, upper-level winds, and sea surface temperatures over the Pacific, Indian, and Atlantic Tropical Oceans.

4.2.1 The Sea Surface Temperatures (SSTs)

The conditions and variations of the SSTs in the global oceans play a crucial role in driving weather and climate worldwide by modulation of general atmospheric circulation. The conditions of SSTs determine other important factors influencing weather and climate events through indices including El Niño and Southern oscillations (ENSO), Indian Ocean Dipole (IOD), and Madden-Julian Oscillation (MJO). The modes of SSTs are associated with enhanced or suppressed rainfall over Malawi.

4.2. 1. 1 El Niño and Southern oscillations (ENSO)

ENSO is a climate phenomenon with three phases of El Niño, Neutral, and La Niña. El Niño is a warming of the ocean surface or above-average SSTs while La Nina is

a cooling of the ocean surface or below-average SSTs in the central and eastern tropical Pacific Ocean. Neutral is neither El Niño nor La Niña and is mostly associated with close to average conditions of SSTs in the Tropical Pacific Ocean. The ENSO is considered El Niño when the average SSTs anomalies are greater than 0.5°C , as La Niña when it is less than -0.5°C , and Neutral when it is between -0.5 and 0.5°C .

The year 2022 season was influenced by La Niña which has a history of bringing more rain over Southern Africa including Malawi. The ENSO observation for historical including 2022 is shown in Figure 16.

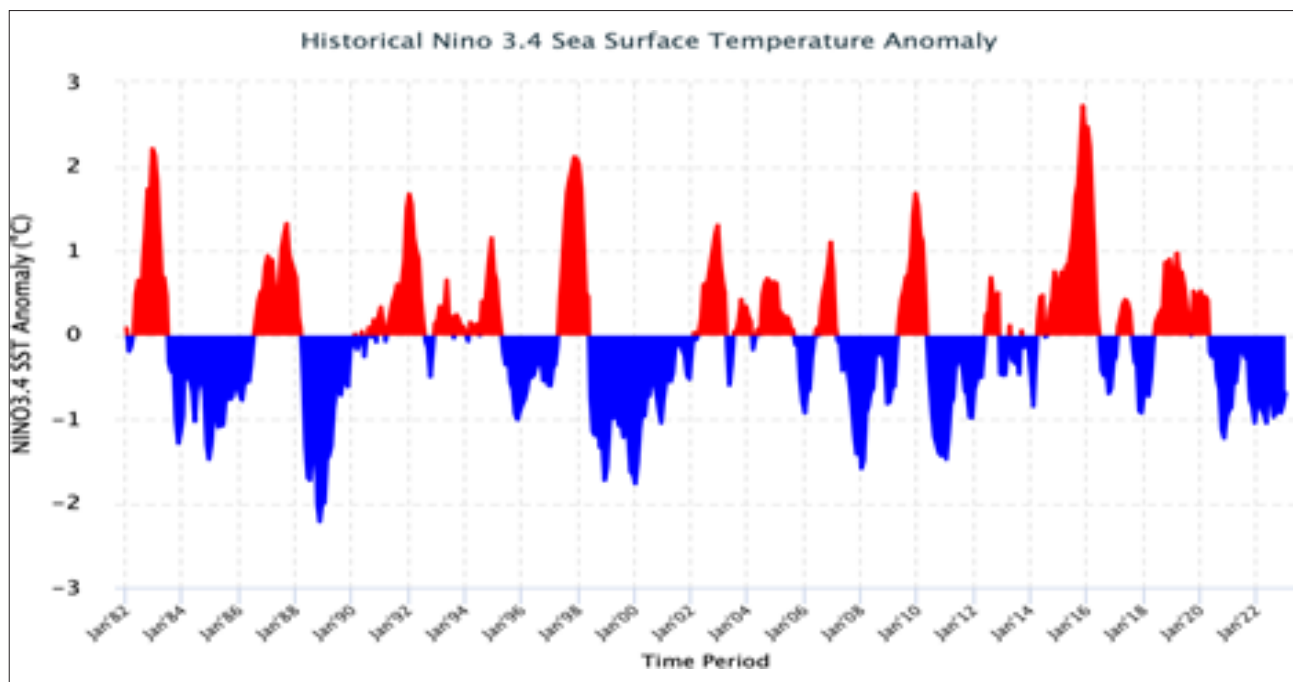


Figure 15: Observed Sea Surface Temperature anomaly for Nino 3.4 including the year 2022 (IRI, 2023)

4.2.1.2 Indian Ocean Dipole (IOD)

The Indian Ocean Dipole (IOD) is a well-known ocean-atmosphere coupled mode in the Indian Ocean which has a significant influence over the surrounding weather and climate events. It is associated with irregular oscillation of SST anomalies in which the western Indian Ocean becomes alternately warmer (positive phase) and then colder (negative phase) than the eastern part of the ocean. The IOD is considered negative when the Dipole Mode Index (DMI) is less than -0.4 , as positive when it is greater than 0.4 and Neutral when it is between -0.4 and 0.4 .

