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TMA
TANZANIA METEOROLOGICAL AUTHORITY

Statement on the Status of Tanzania Climate in 2021

March, 2022

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(TMA)

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Abbreviations

AAKIA	Abeid Amani Karume International Airport
ENSO	El Niño–Southern Oscillation
GIS	Geographic Information System
IDW	Inverse Distance Weighting
IOD	Indian Ocean Dipole
ITCZ	Inter-Tropical Convergence Zone
JF	January–February
KIA	Kilimanjaro International Airport
MAM	March to May
MJO	Madden Julian Oscillations
NDJFMA	November to April
OND	October to December
PMO	Prime Minister's Office
SSTs	Sea Surface Temperatures
SSTA	Sea Surface Temperature Anomalies
SWFDP	Severe Weather Forecasting Demonstration Project
SWIO	South Western Indian Ocean
TC	Tropical Cyclone
TMA	Tanzania Meteorological Authority
Tmax	Maximum temperature
Tmean	Mean temperature
Tmin	Minimum temperature
WMO	World Meteorological Organization
ZDMC	Zanzibar Disaster Management Commission

Foreword

Tanzania like many other developing countries is vulnerable to the impacts of climate change and variability. Increasing temperatures, sea level rise, changing precipitation patterns and frequent extreme weather events have threatened human life and safety, water and pasture availability, food security, and socio-economic development. Extreme temperatures, heavy rainfall, floods, prolonged dry spells, and droughts have significantly caused damage to infrastructures, disruptions of agricultural activities, and even increased habitat suitability for biting insects, pests, and transmission of vector-borne diseases.

In 2021, the country experienced impacts of extreme weather events mainly heavy rainfall, floods, prolonged dry spells, strong winds and high temperatures, which have greatly affected people's livelihoods. The year 2021 was also characterized by record breaking extreme rainfall events that caused widespread flooding in few parts of the country especially southern and western regions which resulted into destruction of infrastructures, settlements, and farm-fields among others. While prolonged dry spells that occurred at the end of the year 2021 caused devastating socio-economic impacts, particularly for pastoral communities, whereby large number of livestock were starved to death in some regions.

Tanzania Meteorological Authority (TMA) has dedicated efforts and resources to conduct robust and comprehensive climate monitoring and analysis and providing an authoritative statement on the status of Tanzania climate every year. This statement presents a detailed information of the significant meteorological and climate events and their consequences in the United Republic of Tanzania from January to December 2021. The statement also provides information on the status of climate by putting it into historical perspectives. The report is essential for planning, decision making and for informing climate change adaptation strategies to various social-economic sectors, research, and academia for sustainable development.

I would like to express my sincere gratitude to all stakeholders for continuous support, constructive comments and ideas, and feedbacks towards improving this series of annual publication on the status of Tanzania climate.

Dr. Agnes L. Kijazi
Director General
Tanzania Meteorological Authority

1. Introduction

Climate change is increasingly affecting every region of the world and every sector of the economy. Lower-income and marginalized populations are highly vulnerable to climate change and variability because of their low adaptive capacity. The observed and projected climate change is already causing and will continue to cause major consequences to food production, water and pasture availability, ecosystems and human health, migration pressures, and regional instability in different parts of the world.

Tanzania like other developing countries is particularly vulnerable to climate related extreme events such as floods and droughts, which are increasing in both frequency and intensity. These extreme events have been causing losses of life and properties, and significant infrastructural damages across the country. Sustained and effective monitoring of climate, including the extremes is pre-requisite and critical inputs for developing climate change adaptation strategies and for reducing the risk associated with extreme events.

To address these challenges, Tanzania Meteorological Authority (TMA) has dedicated efforts and resources to enhance climate monitoring, and to conduct robust climate analysis every year. The major weather and climate events are documented using various weather and climate observations network as well as information obtained from other sources such as reports from the Prime Minister's Office - Disaster Management Department (PMO-DMD), the Zanzibar Disaster Management Commission (ZDMC), newspapers and media.

The 2021 statement therefore presents summary statistics, maps and graphs of temperature and rainfall patterns for the year 2021 with respect to 1981-2010 baseline climatology to explore the emerging signals of climate change and variability in the country. The major drivers of weather and climatic events that occurred in 2021 are also included in this statement.

2. Temperature distribution

In 2021, the country average air temperature (Tmean), minimum and maximum temperatures were slightly warmer than long term average for all months. On average, November and December were the warmest months of the year 2021, November being a record break in historical perspective while December being the third warmest on record since 1970. In those months the country average air temperature anomaly was 1.3 °C and 1 °C above long term average (1981-2010). In addition, higher maximum temperature anomaly between 1°C and 2 °C above long term average were observed over large part of the country in November, except northern coast, north-eastern highlands, and southern regions whose temperature anomaly exceeded 2 °C. Likewise, maximum temperature anomaly exceeding 2 °C was observed in southern region extending to southwestern highlands during December. On the other hand, September recorded relatively warmer nights, whereby many parts of the country recorded temperature anomalies between 1°C and 2 °C above long term average.

2.1 Annual mean, maximum and minimum temperature

The country annual average air temperature (Tmean) for 2021 was 23.8 °C, which is 0.5 °C warmer than long-term average but cooler than 2020 by 0.1°C. The annual mean temperature anomalies across the country (Figure 1) were slightly warmer than average, between 0 °C and 1°C except for few locations over Rukwa, Unguja island, and areas surrounding Lake Victoria, whose temperature anomalies were above average in the range of 1°C and 2 °C. The observed higher temperature anomalies in areas surrounding Lake Victoria, Rukwa and the Islands of Zanzibar (Unguja and Pemba) were mainly contributed by anomalous warmer nights with temperature anomalies between 1°C and 2 °C (Figure 2 left panel).

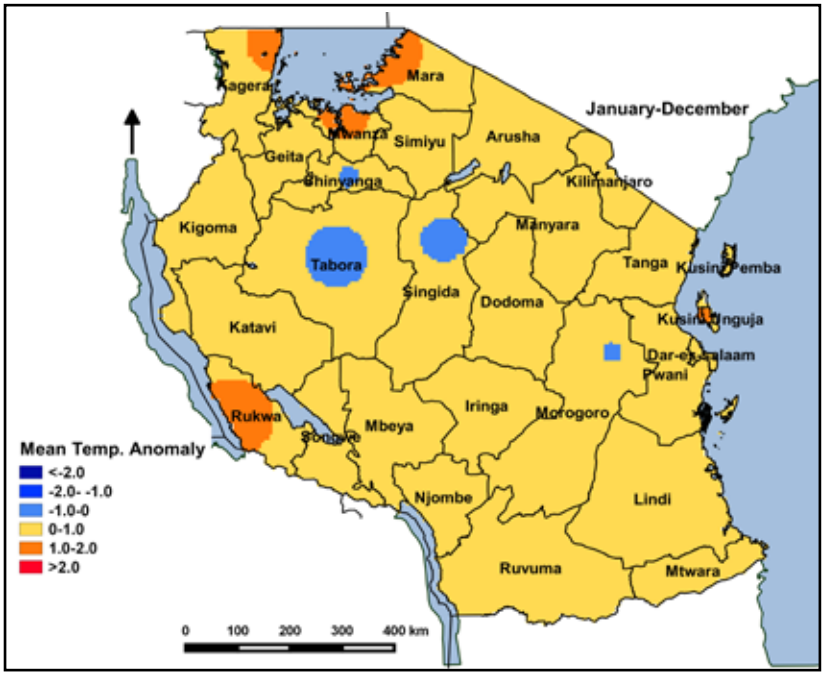

Figure 1: Annual mean temperature departure (°C) for 2021 from long-term average

The country annual maximum temperature (Tmax) was 29.0 °C which is 0.4 °C higher than long-term average but lower than 2020 maximum temperature by 0.6 °C. On average, the temperature anomalies (Figure 2 right panel) were above long-term average in the range of 0 °C and 1 °C for many parts of the country but cooler than average temperature in the range between 0 °C and 1 °C as observed over few locations in the country including Pemba Island.

On the other hand, the country annual minimum temperature (Tmin) was 18.6 °C which is 0.7 °C warmer than long-term average but cooler than the year 2020 minimum temperature by 0.3 °C. The anomalies (Figure 2 left panel) were above long-term average in the range of 0 °C and 1 °C across large part of the country except few locations surrounding Lake Victoria, northern coast including Unguja and Pemba islands, and few parts over northeastern highlands and Rukwa region, which recorded slightly higher night temperature anomaly in the range between 1°C and 2 °C.

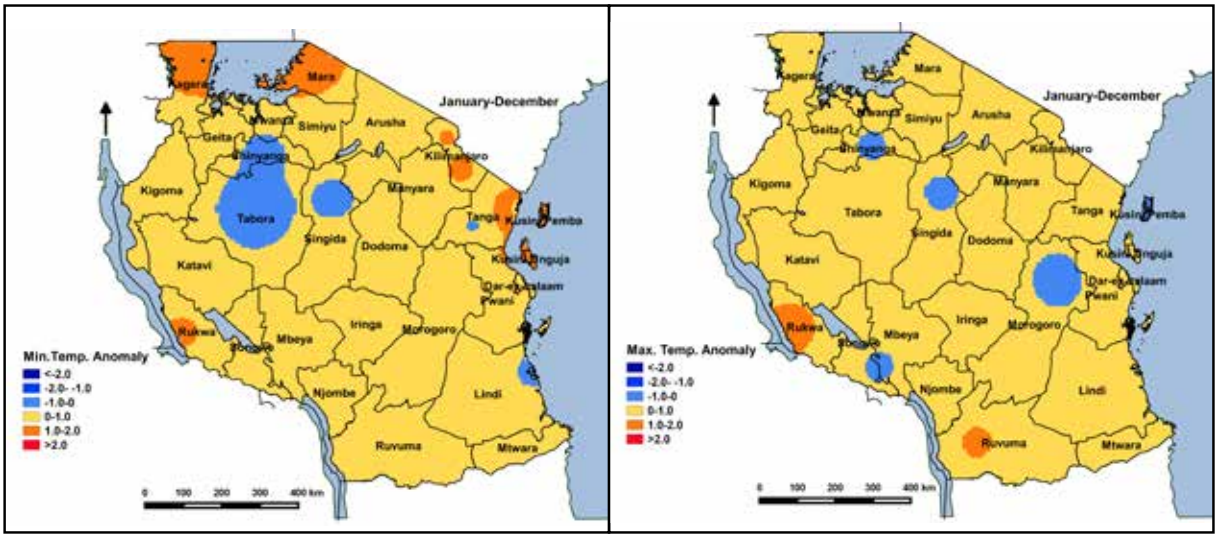

Figure 2: Annual minimum (left panel) and maximum (right panel) temperature departure (°C) from long-term average for 2021

2.2 Monthly mean temperature

The country monthly average air temperature in 2021 was relatively warm during August, September, October, November, and December with mean temperature anomalies of 0.8 °C, 0.7 °C, 0.8 °C, 1.3 °C and 1 °C above long-term average, respectively. On average, November was the warmest month of the year, and a record break in history of country meteorological observations since 1970.

