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TMA
TANZANIA METEOROLOGICAL AUTHORITY

Statement on the Status of Tanzania Climate in 2019

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Abbreviations

ENSO	El Niño–Southern Oscillation
IDW	Inverse Distance Weighting
IOD	Indian Ocean Dipole
ITCZ	Inter-Tropical Convergence Zone
JF	January–February
JNIA	Julius Nyerere International Airport
KIA	Kilimanjaro International Airport
MAM	March to May
MJO	Madden Julian Oscillations
NDJFMA	November to April
OND	October to December
SSTs	Sea Surface Temperatures
SSTA	Sea Surface Temperature Anomalies
SWFDP	Severe Weather Forecasting Demonstration Project
TMA	Tanzania Meteorological Authority
Tmax	Maximum temperature
Tmean	Mean temperature
Tmin	Minimum temperature

Foreword

Climate observation and monitoring is critical for facilitating effective and efficiency planning and implementation in socio-economic sectors, particularly in Agriculture, Water and Energy. Over the recent years, annual global average temperature anomaly have been observed to increase from year to year. According to the United Nations, about 80 percent of the world's food is produced by family farms. Yet, agriculture has always been deeply dependent on the weather that includes a mixture of sun, warmth, and rains in order to reliably produce the food. Tanzania like many other African countries, have continued to experience impacts of extreme events such as heavy rainfall and floods, strong winds and higher temperatures which have greatly impacted people's livelihoods.

Tanzania Meteorological Authority (TMA) is responsible for provision of weather and climate services in the United Republic of Tanzania. The Authority have continued to monitor and document the state of climate and explore the emerging signals of climate variability and change and preparing the report on the status of Tanzania climate since 2011. The current report provides a comprehensive summary of the main weather and climate events that occurred in Tanzania during the calendar year of 2019 and their associated impacts. The major weather and climate events are documented using observed precipitation and temperature data as well as information obtained from other relevant sources such as newspapers, media and reports from the national disaster management authority.

This report is intended for providing information on current climate, extreme events and their associated impacts for effective planning and decision making in various sectors, such as agriculture and food security, water resource management, energy, disaster risks management, and public health. The report is also useful for researchers and academia, and for enhancing public awareness on climate change and its impacts.

TMA would like to take this opportunity to express sincere gratitude to all stakeholders for continuous support, constructive comments, 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

The impacts of climate change and variability are felt globally but the magnitude and severity alter from region to region and from country to country depending on exposure, level of vulnerability to these events and adaption capacity. Understanding the linkage between observed climate variability and change and how they impact different community is very crucial for wellbeing of world's population. Increasing temperature, decreasing/increasing rainfall, and increased frequency and magnitude of extreme weather and climate events, particularly floods and droughts, are the major weather and climate phenomena experienced in different parts of the world. The observed impacts are often associated with devastating socio-economic and ecological implications.

In Tanzania, the impacts of climate change and variability are already witnessed in various areas. The major ones include recurring floods and droughts that have caused detrimental impacts to socio-economic development. These events have contributed to the loss of lives and properties, damage of infrastructures, destruction of environment, reduction in agricultural production, and have caused disruption to socio-economic activities.

Continual monitoring of weather and climate, and provision of accurate and reliable climate services may serve as a remedy to lessen risks of climate change impacts. Cognizant of the enormous challenges and increasing need of information, TMA has committed and dedicated efforts and resources to conduct robust and comprehensive climate analysis and provide an authoritative statement/report on the status of Tanzania climate every year. The statement saves as a monitoring tool for climate variability and change on annual basis. It provides information on the status of climate for a respective year and the associated extremes with the goal of enhancing awareness and understanding of climate variability and change among stakeholders.

The current statement provides analyses of weather and climate events that occurred in 2019. A comprehensive summary of the main weather and climate events that occurred in different regions in Tanzania from January to December, and their associated impacts are presented by placing them into proper historical perspectives. Maximum and minimum temperature anomalies, rainfall anomalies, cumulative rainfall, extreme events and associated socio-economic impacts, are extensively and detailed presented in the report. Also, the major drivers of weather and climatic events that have contributed to severe and extreme climate events are included in this report.

2. Temperature distribution

In 2019, the country experienced anomalously warmer than average annual mean temperatures (Tmean) with minimum temperatures (Tmin) being anomalously warmer compared to maximum temperatures (Tmax). Higher anomalies for annual Tmin were observed over areas surrounding Lake Victoria, north eastern highlands, northern coast and central parts of the country while higher anomalies for Tmax were observed over Mbeya region.

2.1 Annual mean, maximum and minimum temperature anomalies

The country average annual mean temperature (Tmean) for 2019 was 23.8 °C, which is 0.8 °C warmer than long-term average (1981-2010). This temperature makes 2019 to be the fourth warmest year in the series of Tanzania observations of meteorological records from 1970. The first, second and third warmer years in the series were 2003, 2010 and 2005 with temperature anomaly of 1.2 °C, 0.9 °C and 0.89 °C respectively.