The year 2022 was influenced by a negative phase of IOD as shown in Figure 17. The DMI index values were within negative bounds throughout the year.



Figure 16: Observed Indian Ocean Dipole Index including the year 2022 (Weatherzone, 2022)

4.2.1.3 Madden-Julian Oscillation (MJO)

The Madden-Julian Oscillation (MJO) is one of the modes of intra-seasonal atmospheric variability in the tropical oceans and can be interpreted as an eastward-propagating disturbance covering about 30–90 days as the passage of an active phase is associated with enhanced tropical disturbances while the inactive phase suppresses tropical disturbances over a region. MJO is defined in the tropics, but its effects are felt deep both in the tropics and the mid-latitudes. In the tropics, Southern Africa, in particular, the effects include; Changes distribution of clouds, rainfall, and wind; modulating monsoonal rains, and enhancing tropical cyclone development.

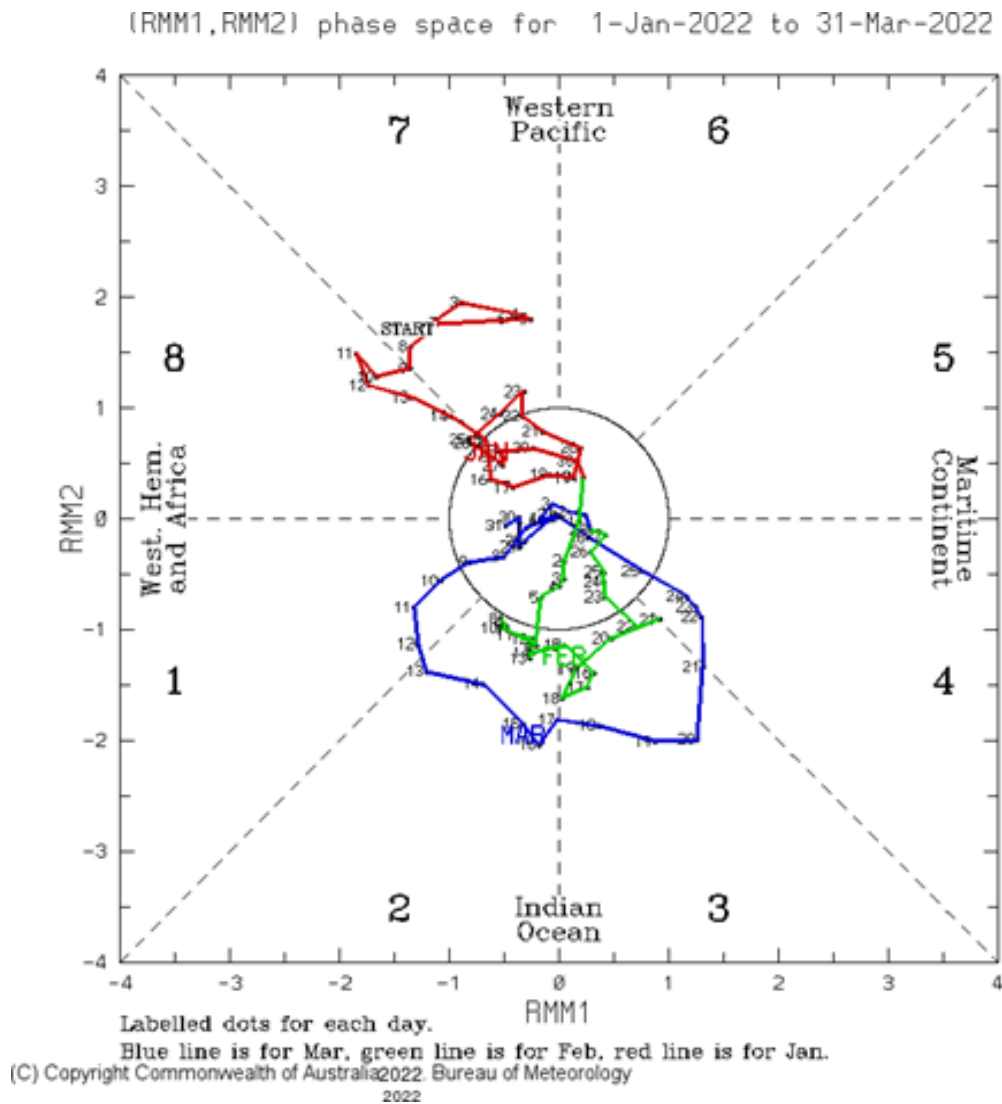


Figure 17: Observed MJO between January and March, 2022 (Australian , 2022)

With reference to Figure 16, the Africa region which falls in phases 1 and 8, the 2022 rainfall season, the MJO was active in January and March represented by red and blue lines respectively. These are the months in which Malawi was hit by Tropical cyclones Ana and Gombe.