The observed warming in September was due to anomalously warmer minimum temperatures (1.2 °C above average) when compared to maximum temperature anomaly (0.2 °C above average). Whereas, observed warming in November was due to anomalous warmer maximum (1.8 °C above average) compared to minimum temperatures (0.8 °C above average). However, the warming observed in August, October, and December was equally contributed by minimum and maximum temperatures in the respective months.

2.3 Monthly maximum temperature

The country monthly maximum temperature anomalies (Tmax) were higher than average for nearly all months except January, February, and April, with higher anomaly of 1.8 °C in November. Spatial distribution of temperature across the country indicates that temperatures were slightly warmer than average (ranging between 0 °C and 1 °C) in March, and in May through October, but was significantly warmer in November and December of which many parts of the country recorded temperature anomaly between 1°C and 2 °C and even exceeding 2 °C in some areas (Figures 3a and 3b). Notably, northern coast, northeastern highlands and southern region recorded anomalously warmer temperature exceeding 2 °C in November but same thresholds were observed over southwestern highlands and southern region during December (Figure 3b). The observed higher temperature anomalies in November and December were partly exacerbated among other factors by anomalous dry condition that persisted during that period.

On the other hand, temperatures were slightly cooler than average in January, February, and April with temperature anomalies between 0 °C and 1 °C below average across most parts of the country (Figure 3a). Notably, anomalous cooling between 1 °C and 2 °C were recorded over northeastern highlands, the hinterlands of northern coast, and few parts of central region during January and February (Figure 3a). The observed cooling condition in the mentioned areas may partly be linked to reduced incoming solar radiation due to cloud cover associated with rainfall events observed in those months.

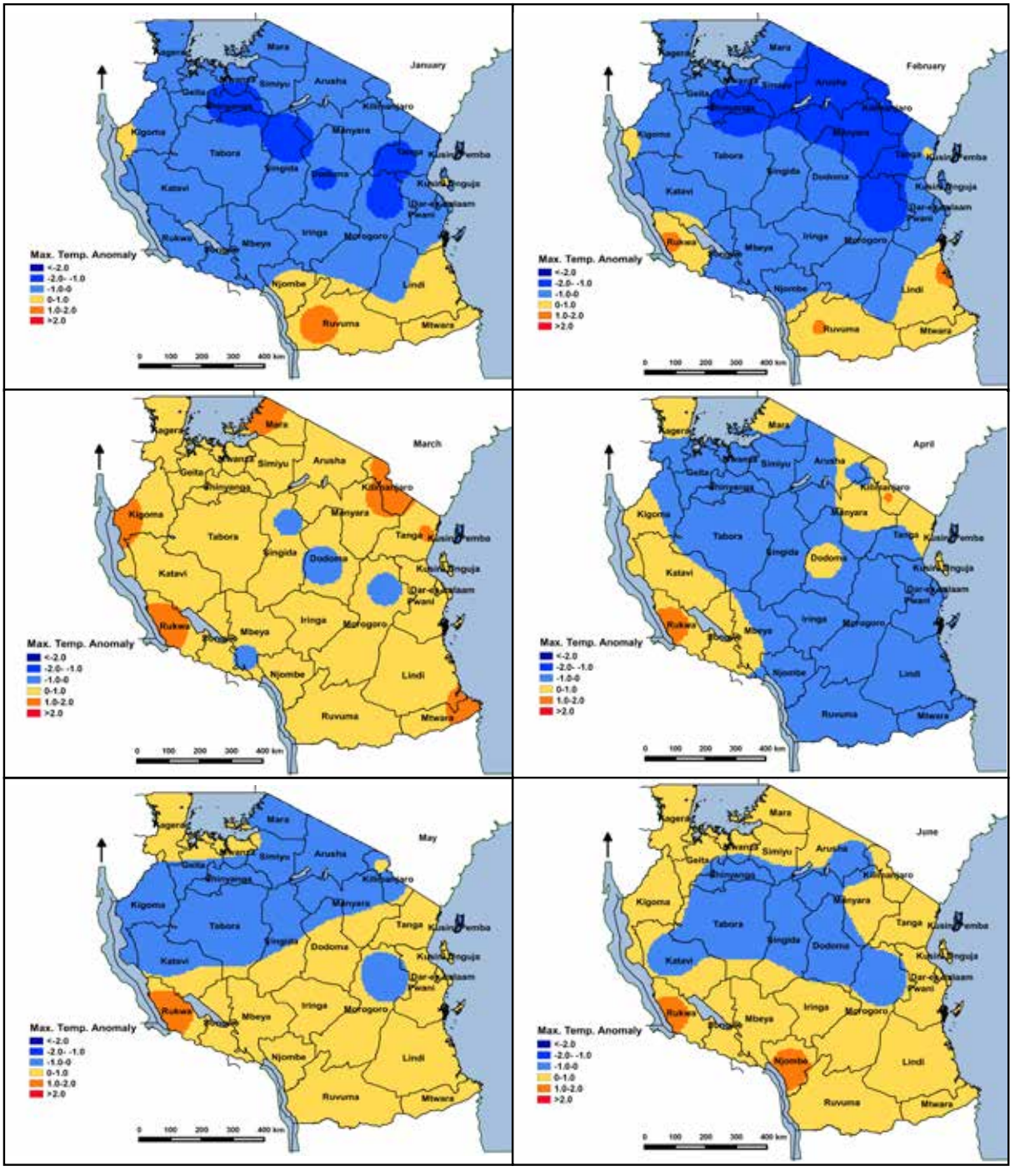

Figure 3a: Monthly maximum temperature departure from long-term average (°C) for January–June 2021

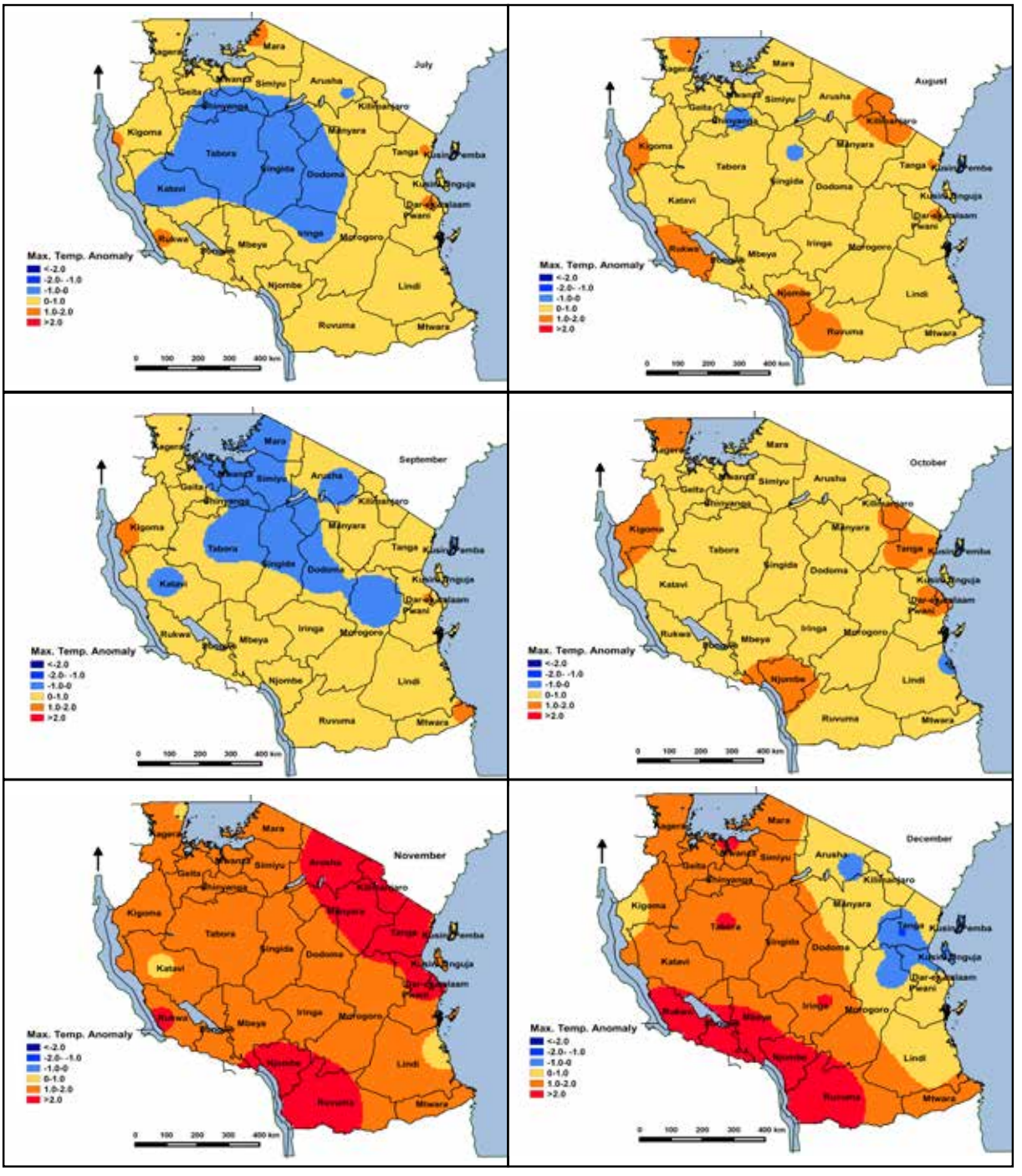

Figure 3b: Monthly maximum temperature departure from long-term average (°C) for July–December 2021

2.4 Monthly minimum temperature

The country monthly minimum temperature anomalies (Tmin) were higher than average for all months with highest anomaly of 1.2 °C recorded in September. The spatial distribution of minimum temperature anomalies across the country (Figures 4a and 4b) indicates that, warmer than average temperatures between 0 °C and 1°C were recorded over the large part of the country during all months except September, where temperature anomalies between 1°C and 2 °C above average were recorded over eastern, northern, and southern regions. Likewise, for areas surrounding Lake Victoria, the same range of temperature anomaly was observed throughout the year.

However, slight cooler than average temperatures ranging between 0 °C and 1°C were observed over the southern coast and southern region extending to southwestern highlands during May (Figures 4a). Notably, below average temperature ranging between 0 °C and 1°C was observed over Singida and Tabora regions throughout the year.