The spatial distribution of annual mean temperature anomalies in the range of 0.75 °C and up to 1.5 °C above long term average (Figure 1) were observed over many parts of the country, except some areas in the northern coast and southern coast extending to Mahenge and parts of Ruvuma region. On average Kagera and Mwanza regions recorded higher anomalously warmer annual temperature between 1°C and 1.5 °C.

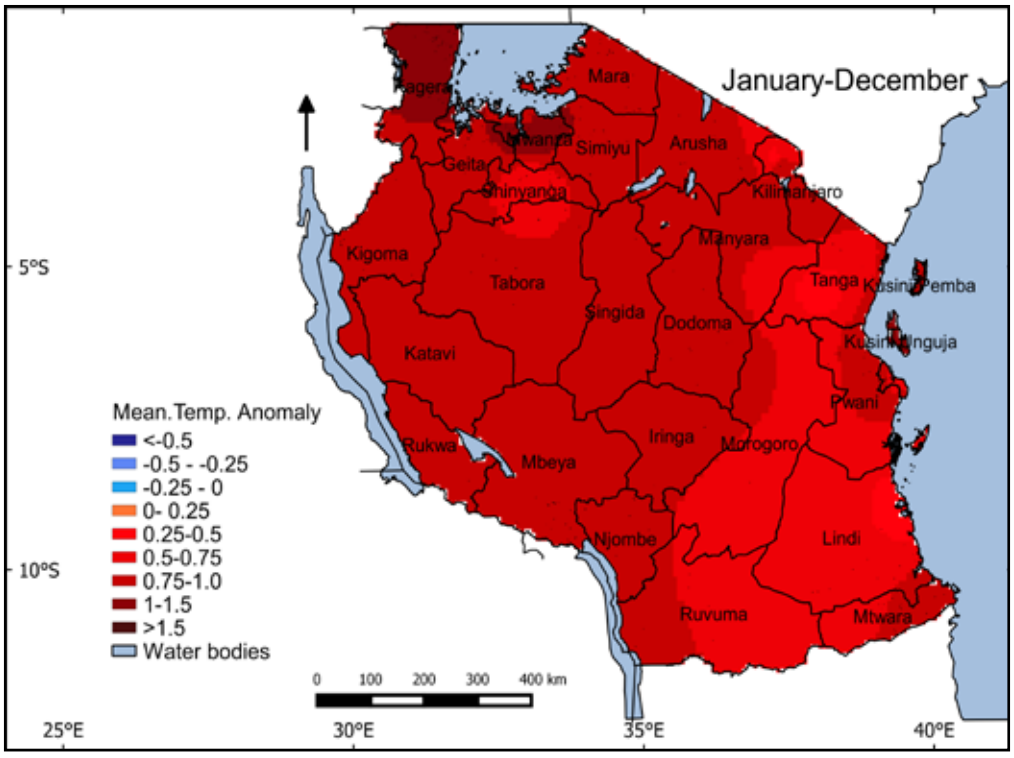

Figure 1: 2019 annual mean temperature departures (°C) from long-term average.

The country average annual maximum temperature (Tmax) was 29.3 °C which is 0.6 °C higher than long-term average. The anomalies (Figure 2 left) were above long-term average in the range of 0.25 °C and 0.75 °C on many parts of the country but exceeding 0.75 °C over southwestern highlands especially in Mbeya region. However, near average temperature anomaly in the range between -0.5 °C and 0.5 °C were mostly observed over few areas of Morogoro and Tanga regions. Likewise, the country average annual minimum temperature (Tmin) was 19.2 °C which is 1 °C warmer than long-term average. The anomalies (Figure 2 right) were above long term average in the range of 0.75 °C and 1.5 °C on many parts of the country but exceeding 1.5 °C, over few areas especially in Kagera, Mara, Kilimanjaro and Tanga regions and Unguja and Pemba Islands.