CHAPTER FIVE

5. Social-economic impacts of extreme Weather and climate events

Extreme weather and climate events can have significant social and economic impacts on individuals, communities, sectors, and entire country. Weather and climate events affect all sectors taking part in social economic activities in Malawi. The key sectors affected by the extreme weather and climate events are disaster risk reduction, agriculture and food security, water resources, transport, energy, health and education.

5.1 Early Warning and Disaster Risk Reduction

The DCCMS issues weather forecasts and severe weather warnings for various hazardous weather conditions. Weather forecasts and weather warnings start with weather monitoring which is critical in understanding the current situation in terms of weather. This is then followed by weather analysis and prediction. Weather analysis tries to understand what weather systems are contributing to the current weather conditions and predicting what is likely going to happen in the near future.

Once all the weather information including warnings is generated it gets packaged in a manner that is user friendly. The weather forecasts and warnings are translated into local languages like Chichewa so as to make sure that the targeted audience understands the severe weather warnings properly and made public. The department uses the fastest and most convenient modes of communication to send weather warnings to the public such as TVs, emails, radios and social media platforms like WhatsApp, Facebook, Twitter and YouTube.

In January 2022 when DCCMS identified Tropical Storm- Ana as having potential to affect Malawi, the general public and key stakeholders were warned in good time to give room for preparations and evacuations. All emergency agencies and government departments including DoDMA were informed in time. The warning detailed the expected threats, their impacts and severity. The warning was as follows:

“WARNING ON “MODERATE TROPICAL STORM ANA” IN THE INDIAN OCEAN

UPDATE: Date and Time of issue: Monday 24 January, 2022; 11:00am

The Department of Climate Change and Meteorological Services would like to inform the Malawi nation that a tropical depression that formed to the north east of Madagascar in the Indian Ocean is located in the Mozambique Channel where it is expected to intensify as it continues moving towards Mozambique coast at a speed of 40km/hour and maximum wind speed of 100km/hour.

Meanwhile, weather models are indicating that Tropical depression is expected to make landfall on the Mozambique coast during the midday of Monday 24th January 2022. The storm is heading towards southern Malawi and likely to pass through Machinga, Zomba, Phalombe and Mulanje districts.

At the current position, the tropical depression will partly enhance fairly moist air from the Indian Ocean into Malawi and the impacts will not be significant. However, heavy rains exceeding 150 mm in a day and very strong winds exceeding 80 km/hour in more areas are expected over southern Malawi spreading to the centre starting from Monday 24th January 2022.

Districts on the highest threat are Mulanje, Thyolo, Phalombe, Chiradzulu, Balaka, Machinga, Blantyre, Chikwawa, Nsanje, Zomba, Mangochi, Mwanza, Neno, Ntcheu, Dedza, Lilongwe and Salima.

Heavy rains and very strong winds are likely to cause floods and downing of trees and power lines, as well as some structural damage. The public is strongly advised to move to higher grounds and avoid crossing flooded rivers and streams.

Meanwhile, DCCMS will continue to monitor the movement and strength of Tropical Depression. Any possible impacts on Malawi Weather will be communicated to the nation accordingly.”

Tropical cyclone Ana disaster assessment report by DoDMA issued on 31 January 2022 highlighted that 64 people have been reported dead, 18 people missing and 206 people injured, over 221,127 households affected and 740 hectares of crops have been destroyed. The cyclone affected 16 districts and two cities and impacted approximately 994,967 people (DoDMA, Malawi, MALAWI: Tropical Storm Ana, 2022a). Chikwawa District was highly affected among the affected districts as shown in Table 1.

District	Affected HHs	Affected Population	No. of Camps	Number of HHs in camps	Deaths	Missings	Injuries
Mchinji	152	745	-		0	0	2
Mulanje	13,210	64,729	19	2,678	5	38	32
Neno	7,783	38,137	2	22	5	25	0
Nsanje	16,612	81,399	18	6,096	0		0
Machinga	2,864	14,034	1		2		24
Chikwawa	84,106	412,119	43	10,159	13	18	19
Zomba	8,320	40,768	6	424	1		2
Mangochi	3,604	17,660	2	179	1		5
Balaka	7,515	36,824	2	1,448	0		0
Blantyre	12,651	61,990	21	197	5		18
Dedza	998	4,890	-		0		0
Thyolo	2,381	11,667	4	179	4		0
Chiradzulu	11,761	57,629	-		0		8
Mwanza	4,378	21,452	3	113	2		8
Ntcheu	3,961	19,409	-		3		28
Phalombe	13,262	64,984	3	869	4		5
Total	193,558	948,434	124	22,364	45	81	151

Table 1: Quantified impacts of Tropical Storm Ana on Malawi districts (Malawi Red Cross Society, 2022).