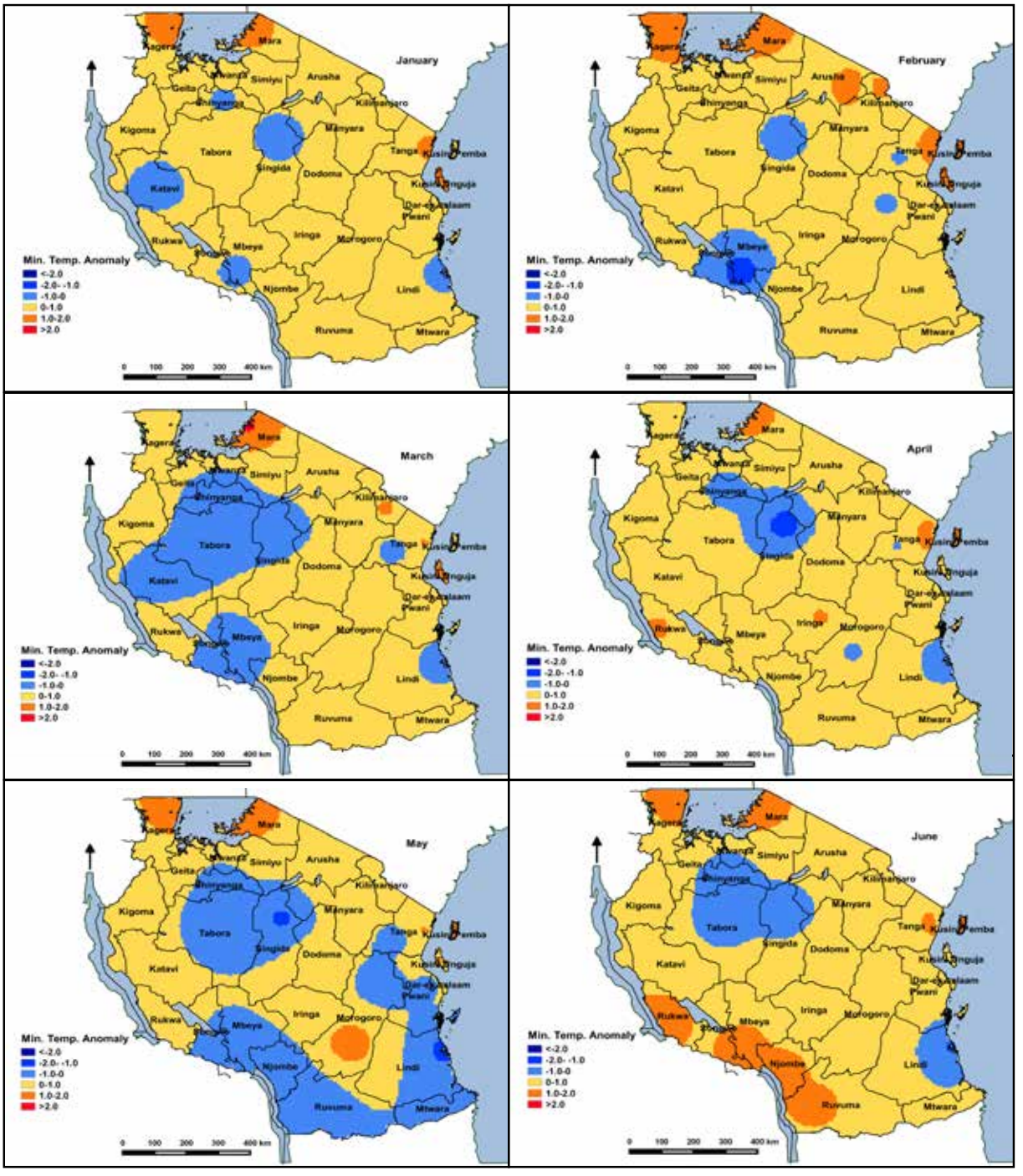

Figure 4a: Monthly minimum temperature departure from long-term average (°C) for January–June 2021

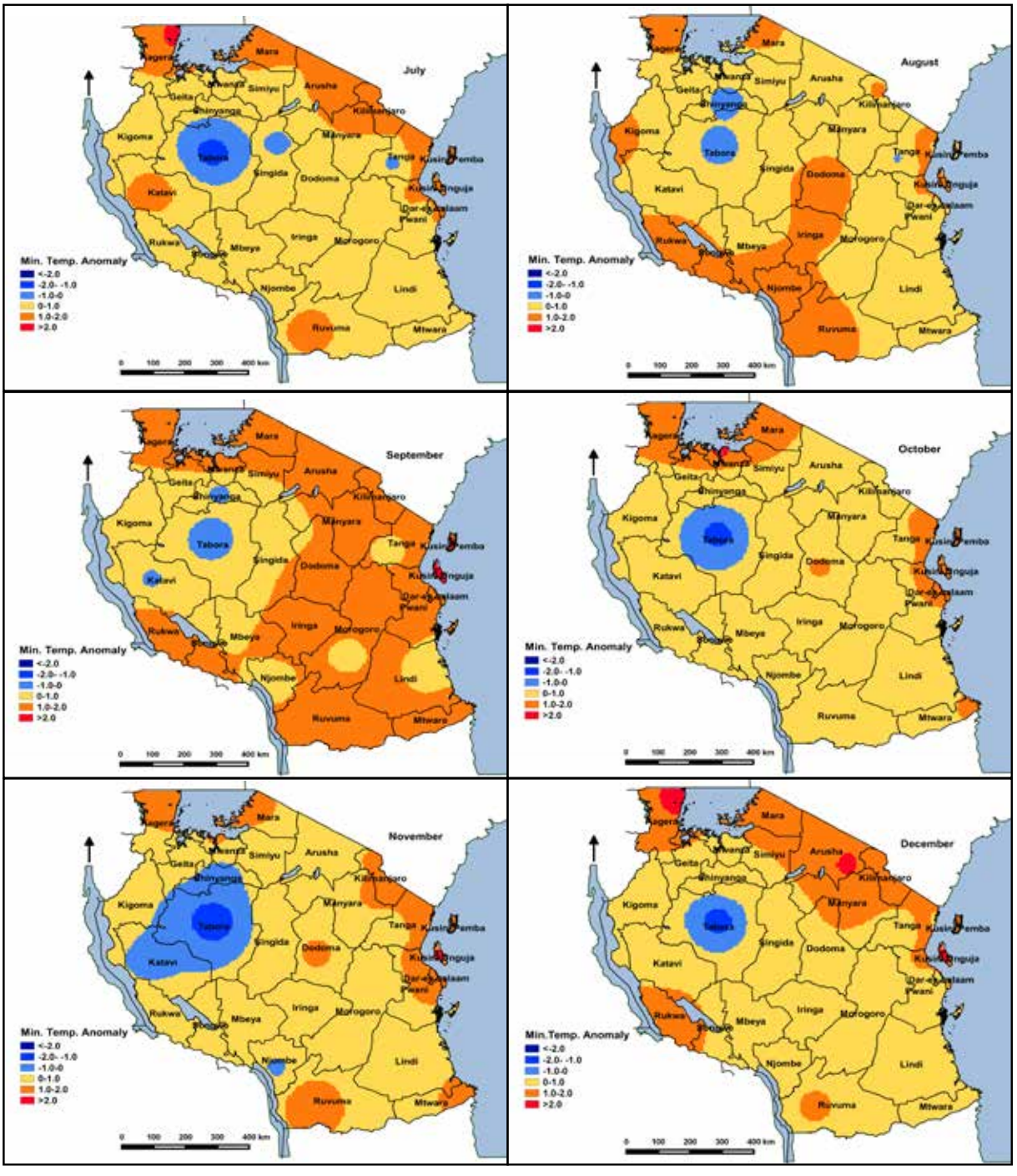

Figure 4b: Monthly minimum temperature departure from long-term average (°C) for July–December 2021

3. Rainfall distribution

The year 2021 was characterized by rainfall deficiency especially during March to May (MAM) and October to December (OND) rainy seasons, specifically over northern coast and northeastern highlands. For those two seasons, March, May, October, and November are positioned in the ten driest months on record since 1970. Specifically, November was the driest month of the year and ranked third driest November on record since 1970 by recording rainfall amounts lower than long term average by 55.6 mm equivalent to 41% of the long-term average.

On the other hand, normal to above normal rainfall was observed during November 2020 to April 2021 (NDJFMA) rainy season and during the transition period of January-February 2021. As such, Mtwara meteorological station recorded 641.5 mm higher than NDJFMA long term average rainfall which is equivalent to 168% of the long-term average. In addition, observed rainfall during this period was associated with the widespread flooding over many areas in west and southern parts of the country.

3.1 Annual rainfall distribution

The country total rainfall for 2021 was 847.2 mm, which is 177.5 mm below the long-term average and equivalent to 82.7% of average. This observation makes 2021 to be the fourth driest year on record since 1970, where 2003, 2012, and 2005 were the first, second, and third driest years respectively. Most parts of the country received normal rainfall ranging between 75% and 100% of average, except for the northern coastline including Zanzibar Islands, which received below normal rainfall ranging between 50% and 75% of average.

However, the year 2021 was particularly wet over southeastern Tanzania, specifically, the eastern part of Mtwara region which recorded above normal rainfall ranging between 125% and 150%.

This situation was exacerbated by heavy rainfall observed over Mtwara meteorological station early in the year. Notably, 609 mm of rainfall was recorded in January.

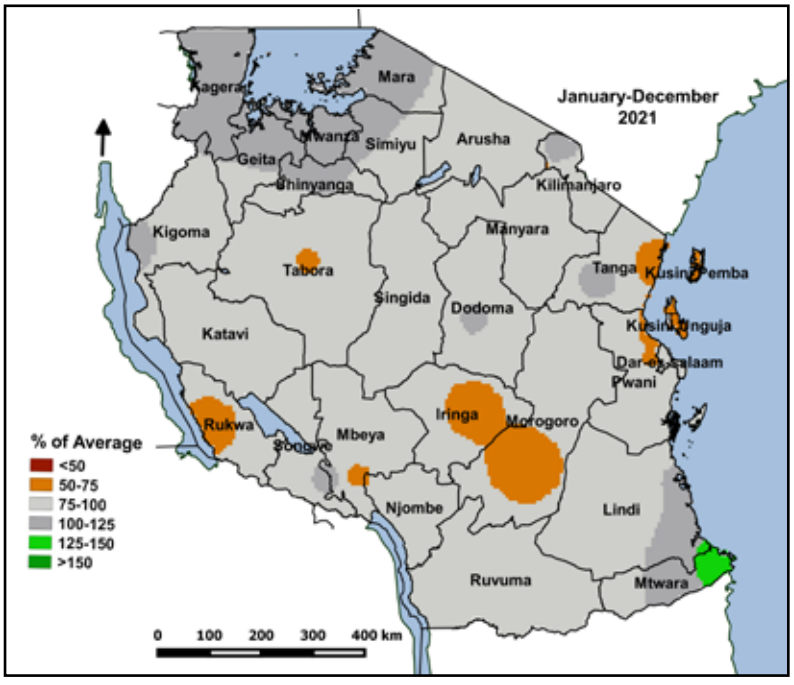

Figure 5: Annual rainfall anomaly for 2021 expressed as percentage of long-term average

3.2 Seasonal rainfall distribution

Mainly normal rainfall was observed over large part of the country during NDJFMA (2020/2021) and MAM 2021 rainy seasons as well as during the transition period of January to February 2021 (Figure 6). The observed rainfall amounts were between 100% and 125% of average over large part of the country during NDJFMA season and the transition period of January to February but rainfall was between 75% and 100% during MAM 2021 season.

During October to December rainy season the country was extremely dry especially over southwestern highlands, southern region extending to central part of the country and northeastern highlands. In these areas rainfall less than 50% of long-term average was observed. However, rainfall ranging from 75% to 100% of long-term average was observed over areas surrounding Lake Victoria and areas along the coast strip of Tanzania mainland. Notably, above normal rainfall ranging from 125% to 200% of average was observed over few areas of northern coast and north-eastern highlands during the transition period of January and February, signifying that these areas received off season rains. In contrary, below normal rainfall between 50% and 75% of average was observed over northern coastal areas during MAM rainy season, especially the coastal strip including Unguja and Pemba Islands.
Based on historical observational records, the 2020/2021NDJFMA rainy season was ranked as the third wettest season since 1970 by receiving around 90 mm of rainfall higher than

the long-term average. On the other hand, OND and MAM 2021 rainy seasons are ranked eleventh (11th) and fourteenth (14th) driest seasons since 1970 by recording 97.7 mm and 23.1 mm of rainfall less than long-term averages, respectively.

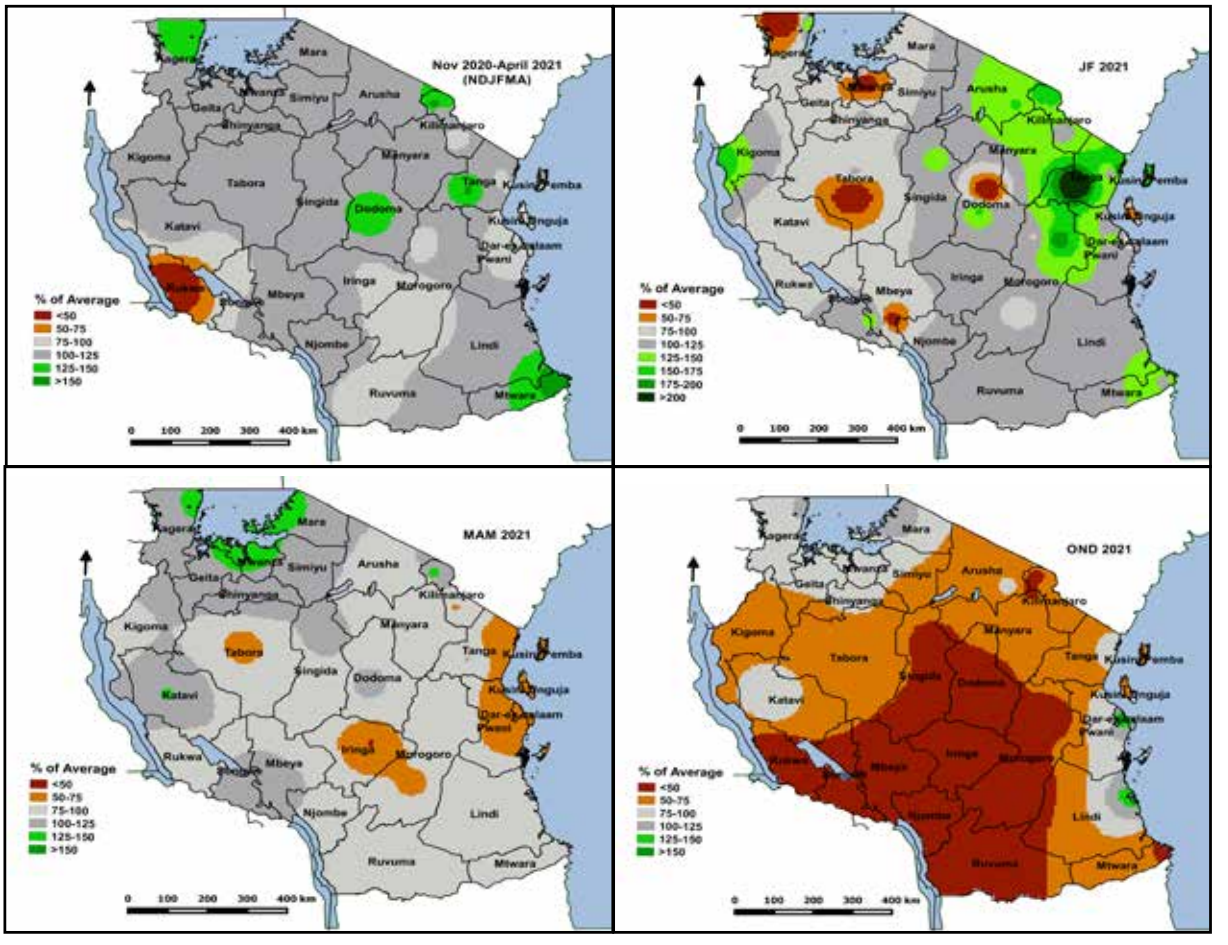

Figure 6: Seasonal rainfall anomaly for 2021, expressed as percentage of long-term average for November 2020 to April 2021 (top left panel), January and February 2021 (top right panel), March to May 2021 (bottom left panel) and October to December 2021 (bottom right panel)

3.3 Monthly rainfall distribution

In 2021 dry conditions were experienced in almost all months within rainy seasons. Notably, November was the driest month by recording only 40.9% of long-term average rainfall and is ranked the third driest November since 1970. In addition, northeastern highlands and coastal areas were relatively dry during March and May with rainfall less than 75% of long - term average, while southern region, southwestern highlands and central regions were significantly dry during December, with rainfall less than 50% of the long-term average (Figures 7a and 7b).
Rainfall distribution across the country (Figures 7a and 7b) shows that most parts of the country were relatively wet during January and February. In January, rainfall amounts exceeding 125% of long - term average were recorded in large part of the country especially those receiving NDJFMA rains as well as in the northern coastal areas of Tanga, Pemba and Handeni. Notably, Mtwara meteorological station recorded a monthly rainfall amount of 609 mm which is almost three times its normal rainfall amount in January, equivalent to 417% of long - term average. In addition, on 12th January 2021, Mtwara meteorological station recorded the highest daily rainfall of 369.7 mm which was the record break since its establishment in 1950. Moreover, 506 mm of rainfall was recorded at this station in 48 hours starting from 11th to 12th January 2021. Likewise, Bukoba and Kigoma meteorological stations recorded rainfall amounts that were twice as much as their normal monthly rainfall amounts for January.

In February, northeastern highlands area extending to central, and the hinterlands of northern coast were relatively wet in comparison to long-term average by recording rainfall amount between 125% and 175% of long-term average. Notably, Singida, Arusha and Morogoro meteorological stations recorded rainfall amounts that were twice as much as its normal February rainfall.

Northern coast (especially, Tanga and Morogoro regions and Pemba Island) and northeastern highlands (especially Arusha region) received rainfall exceeding 200% of long-term average during January and February. However, the recorded rainfall amounts were not as high as those recorded in the southern and western parts of the country because this area is normally relatively dry during January and February. Therefore, this condition signifies that the areas continued to receive off seasonal rains that continued after the end of OND 2020.

In March and April, mainly normal rainfall between 75% and 125% of long-term average was observed over many parts of the country, while above normal rainfall exceeding 125% of average was observed over areas surrounding Lake Victoria and central parts of the country. In contrast, below normal rainfall between 50% and 75% of long-term average, was observed over the entire coastline extending to northeastern highlands and southern parts of the country during March and May. Generally, March and May were remarkably dry for most of the bimodal areas except for Lake Victoria regions.

During June, July, August, September, and November, many areas in the country were dry, whereas during October and December most of the bimodal and unimodal areas were respectively relatively dry. Extremely below normal rainfall with rainfall amount less than 50% of long-term monthly average was recorded over large parts of the country (Figures 7a and 7b). Below normal rainfall observed in October, November and December was exacerbated by late onset and poor performance of rainfall.

The observed dry conditions in October and November marked these two months to be the fourth and third driest month on record since 1970. However, the observed dry condition in June, July, August, and September should not be translated as drier condition experienced in the country, because these months are climatologically dry, although occasional rains do occur.

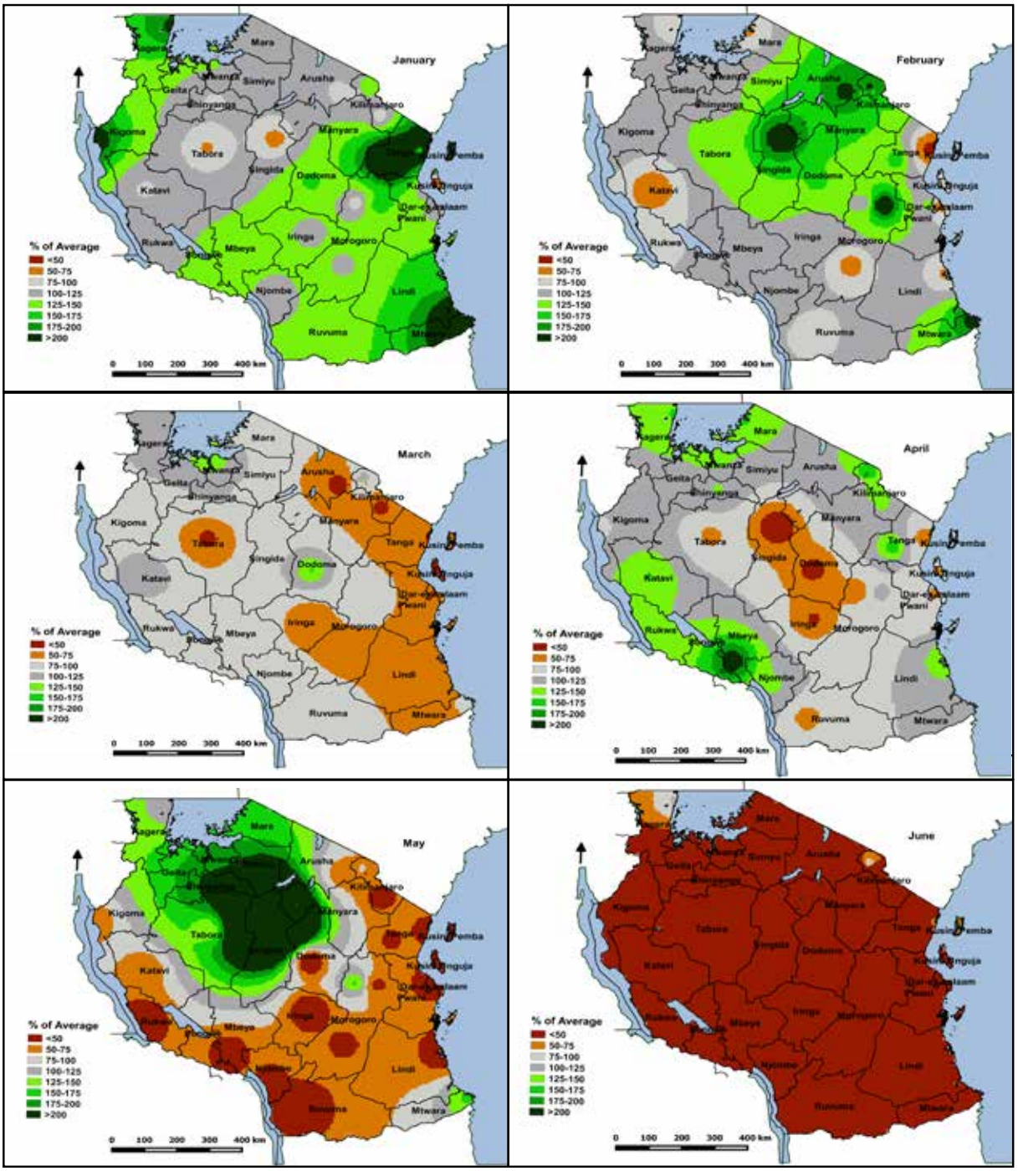

Figure 7a: Monthly rainfall anomaly expressed as percentage of long-term average for January–June 2021