In March 2022, another Tropical Storm named Gombe was detected by DCCMS. Again, the public and all emergence agencies and departments were informed. A warning was also issued to the general public detailing all the expected threats, their impacts and severity. The warning was as follows:

“WARNING OF TROPICAL STORM GOMBE

Date and Time of issue: Wednesday 09 March, 2022; 11:00 am

The Department of Climate and Meteorological Services (DCCMS) would like to update the Malawi national that Tropical Storm Gombe is now in the Mozambique Channel and still moving westwards at 13 km per hour and intensifying along the way.

As of today, 9 March 2022 at 11:00 am, Tropical Storm Gombe was located about 500 km away from the Mozambique coast. Meanwhile, weather models are indicating that Gombe is expected to reach the Mozambique coast by Friday 11 March and enhance rainfall over Southern Malawi at the same time drawing Congo air mass over Central and Northern areas. The rainfall may exceed 100 mm in 24 hours in some areas on Saturday and these include Mulanje, Nsanje, Chikwawa, Phalombe, Zomba, Machinga, Mangochi and Salima districts. This amount of rainfall may trigger flash floods in some areas.”

The disaster assessment report for tropical cyclone Gombe revealed 39 people dead, 3 people missing, 20 people injured, 11,008 households displaced, and 35,383 households affected. The TC Gombe affected 11 district councils and 159,226 people (DoDMA, Malawi, Effects of tropical cyclone Gombe-induced heavy rains, flash floods, 2022b).

The two Tropical Cyclones resulted in the Malawi government declaring a state of emergency in the Southern half of the country.

5.2 Agriculture and food security

Malawi economy is predominantly agriculture based. Agriculture accounts for 30% of Gross Domestic Product and generates over 80% of national export earnings. Furthermore, the agriculture sector employs 64% of Malawi's workforce. (National Agriculture Policy, 2016).

Malawi is extremely vulnerable to weather and climate shocks. During the 2021/2022 rainy season, the country experienced a delayed seasonal onset coupled with false onsets particularly over southern areas. During the month of January 2022, the country was hit by

Tropical storm Ana, as was during the month of February when the country was hit by Tropical Cyclone Gombe which resulted in flooding particularly over southern Malawi resulting in crop wash-away, loss of property, livestock death as well as loss of human life. The agriculture sector was heavily affected as the climate shocks had adverse effects as shown in Figure 17 and Table 2.



Figure 18: Wash away maize field, Mikalango EPA, southern Malawi.

As a consequence of the delayed onset as well as dry spells experienced during the 2021/2022.

Crops	Third Round 2021/22 Production(mt)	Third Round 2020/21 Production(mt)	% Change against Third Round 2020/21
Maize	3,716,479	4,581,524	(18.9)
Rice	136,083	155,433	(12.4)
Millet	41,071	42,289	(2.9)
Sorghum	116,918	118,351	(1.2)
Groundnuts	434,762	402,993	7.9
Cotton	20,666	21,075	(1.9)
Sesame	7,031	5,873	19.7
Sunflower	20,884	21,356	(2.2)
Wheat	163	302	(46.0)
Pulses	1,038,086	1,001,739	3.6
Beans	218,889	227,795	(3.9)
Pigeon Peas	428,609	421,402	1.7
Cow Peas	52,035	52,344	(0.6)
Soya Beans	303,084	264,497	14.6

Table 2: 2021_2022 National Field crops production (APES, 2022)

The majority of Field crops registered a decrease in production during the 2021/2022 farming season as compared to 2020/2021 with unfavourable weather among the major factors for the decrease. The highest decrease was registered in Wheat at 46% seconded by maize at 18.9% with unfavourable weather conditions cited as one of the major contributing factors in the experienced decrease in production (APES, 2022).

The various related climate shocks also contributed to 13% of the Malawi population facing high acute food insecurity (IPC Phase 3 or above as of June 2022 which was projected to hit 20% as of March 2023 according to the Malawi Vulnerability Assessment Committee August 2022 report as depicted in Figure 20 (IPC Malawi, 2022).