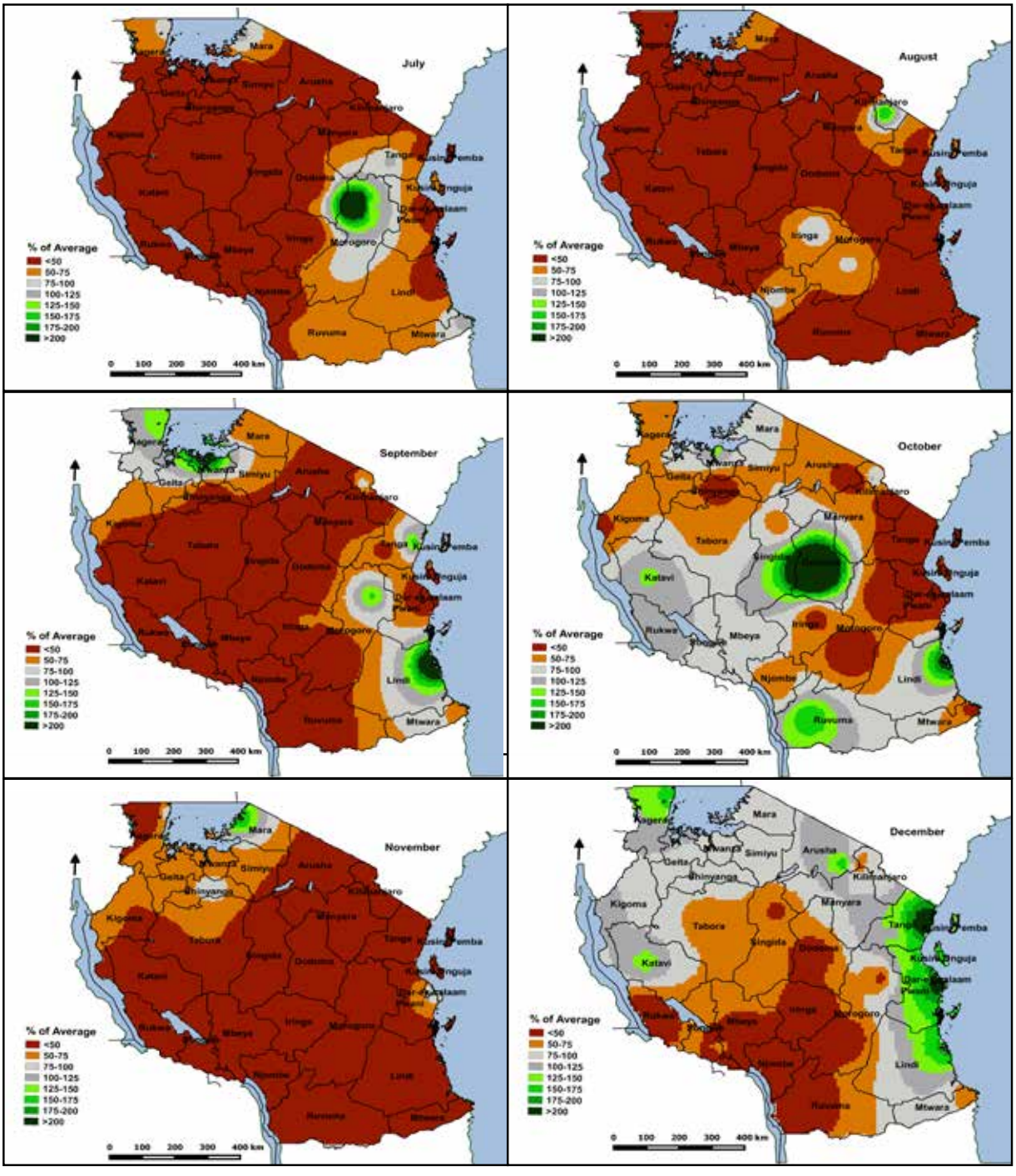

Figure 7b: Monthly rainfall anomaly expressed as percentage of long-term average for July–December 2021

3.4 Cumulative rainfall

Cumulative rainfall curves describe characteristics of 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 (observed total rainfall lower than long term average rainfall) or abundant rainfall (observed total rainfall higher than long term average rainfall) during the season. On average, the cumulative rainfall plots indicate that northern coast and parts of northeastern highlands received insufficient rainfall during MAM rainy season while sufficient rainfall was observed over most areas surrounding Lake Victoria during MAM season and over central, west and southern parts of the country during NDJFMA rainy season. In addition, most parts of the country received less rainfall amounts in 2021 compared to 2020.

During NDJFMA (2020/2021) rainy season, sufficient rainfall (nearly normal total rainfall) was observed over many stations receiving one rainy season (i.e., west, central, and southern parts of the country) except Mtwara and Dodoma meteorological stations that received higher amounts of rainfall with respect to long-term average (Figure 8a). For example, Mtwara and Dodoma meteorological stations recorded 641.5 mm and 276.6 mm of rainfall higher than long term average of seasonal total rainfall, respectively. This indicates that, sufficient rains were observed over central and southern parts of the country. On average recorded rainfall during NDJFMA (2019/2020) rainy season was slightly lower than that of (2020/2021) rainy season except for Kigoma and Mtwara stations.

The bimodal areas (northern coast, northeastern highlands, and Lake Victoria region) observed insufficient rainfall mainly over the northern coast (Dar es Salaam, Tanga and Unguja) during MAM rainy season, but over all areas during OND seasons (Figures 8b and 8c). Whereas sufficient rains (near to a slightly higher than long term average total rainfall) were observed over the areas surrounding the Lake Victoria (Mwanza, Musoma, Bukoba and Shinyanga) and northeastern highlands (Moshi and Arusha) during MAM season.

In addition, the temporal evolution of rainfall during the seasons indicates that, the rainfall events were fairly distributed throughout the season for many areas during NDJFMA and MAM but poorly distributed during OND season, specifically over northern coast and northeastern highlands where belated onset was observed during the third dekad of November.

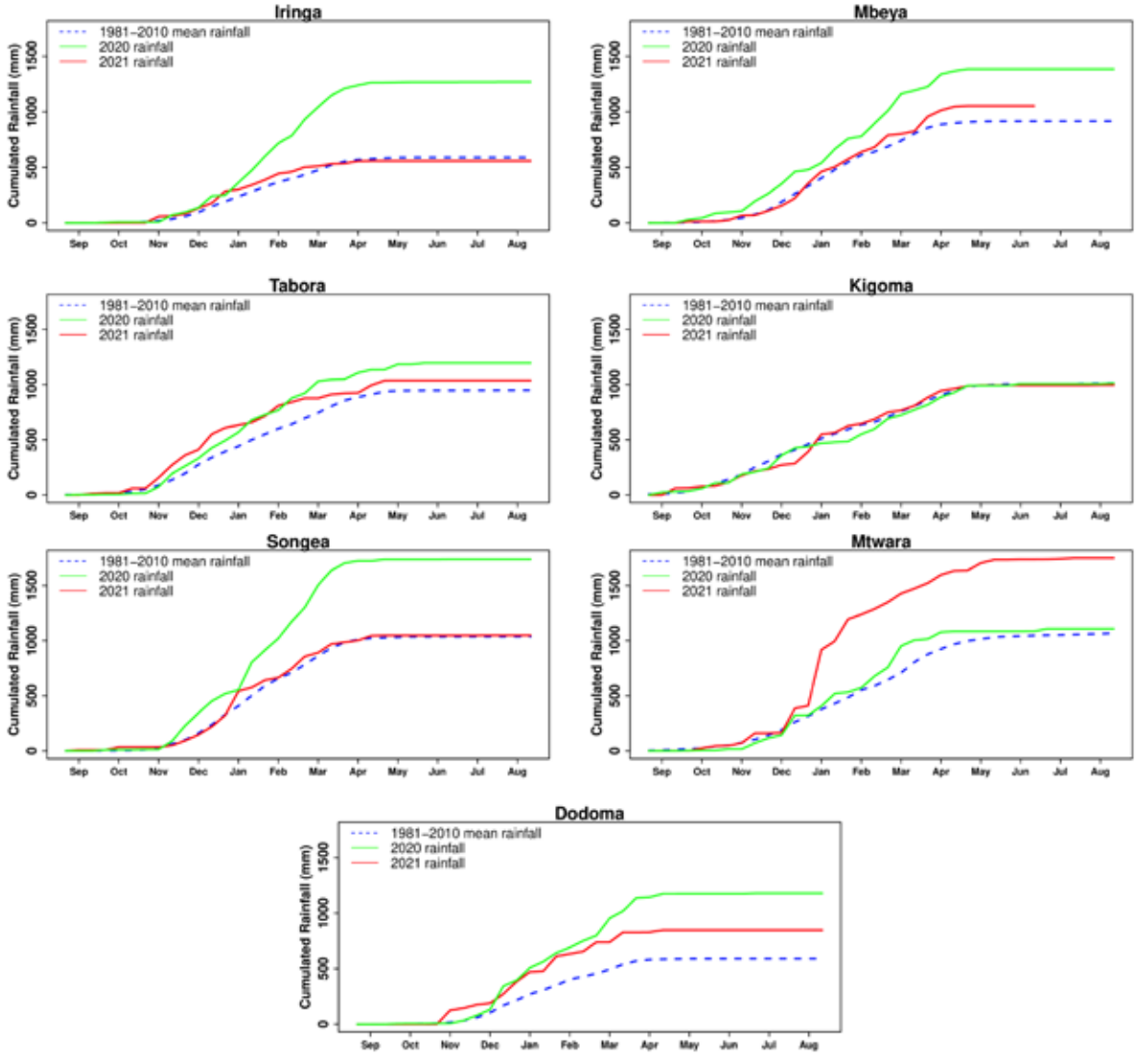

Figure 8a: Cumulative rainfall plots for NDJFMA (2020/2021) rainy season for Dodoma, Tabora, Kigoma, Iringa, Mtwara, Mbeya and Songea meteorological stations