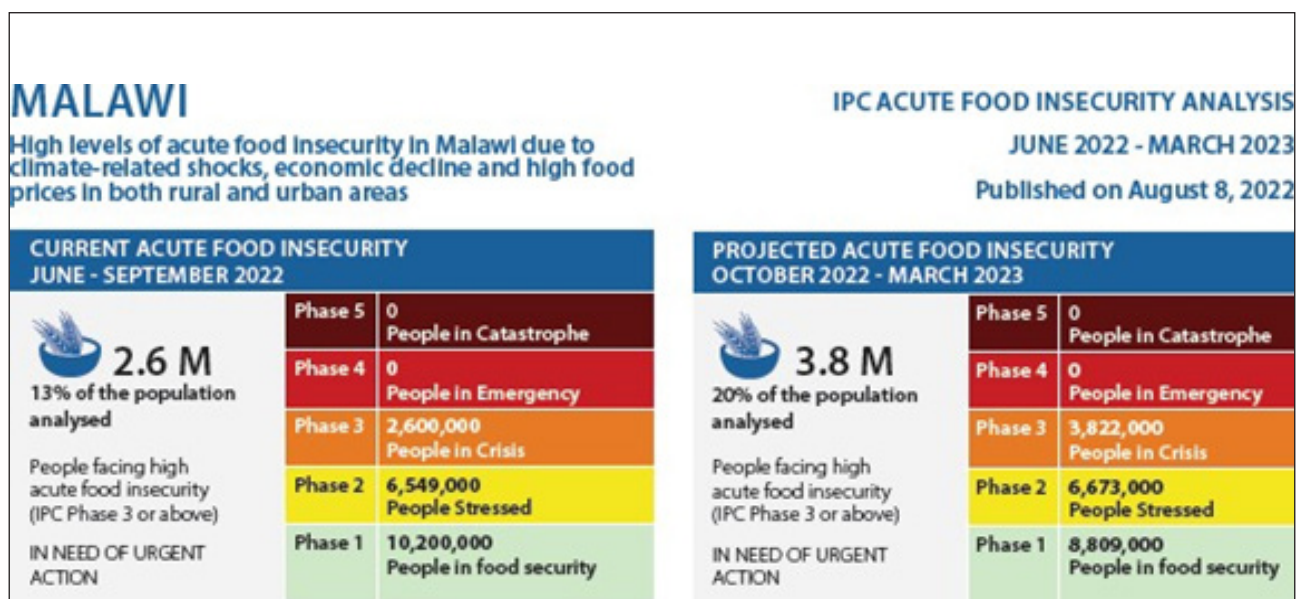


Figure 19: Acute food insecurity situation (IPC Malawi, 2022)

5.3 Water Resources

Malawi has a total surface area of 118,484 km² of which 20% is covered by surface water (Department of Fisheries, 2012), and Lake Malawi alone has a surface area of 29,000 km². The lake has a drainage system made up of rivers such as Shire, Linthipe, Bua, Dwangwa, Songwe, North Rukuru and South Rukuru, among others. The Lake Malawi is the third largest lake in Africa with an average depth of 292m. It is bordered

by three countries Malawi, Mozambique and Tanzania and is situated in the Great African Rift Valley between 09°30'S and 14°30'S (Patterson & Kachinjika, 1995). The most productive areas on the lake are the shallow areas found in the southeast and southwest arms of the lake (Kanyerere, 2001).

During the 2022 rainfall season, water levels of Lake Malawi had gone up, according to the National Water Resources Authority (NWRA), an upward trend that had been recorded since 2017. The authority cited increased rainfall as one of the factors contributing to the trend. According to the authority, the hydrological year under study was from November 1 2021 to October 31 2022. In the 2021-22 hydrological year, the lake reached a highest level of 475.31 metres above sea level (masl). This was a 0.1 percent increase from the previous year. In the previous year 2020/21, the highest level reached was 474.84masl (Malekeza, 2022).



Figure 20: Increased water levels in Lake Malawi (Malekeza, 2022)

5.4 Transport

Extreme weather and climate events have significant social and economic impacts on transport systems, which lead to disruption of transportation networks. It affects all modes of transport like road, marine, rail and air by damaging infrastructure, disrupting services, and causing delays and cancellations.

Road transport

Tropical cyclones Ana and Gombe caused flooding due heavy rainfall which adversely affected the road network infrastructure. For example, the road from Nsanje to Blantyre (M1) was cut off on three points; at Domasi, Bereu and Sekeni and was rendered impassable to vehicles as pictured in Figure 19.



Figure 21: The M1 road in Chikwawa district was damaged by the floods

Records showed the affected roads to be; Mkando bridge on the Thuchila river in Mulanje District damaged but still passable with caution; The road to Dindi school in TA Chiwalo was damaged by the floods; Mtenangokwe bridge in TA Mponda was washed away by the floods and remained unpassable; The road to Kapichira was not passable for reasons of rehabilitation of power lines; The road from Blantyre to Lilongwe between Chingeni and Zalewa Roadblocks (Kammwamba) was temporarily closed to heavy duty vehicles above 2 MT due to the damages caused by the floods. The road remained accessible to small vehicles. Heavy vehicles were advised to use the Chingeni – Balaka – Liwonde – Zomba – Blantyre Road. Acut off road in East Bank of Shire River is seen on the picture in Figure 20.



Figure 22: A cut off road in East Bank of Shire River

Floods lead to vehicle wash aways which are particularly common in low-lying areas and near river banks, where floodwaters can quickly rise and become very powerful. The floods washed away a vehicle while a driver was trying to cross flooded river as shown in Figure 21.



Figure 23: Washed away vehicle in Lower Shire

Marine transport

Weather, more especially storms, heavy rainfall, moderate and strong winds, affect marine transport. Typically, tropical cyclones are associated with storms. The tropical cyclones Ana and Gombe had significant impact on marine transport operations. Due to impassable roads, in times of tropical cyclones, rescue efforts depend on marine and air transport. During the tropical cyclone Ana and Gombe disaster; DoDMA activated and deployed the search and rescue team to Chikwawa, Nsanje, Mulanje and Phalombe districts where boats were dispatched to conduct search and rescue operations in the areas that were cut-off. The boats were provided by the Malawi Defence Force (MDF), Malawi Police Service- Marine and Marine Department in the Ministry of Transport and Public Infrastructure.