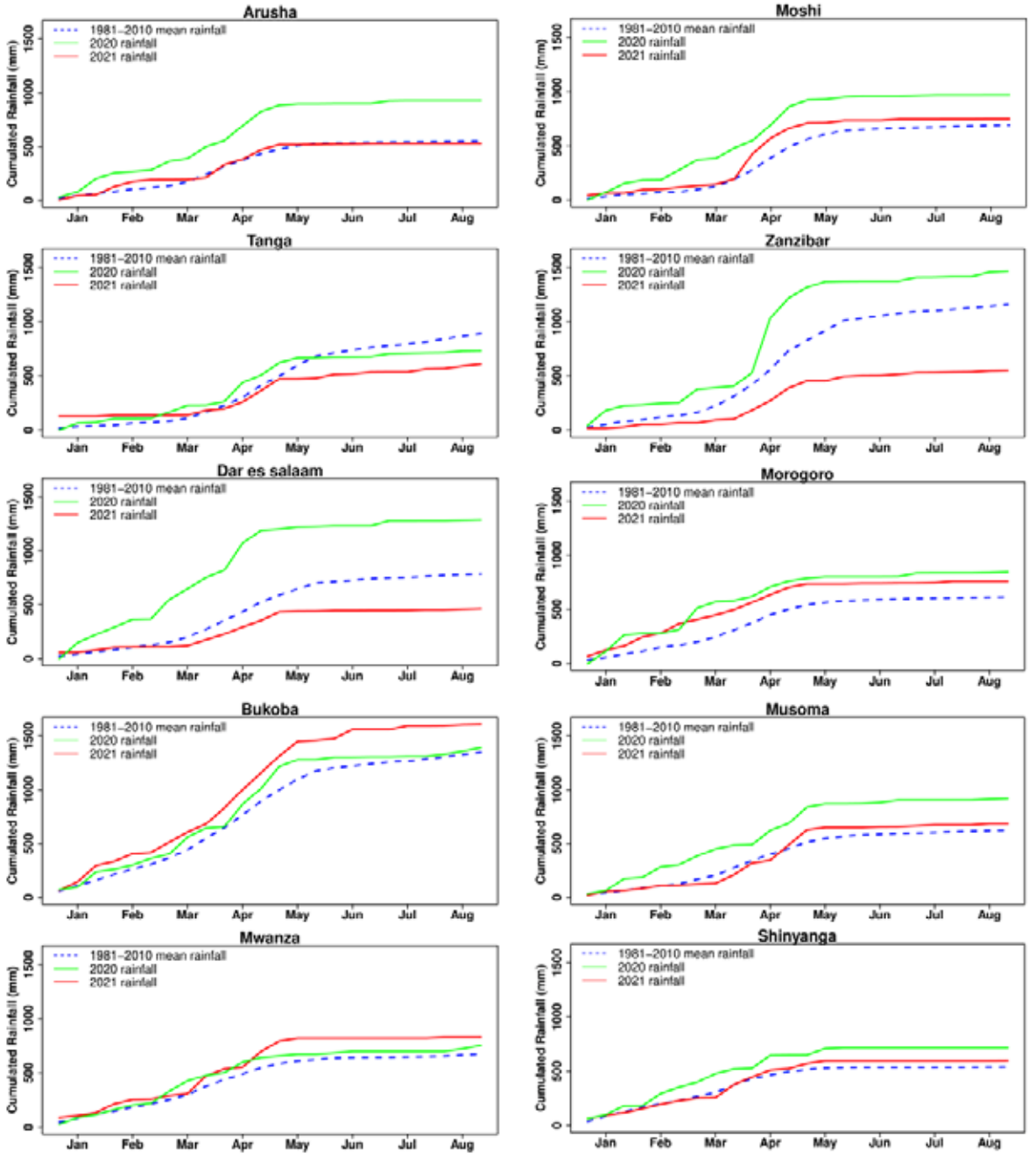

Figure 8b: Cumulative rainfall plots for MAM 2021 rainy season for Bukoba, Mwanza, Musoma, Shinyanga, Dar es Salaam, Morogoro, Tanga, Zanzibar (AAKIA), Arusha and Moshi meteorological stations

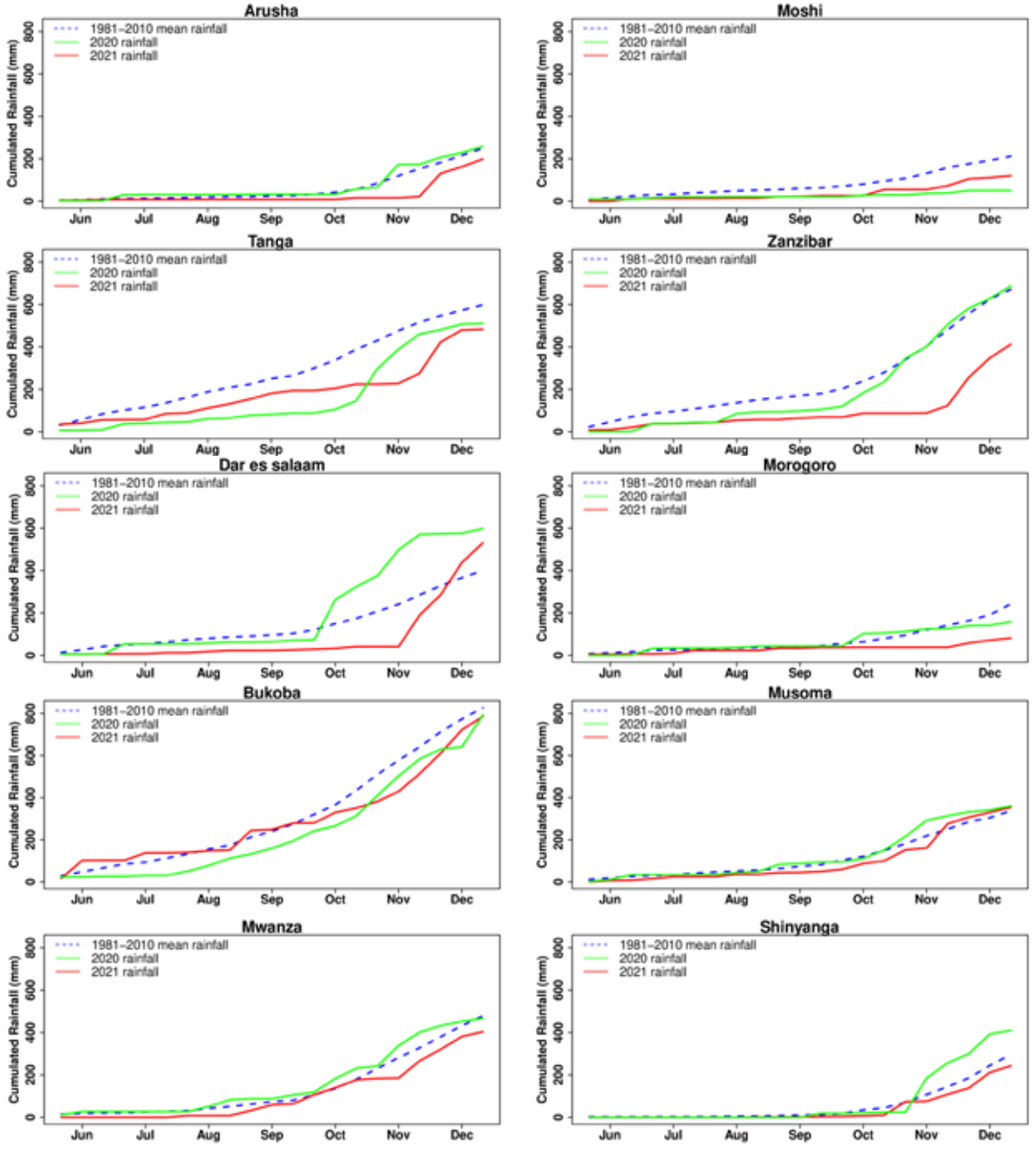

Figure 8c: Cumulative rainfall plots for OND 2021 rainy season for Bukoba, Mwanza, Musoma, Shinyanga, Dar es Salaam, Morogoro, Tanga, Zanzibar (AAKIA), Arusha and Moshi meteorological stations

4. Extreme weather and climatic events

In the year 2021, several extreme weather events particularly heavy rains, prolonged dry spells and high temperature episodes were reported. Unusual and widespread flood events with severe socio-economic impacts were reported in different parts of the country. Heavy rains and hence floods were observed in the beginning of the year especially over the western and southern parts of the country, a condition that was exacerbated by the presence of tropical cyclones among other factors. On the other hand, high temperatures and dry conditions were observed over many parts of the country especially northern parts towards the end of the year.

4.1 Extreme rainfall and flood events

In the beginning of the year 2021, several events of heavy rainfall were observed over different parts of the country. Unusual heavy rains were observed over the southern parts of the country in January and February but over northern parts in April and May as described below.

On 12th January 2021, heavy rainfall totaling 369.7 mm was observed over Mtwara meteorological station in 24 hours period, but a total of 506 mm of rainfall was recorded in 48 hours in two consecutive days (11th and 12th January 2021). The recorded 369.7mm of rainfall in a 24-hour is extraordinary to the station and a record break since the station was established in April 1950, whereas the 136.3 mm was the second highest rainfall amount observed in this station in the recent two decades. Rainfall amount of 506 mm was observed Mtwara meteorological stations in 48 hours whereby 136.3 and 369.7 mm of rainfall were recorded on 11th and 12th January 2021, respectively. The recorded 369.7 mm of rainfall in a 24-hour is extraordinary to the station and a record break since the station was established in April 1950, whereas the 136.3 mm was the second highest rainfall amount observed in this station in the recent two decades. In addition, on 8th January 2021 Matangatuani agrometeorological station recorded 24 hours rainfall of 124.5 mm. Furthermore, about 19 events of heavy rainfall exceeding 50 mm, but less than 100 mm were observed over different parts of the country including Songea which recorded 90.8 mm on 13th January 2021, while Handeni and Pemba (Karume Airport) recorded 87.4 mm and 75 mm on 9th February 2021, respectively.

In February, a 24-hour rainfall totaling 109.1 mm and 123.5 mm were recorded over Mtwara and Naliendele meteorological stations on 9th February 2021, respectively. The 109.1 mm of rainfall recorded at Mtwara meteorological station is the second record break of 24-hour rainfall for this station in the month of February for the recent two decades. Also, on 10th February 2021 the aforementioned stations recorded rainfall amounts of 87.1 mm and 86.5 mm respectively. In addition, there were about eight (8) more rainfall events with amounts exceeding 50 mm that were observed in different parts of the country in February.

March 2021 was relatively dry compared to March 2020. However, heavy rains were observed in different parts of the country especially northern parts. For example, a 24-hour rainfall reaching 116.8 mm fell in northeastern highlands of Tanzania (Lyamungu-Kilimanjaro region) on 31st March 2021. This rainfall amount is the third highest recorded in March, since the station was established in 1935, but it is the seventh highest amount at this station in recent two decades. Also, 106.5 mm was observed over Ilonga agrometeorological station in Morogoro region on 5th March 2021. Generally, there were about 10 heavy rainfall events (rainfall amount greater than 50 mm) that were observed in March 2021.