For lake operations, the Malawi Shipping Company, a privately owned company, runs services for both passengers and business on Lake Malawi, as well as shipyard activities. The company says they were affected by Tropical Cyclone Ana for 5 days during which they encountered severe North Easterly winds which negatively affected their operations on the lake. They were mostly affected by delays of between seven and eight hours (7 and 8) in offloading and boarding of passengers since the boats they were using were small and could not withstand the strong winds. In one of their operations, they failed to stop at Makanjira due to the strong winds.

Rail transport

Rail transport forms one of the major modes of transport of goods and passengers in the country. Most of the railway lines in the country need maintenance and rehabilitation.

The Ministry of Transport and Public Works attributed that cyclones Ana and Gombe were major factors that delayed the completion of the Limbe-Sandama railways line which were slated for May 2022.

Air transport

Extreme weather events such as tropical cyclones, thunderstorms, and fog disrupt air travel by causing flight cancellations and delays. Flight cancellations and delays were common in 2022 during the periods of Tropical cyclones Ana and Gombe. Delays also occurred in the winter months of May to August due to heavy fog. In addition, extreme heat is also known to affect air travel by reducing the lift capacity of planes. High temperature conditions cause some aircrafts to operate early in the day or late towards evening when it is a bit cool.

5.5 Energy

The impacts of extreme weather and climate events on the energy sector are significant and costly in Malawi. It results into disruption of energy production and supply which lead to more frequent blackouts. It also affects renewable energy systems as high winds or hail can damage solar panels.

In 2022, Tropical cyclone Ana affected the hydro-power generation facilities of Kapichira, Tedzani, Nkula I, and Nkula II Stations belonging to EGENCO. This resulted in a National wide blackout for more than 24 hours. Kapichira station was highly affected due to the overtopping of the Shire River training dike and fuse plug, erosion of the main dam slopes, and damage to steel structures on the spillway bridge of the station as shown in Figure 22.

Apart from the permanent structures, the storm and floods also washed away heavy machinery on the dike and water vessels from where they were docked. Such being the case, Kapichira Power Station could no longer generate power amounting to 129.6MW, reducing EGENCO's power generation capacity by 32%, and consequently reducing the power available to the national grid (EGENCO, 2022).



Figure 24: Kapichira power station dike, extensively damaged by Tropical storm Ana in January 2022 (EGENCO, 2022)

5.6 Health

According to Kalkstein and Valimont (1987), human health and wellbeing is directly or indirectly affected by weather. Over the years, it has been proved that weather is associated with outbreaks of some pandemics and endemics which are vector borne (Malaria, Lymphatic Filariasis, Chikungunya, Dengue Fever, Schistosomiasis, Pneumonia, Influenza bronchitis

and others), tick borne and also water borne diseases like Cholera and dysentery amongst others. The rate of deaths resulting from weather hazards is also increasing, like drowning during floods, being hit by poles or fallen trees after heavy rains, amongst others (Kalkstein & Valimont, 1987).

In the rainy season of 2021/2022, Malawi was hit by Tropical Storm Ana, and subsequently Cyclone Gombe that affected most parts of southern Malawi, bringing heavy rains and flash floods in some districts. The heavy rains resulted in extensive destruction of infrastructure (Including health facilities) and disruption of water and

sanitation systems with a high likelihood of resulting in Cholera outbreak, which started on 3rd March 2022 with the first case reported from Machinga district (WHO, 2023).



Figure 25: A child undergoing nutritional screening at Matsukambiya in Chikwawa after Tropical Storm Ana (WHO, 2023).

The cholera outbreak was limited to the flood-affected areas in the southern region until August 2022 when it spread to the northern and central parts of the country. By December 2022, cases had spread back towards the south of the country with all regions affected including Blantyre and Lilongwe, the two main cities of the country (WHO, 2023).

Since the beginning of the outbreak, and as of 3 February 2023, the age group 21 to 30 years has been the most affected (27.7% of cases), followed by the 11 to 20 age group (22.8%).

Of all the cases, 17 943 are males representing 57% of the caseload. Most deaths have been reported among those aged 60 years and above as of 29 January 2023. Most deaths have occurred among males (66%) (WHO, 2023). The figures 26 and 27 show the number of suspected and confirmed cholera cases (n=36 943) and deaths (n=1210) per day in Malawi, 3 March 2022 to 3 February 2023.