In April, about 28 heavy rainfall events exceeding 50 mm were recorded in different parts of the country. Specifically, extreme rainfall events totaling 108.9 and 104.4 mm in 24 hours were recorded over Lyamungu meteorological station on 4th and 8th April 2021, respectively, whereas 60.5 mm and 73.2 mm of rainfall were observed at Victoria Garden in Zanzibar on 10th and 28th April 2021, respectively. Generally, extreme heavy rainfall events for April 2021 were few (28 events) compared to last year which were 42.

Besides, October and November 2021 were dry months especially for bimodal areas, and December 2021 for unimodal areas. However, occasional heavy rainfall events were observed in the first dekad of December especially over the coastline and the hinterlands. For example, rainfall amounts reaching 104.7 mm was recorded in 24 hours at Tanga meteorological station on 4th December 2021, which is the third highest amount recorded at this station for December but 48th highest amount in historical record for this station since it was established in 1941. Moreover, 61.5 mm of rainfall was observed at AAKIA on 1st December 2021.

4.2 Extreme temperature events

In the year 2021, there were few numbers of higher daily maximum temperature (Tmax) events exceeding 35 °C recorded in hotter months, January, February, especially for northeastern parts of the country due to off season rainfall events that were observed over much of bimodal areas. However, the month of March was slightly warmer because of dry condition observed especially for bimodal areas, where at least 28 events of daily maximum temperature exceeding 35 °C were recorded mainly over the northeastern parts of the country. In addition, large number of warmer nights (Tmin greater or equal to 25 °C) were observed in this month. At least 63 events were observed especially for stations aligned closer to Indian Ocean.

In contrary, large number of hot days were recorded in November 2021 corresponding to prolonged dry condition that was observed during OND rainy season. Specifically, there were 48 events of temperature exceeding 35 °C, mostly recorded over the northern coast and the hinterlands, northeastern highlands, central, western, and southwestern parts of the country. This condition is slightly different to February, March and April whereby higher

temperatures are normally observed over northeastern parts of the country. The highest daily maximum temperatures in November were recorded across few stations on 24th November 2021. Specifically, the highest temperature exceeding 36°C (i.e., 37.7 °C, 37.3 °C, 36.5 °C and 36.2 °C) were recorded over Ilonga, KIA, Moshi and Morogoro meteorological stations respectively, all being second highest recorded temperature in November for the mentioned stations since their establishments. Also, the recorded temperature at Ilonga was the 8th highest on record since the station was established in January 1961. Besides, large number of warmer nights with temperature exceeding 25 °C were also observed in this month especially along the coastline.

On the other hand, the country especially southwestern highlands areas were cool during May, June, July, and August 2021 but was extremely cool during July where large number of cold nights with temperature lower than 5 °C was recorded. At least 15 days with cold nights were recorded in July over different parts in southwestern highlands, while only 4 events were recorded in June. Specifically, the lowest night temperature in the year 2021 was 3 °C, recorded at Uyole meteorological station on 4th July 2021.

5. Major drivers of weather and climate events in 2021

The observed weather and climatic events in 2021, were derived from various factors occurring at local, regional, and global scale. The global scale factors are mainly driven by variations of sea surface temperatures (SSTs) over global oceans. The SST variations further modulate atmospheric general circulations and hence variations in weather and climate condition for different locations of the world. The variation of SSTs is normally assessed by its Sea Surface Temperature Anomaly (SSTA) and indices including El Niño and Southern oscillations (ENSO) and Indian Ocean Dipole (IOD). Normally these modes are associated with enhanced or suppressed/decline rainfall across the country when they are in different phases (Positive, negative, or neutral phase). For example, positive/negative ENSO and IOD are characterized by enhanced/declined rainfall over the country.

Observation of SSTA for the global oceans indicates that the year 2021 started with weak La Niña, a condition that is characterized by anomalous cooling over central and eastern part of tropical Pacific (Figure 9, black circled area). This condition spanned from August 2020 and continued through May 2021. From June to August 2021 the condition changed to neutral ENSO and there after retreated to La Niña towards the end of the year.

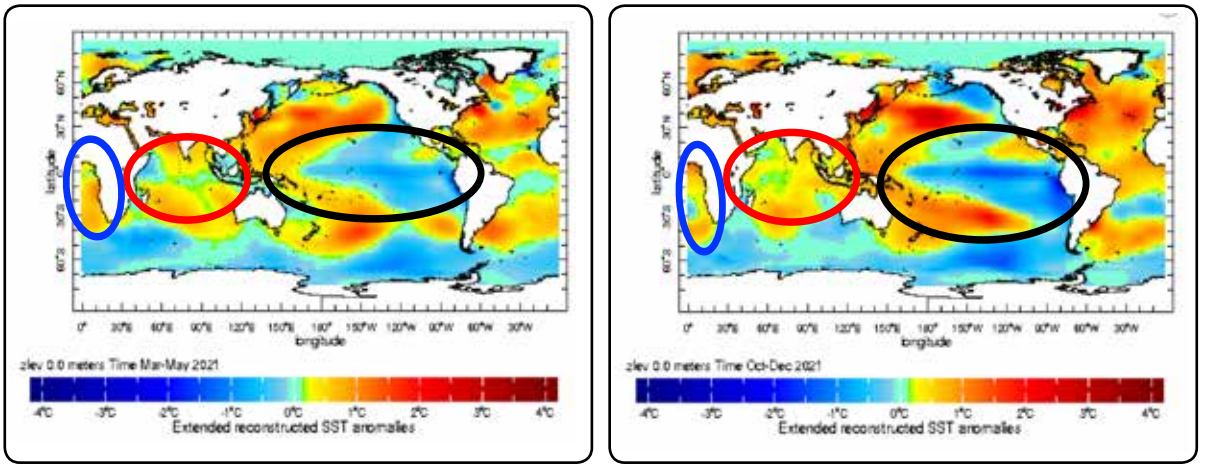

Figure 9: Sea surface temperature anomalies for March-May (left) and October-December (right) 2021, showing Atlantic Ocean basin (blue circled), Indian Ocean basin (red circled) and central Pacific basin (black circled). (Source: https://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCDC/.ERSST/.version5/.anom/)

The observed evolution of ENSO condition in 2021 indicates that, the MAM and OND 2021 rainy seasons experienced La Niña condition that is normally characterized by less/suppressed rainfall in most parts of the country, especially the bimodal areas. This is evident in Figure 6 whereby the northern coast and northeastern highlands received below normal rainfall during MAM and OND seasons.

On the other hand, the Indian Ocean basin (Figure 9, red circled area) condition started with the neutral IOD, that lasted to May 2021 and thereafter changed to negative phase through the end of the year. Moreover, SSTA across the Indian Ocean basin was relatively weak (cool to neutral on western block and neutral to warm eastern block) throughout the year. Due to this, convection was enhanced over the eastern Indian Ocean consistent with the negative IOD. This condition is supported by observed westerly anomaly winds at low level that persisted over the tropical Indian Ocean and extended to the eastern parts of the country in almost the whole year except December, which was dominated by easterly anomaly winds (Figure 10, top panel). As a result, less moisture was transported towards the country leading to suppressed rainfall over many parts, especially the eastern parts as portrayed in monthly rainfall anomaly observed in March, April, May, October, and November (Figure 7a and 7b). In contrary, the observed anomalous low level easterly during December may partly be associated with the observed above normal rainfall over the coast and northeastern highlands.

In addition, anomalous warming was observed in the tropical Atlantic Ocean and along the African coast (Benguela Niño region) (Figure 9, blue circled area). A positive phase of the meridional dipole mode persisted from January to March 2021 and changed to a negative phase during May through December, the condition that is linked to the development of the Atlantic Niño condition. The presence of Atlantic Niño condition triggered the low level anomalous easterly winds from Congo (Figure10, bottom panel). This condition reduced influx of moisture from Congo forests towards the country, thus, below normal rainfall was observed over most parts of western Tanzania, southwestern highlands, and Lake Victoria basin during the OND rainy season (Figure 7b)

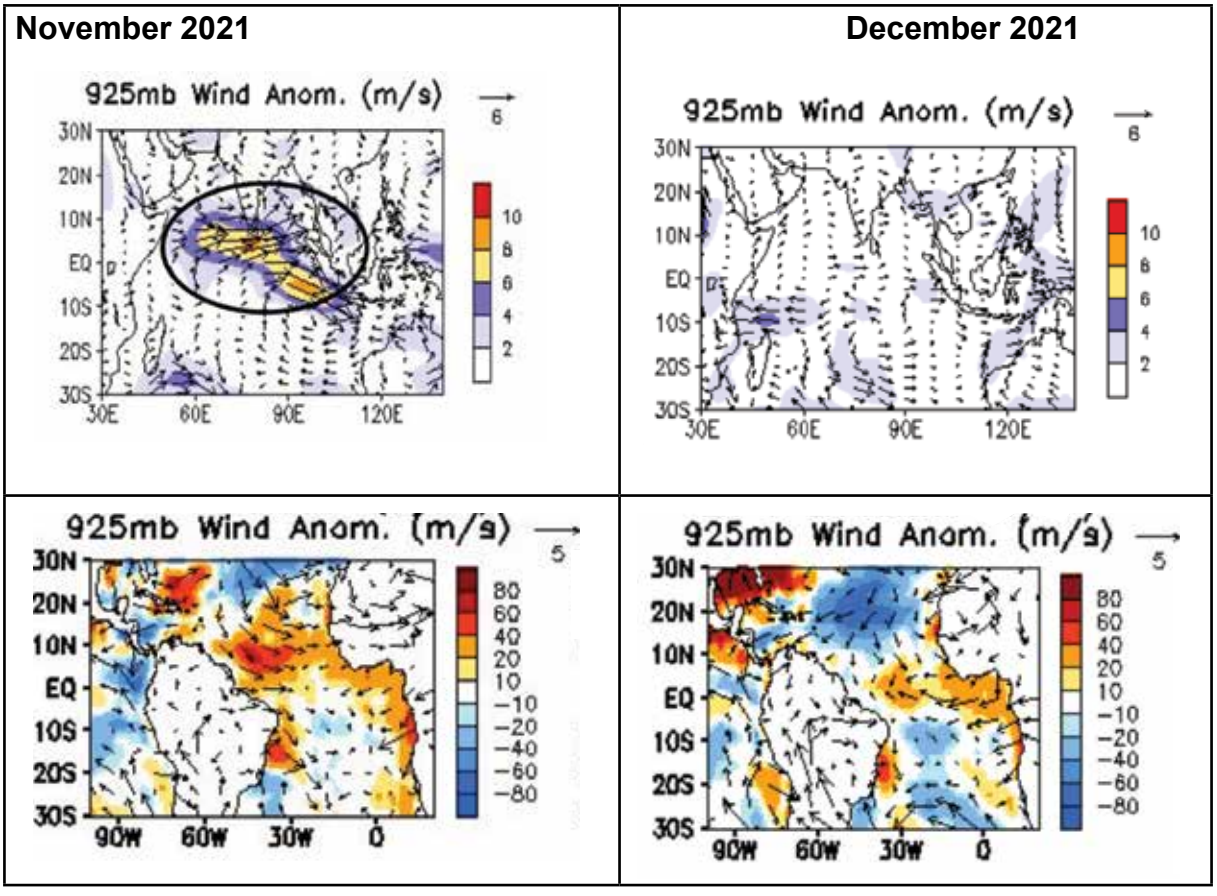

Figure 10: Wind anomaly vector at 925mb for Tropical Indian Ocean in November (top-left) and December (top-right) and for Tropical Atlantic Ocean in November (bottom-left) and December (bottom-right). (Source:https://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing_archive_pdf.shtml)

Apart from the fluctuation of the global oceans SSTA across the year, other drivers such as tropical cyclones in the Southwestern Indian Ocean (SWIO) basin brought various weather condition across the country. Tropical Cyclones (TCs) and tropical depressions (TDs) that occurred from January to April brought significant rains to some areas and dry conditions depending on their strength, positions, and tracks in the Indian Ocean. For example, severe tropical storm DANILO (28th December 2020 to 12th January 2021) and TC ELOISE (14th to 25th January 2021) had significant impacts to the country. The severe tropical storm DANILO favoured convergence of westerlies and northerlies over the southern parts of the country especially along the southern coast which in turn brought heavy and record break rainfall in the southern coast of Tanzania. Similarly, TC ELOISE, brought westerlies from Congo to the southern parts of the country which in turn favoured converging winds in those areas especially in the third dekad of January 2021.