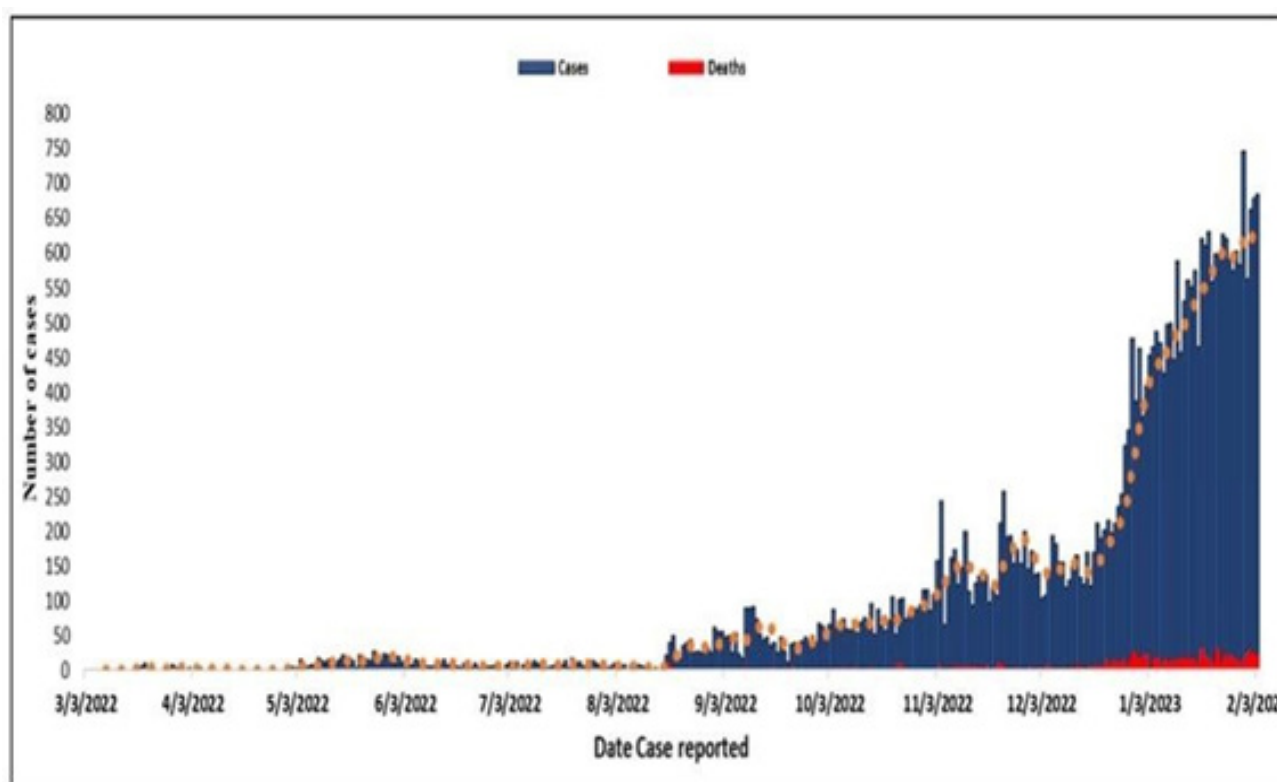


Figure 26: Presentation of suspected and confirmed cholera cases (n=36 943) and deaths (n=1210) per day in Malawi, 3 March 2022 to 3 February 2023 (WHO, 2023)