In addition, the presence of TDs over the Mozambique Channel during February and March brought significant rainfall over different parts of the country. However, the development of severe tropical storm JOBO that lasted for about three days from 22nd to 24th April was associated with strong onshore winds along the southern coast of Tanzania, but slightly offshore winds over the northern coast. This condition in turn enhanced weak advection of moisture and hence light rains over the southern coast while leaving the northern coast dry.

Other drivers such as the Madden Julian Oscillations (MJOs), near equatorial trough in combination with Inter-Tropical Convergence Zone (ITCZ) also brought significant weather conditions over different parts of the country.

6. Weather and climate related impacts

Observed extreme weather events in 2021 had major and adverse impacts on population displacement, destruction of infrastructure and loss of lives and properties. In addition, due to less rainfall especially towards the end of the year many areas in the country were affected by prolonged dry spells which impaired agricultural activities, pasture, and water availability.

Prolonged dry spells coupled with high temperatures during September to December 2021 caused severe shortage of water and pastures. This condition resulted into starvation and deaths of thousands of livestock in different parts of the country especially in Manyara, Morogoro, Coast, Arusha, and Kilimanjaro regions as seen Figure 11. Based on Prime Minister's Office (Disaster Management Department) report, a total of 306,358 livestock died, which includes 157,695 cattle, 94,230 sheep, 48,290 goats, and 6,135 donkeys and 8 camels. Also, other areas of Unguja and Pemba Islands including Micheweni, Kojani and nearly the entire eastern strip of Pemba Island were affected by the prolonged dry spells. The impacts went farther in which some of the pastoralists moved to distant places, desperately looking for water to rescue their remaining livestock.

Figure 11: Starved and dead livestock because of lack of water and pasture in Simanjiro district (Manyara region). This condition was caused by prolonged dry condition that occurred during October to December 2021 rainy season. (Source: Charles Ndalechi, Extension Officer, Msitu wa Tembo Ward, Simanjiro district)

In the beginning of 2021, heavy rainfall events occurred in southern parts of the country especially Mtwara regions, the rainfall events were associated with widespread flooding which in turn caused adverse impacts to livelihoods and damage to infrastructures. For example, heavy rainfall that fell on 11th and 12th January 2021 caused widespread floods in Mtwara Mikindani Municipal (Figure 12). The floods caused severe damage to infrastructures, livelihoods, human and livestock settlement, farm fields and crops and personal properties. An estimate of 19 roads, 2,648 households with 13,240 residents were affected, while 2,617 houses were destroyed by flooded water out of which 566 were washed away (PMO, Department of Disaster Management). In addition, one casualty and one death were also reported.

Moreover, heavy rainfall that fell in Pemba on 8th and 9th January 2021, and in Unguja on 28th April and on 1st and 14th December 2021 resulted into floods which damaged about 186 houses of which 166 in Unguja and 20 houses in Pemba (ZDMC).

Figure 12: Effects of floods in Mtwara Mikindani Municipal after heavy rainfall event that occurred between 11th and 12th January 2021. (Source: Tanzania Disaster Management blog and IPP media: https://www.itv.co.tz/news/)

On 14th August 2021, unusual hailstorm occurred in Biharamulo district (Kagera region). The event occurred unexpectedly because in this area August is normally dry. This incident lasted for three hours and was associated with severe thunderstorms, strong winds and large hailstones reaching 0.5 cm in diameter. The observed hailstones spread across large part of the area including the highway linking Bwanga to Biharamulo caused delays to people commuting in this highway for some hours. The event also severely damaged crops especially banana plants (Figure 13).

Figure 13: Deposits of hailstones in farms and road from Bwanga to Biharamulo in Biharamulo district observed on 14th August 2021. (Source: Mwananchi newspaper, 15th August 2021 and http://www.diramakini.co.tz/2021)

7. Summary and conclusion

In 2021, the country was generally dry over most of the bimodal areas especially during OND rainy season owing to insufficient rainfall observed over many parts of the country, but it was relatively dry during MAM rainy season. However, the country was relatively wet for unimodal areas during NDJFMA 2020/2021 rainy season. On average, November 2021 was the driest month of the year, and it is ranked the third driest November since 1970. Comparing previous year's annual rainfall records, the year 2021 is the fourth driest year on record since 1970 after 2003 (first driest), 2012 (second driest), and 2005 (third driest)

The country average temperature was slightly higher than long term average for all months. On average, November and December were the warmest months of the year, November being a record break in historical observational perspective while December being the third warmest on record since 1970. Large number of events with daily temperature greater than 35°C were mainly witnessed in March and November especially over northern coast and northeastern highlands, while large number of cooler nights with temperature lower than 10 °C occurred mainly during June to August and sometimes to September over the southwestern highlands.

The occurrence of extreme weather events especially heavy rainfall and prolonged dry conditions were witnessed over many parts of the country during the year 2021. Heavy rainfall associated with floods occurred mostly during the transition period of January to February, the occurrence of floods impacted socio-economic activities which in turn caused loss of lives and properties, damage to infrastructures (including bridges and roads), destruction of farm fields and settlements. Likewise, the effects of prolonged dry condition especially during October to December rainy season led to massive loss of animals due to lack of water and pasture particularly in northeastern parts of the country.

The observed extreme weather impacts and its associated risks could have been significantly reduced if the public, government, and non-government sectors follow closely and use effectively weather forecasts and climate outlooks, and warnings and updates issued by TMA on seasonal, monthly, dekadal, and daily time scales.

8. Appendix

8.1 Climate of Tanzania

8.1.1 Temperature distribution

Temperatures across the country are normally characterized by relatively less fluctuation throughout the year. The annual long-term average temperature over different stations in the country ranges from 14.4 °C to 26.4 °C. Regions with the highest temperatures are along the coast and western parts of the country. The season with high temperatures starts from October through February or March of the following year, whilst the cold season is from May to August. The annual minimum air temperature (Tmin) and maximum air temperature (Tmax) across the stations ranges from 9.6 °C to 22 °C and 19.1 °C to 30.7 °C respectively.

8.1.2 Rainfall distribution

The rainfall distribution and variability are driven by multiple factors including East African Monsoon, El-Niño Southern Oscillation (ENSO), and westerlies from Congo, tropical cyclones, and Inter-Tropical Convergence Zone (ITCZ). The migration of ITCZ north and south across the equator is among the main factors affecting the distribution and variability of rainfall in Tanzania and the entire East African region. The migration of ITCZ lags the overhead sun by 3-4 weeks over the region. The ITCZ migrates to southern regions of Tanzania in October to December, reaching southern part of the country in February and reverses northwards in March, April, and May. Due to this movement, some areas experience single and double passages of the ITCZ. The areas that coincide with single passage are known as unimodal areas. These include the southern, southwestern, central, and western parts of the country, which receive rainfall from November to April or May (NDJFMA, also known as Msimu). Areas that experience double passage are known as bimodal, and include northern coast, northeastern highlands, Lake Victoria areas, and the Islands of Zanzibar (Unguja and Pemba). These regions receive two distinct rainfall seasons. The long rainy season (also known as Masika), which starts mainly in March and continues through May (MAM) and the short rainfall season (also called Vuli) which starts in October and continues through December (OND). January and February are the transition period (relatively dry) for bimodal areas while June, July, August, and September are dry months for the entire country.

8.2 Percentage rainfall

Percentage rainfall is obtained by taking the ratio of the (monthly/seasonal/annual) rainfall of the current year to long-term average (period between 1981-2010) of monthly/seasonal/annual rainfall multiplied by 100. The percentage value greater than 125 is regarded as above normal rainfall and the value between 75 and 125 is referred to as normal rainfall. The value less than 75 percent of long-term average is below normal rainfall.

8.3 Temperature anomaly

Temperature anomaly is calculated by taking the difference between the observed values (monthly/seasonal/annual) for the current year and the long-term mean. Anomalies are computed with respect to the 1981-2010 base period means.

8.4 Cumulative rainfall analysis

Cumulative rainfall is defined as the rainfall that has accumulated in a prescribed period (e.g. 10 day or monthly interval). 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 is a concept used to evaluate the temporal correlation of the seasonal rainfall with the long-term average rainfall. Cumulative rainfall is used to indicate how much rain has fallen in the region within the prescribed period such as previous week, month, season, or year. The concept has agricultural and hydrological meaning in the short term as a generalized evaluation of either insufficient or abundant rainfall. In addition, the cumulated rainfall saves as a tool to detect the start and end of the rainy season and the presence of wet and dry spells in the season.

In this statement, cumulative rainfall is an accumulation of observed dekadal rainfall from a selected reference point.

8.5 Spatial analysis for temperature and rainfall distribution

Temperature and rainfall were analyzed as point data for the selected stations across the country. 31 stations were used for rainfall analysis and 25 stations for temperature analysis. They were analyzed by the Inverse Distance Weighting (IDW) interpolation method in Quantum GIS to generate spatial distribution maps. The IDW interpolator assumes each input point has local influence that diminishes with distance. It weighs the points closer to the processing cell greater than those far away. The IDW algorithm is a moving average interpolator that is usually applied to highly variable data.

8.6 Severe weather

Severe weather is defined as any aspect of the weather that poses risks to life, property or requires the intervention of authorities. While extreme weather is described as unusual weather events that are at the extreme of historical distribution for a given area such as strong winds, high temperatures, hail, and excessive rainfall.

Rainfall threshold in this statement adopted those prescribed by Severe Weather Forecasting Demonstration Project (SWFDP) in East and Southern Africa, which is 50 mm or more, recorded in 24 hours. However, extreme weather and climate events can also be described by other statistical terms such as percentiles and on the magnitude of impact caused even if it does not reach the prescribed threshold.