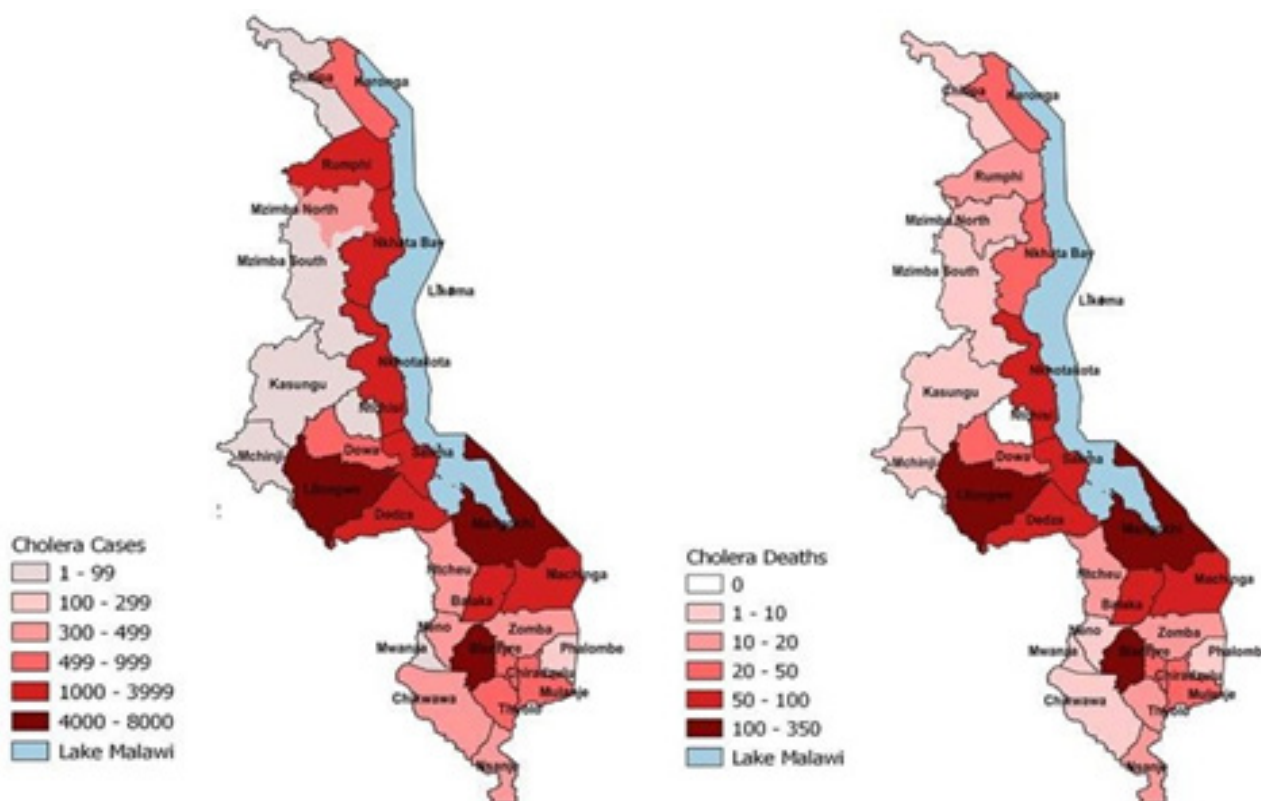


Figure 27: Geographical distribution of confirmed and suspected cholera cases ($n=36\,943$) and deaths ($n=1\,210$) by District in Malawi, 3 March 2022 to 3 February 2023 (WHO, 2023)

5.7 Education

The extreme weather and climate events have significant social and economic impacts on education systems. These impacts can lead to reduced academic performance, increased absenteeism, reduced access to education and psychological stress on students and teachers.

In the year 2022, most parts of Malawi were affected by floods and heat waves. These extreme climate events posed a challenge to the provision of education to learners.

In rainy season, the sector was highly affected by floods as a result of heavy rains and strong winds due to Tropical cyclone Ana. Schools in southern Malawi resumed on 26 January after a temporary closure on 25 January 2022, when the rainfall activities were most intense. In the five worst hit districts of Chikwawa, Mangochi, Mulanje, Nsanje and Phalombe, 70 primary schools were affected of which 35 schools hosted internally displaced people (IDPs), 30 suffered infrastructural damages and five lost teaching and learning materials affecting approximately 108,776 learners (UNICEF, 2022). In Chikwawa, Gonda Junior Primary

School, Nchalo Community Day Secondary School and Bereu Primary School were

affected by the storm. The storm also damaged a classroom in Neno District as shown in Figure 29. The affected communities seek shelter at a local school depicted in Figure 29. Both situations disrupt education system in affected areas.



Figure 28: Left: Classroom damaged. Right: Families shelter at a local school in Neno District during by cyclone Ana (Partners In Health, 2022).

In summer October 2022, the southern tip of Malawi, the lower Shire, experienced a heat wave whereby temperatures rose up to 42°C. A statement by the Minister of Education was issued suspending classes in the Lower shire following advice from DCCMS. The suspensions of classes were the only way to protect learners from the scorching sun and the high temperatures. In November, 2022, strong winds blew off the roof of Namitambo Primary School, as shown in Figure 27. The strong winds are associated with first rains also known as “Chizimalupsa” which marks the start of the rainfall season.



Figure 29: Primary school roof blown by strong wind in Mangochi, November, 2022

CHAPTER SIX

6.0 Summary and conclusion

During the year 2022, temperature observations indicate that the mean, maximum and minimum temperatures were slightly warmer than long term average for all months. On average, normal temperatures were observed over most areas with slightly higher than normal minimum and maximum temperatures in the ranges of 1.0 to 1.5°C and 0.5 to 1.5°C respectively. Whereas for rainfall, total cumulative rainfall amounts were generally Normal. With pockets of above normal and below normal rainfall amounts recorded over some parts of Malawi.

Malawi experienced varying degrees of extreme events during the year 2022. These included drought conditions, Tropical Storms Ana and Gombe, inducing heavy rains resulting in destruction of infrastructure both public and private as well as loss of lives. Hydroelectricity generation was delt a heavy blow at Kapichira Power station resulting in loss of 129.6 Megawatts from the national grid. Malawi also experienced very high temperatures during October to December 2022. Areas in the Lower Shire Valley and Lakeshore experienced heat waves that at some point led to the suspension of learning in schools in those areas due to the intensity of the heatwave. Other sectors affected by extreme weather events include Disaster Risk Management, Agriculture and Food Security, Water Resources, Transport (Road, Rail, Air, Marine), Health and Education. These contributed negatively to the growth of the Malawi economy in one way or the other.

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