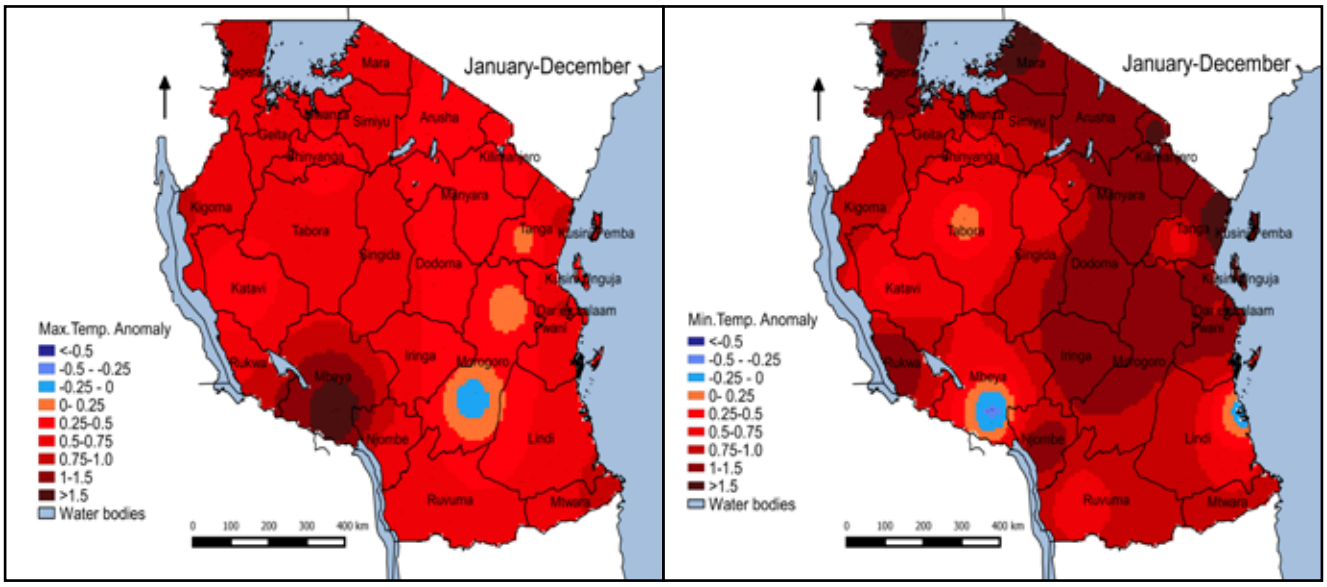

Figure 2: Annual maximum (left panel) and minimum (right panel) temperature departures (°C) from long-term average for 2019

2.2 Monthly mean temperature anomalies

During 2019, March, April, July, August and September were the warmest months with country average mean temperature anomaly of 1.2 °C and 1.6 °C, 1.2 °C, 0.9 °C, 0.9 °C above their long-term average respectively. July and September were exceptional warmest months and record-breaking since 1970, while April and August are ranked second on record and March ranked the third on record.

The warming in March and April is mainly due to anomalously warmer maximum temperatures observed in the respective months (Figure 3a) as compared to minimum temperature anomaly. The country average maximum temperature anomaly in these months were 1.6 °C and 1.9 °C while the minimum temperature anomaly was 0.7 °C and 1.4 °C respectively. On the other hand, warming in July, August, and September was mainly due to anomalously warmer minimum temperatures observed in the respective months (Figure 3b) compared to maximum temperature anomaly. The country average minimum temperature anomaly in July, August, and September were 1.1 °C, 1.3°C and 1.3 °C as compared to the maximum temperature anomaly which were 1 °C, 1 °C and 0.8 °C respectively.

However, October, November and December were slight warm compared to other months of the year. The mean temperature anomaly for October and November were 0.4 °C and for December was 0.2 °C above long-term average. This slight warming is linked to anomalously cooler maximum temperatures observed on the respective months (Figure 3a). The country maximum temperature anomaly for October, November and December were -0.5 °C, -0.2 °C and -0.6 °C respectively in comparison to minimum temperature anomaly 1.3 °C, 0.9 °C and 0.9 °C respectively.

2.3 Monthly maximum temperature anomalies

Warmer than average maximum temperatures (Tmax) were mostly observed during April (anomaly value of 1.9 °C), March (anomaly value of 1.6 °C), February, July and August (anomaly value of 1.0 °C). Temperature anomalies in the range of 0.5 °C and 1.5 °C was observed over many parts of the country during January, February, July, August and September but anomaly exceeding 1.5°C was observed during March and April especially over northeastern highlands, northern coast, eastern parts of Lake Victoria, parts of central, western and southwestern highlands of Tanzania (Figures 3a and 3b). In addition, higher anomalies exceeding 1.5 °C were also observed over areas surrounding Lake Victoria, northeastern highlands and parts of central and southwestern highlands during February, July and September. For example, the highest temperature anomalies of 3 (2.8) °C and 3.6 (3.5) °C were recorded over Moshi (Same) meteorological stations during March and April respectively, and anomaly values of 2.9 °C, 2.7 °C, and 2.9 °C were observed over Mbeya meteorological station during February, March and April respectively.

In contrast, anomalous cooler temperatures (Tmax) were mostly observed during May (anomaly value -0.1 °C), October (anomaly value -0.5 °C), November (anomaly value -0.2 °C) and December (anomaly value -0.6 °C). This cooling condition may partly be linked to reduced incoming solar radiation due to enhanced cloud cover and unusual heavy rainfall events observed in these months. The spatial distribution of temperature indicates anomalous cooling in the range of -0.5 °C and -1.5 °C over many parts of the country during October and December and over the eastern half of the country during May and November. However, temperature anomaly lower than -1.5 °C were observed over northeastern highlands and few areas of Lake Victoria, northern coast and Ruvuma regions during October, November and December. For example, the highest cooling temperature anomaly of -2.4 °C, -2.3 °C and -1.9 °C was recorded over Same, Moshi and Kilimanjaro International Airport (KIA) meteorological stations during October. On the other hand, cooling temperature anomaly of -1.9 °C was recorded over Songea meteorological station during November.

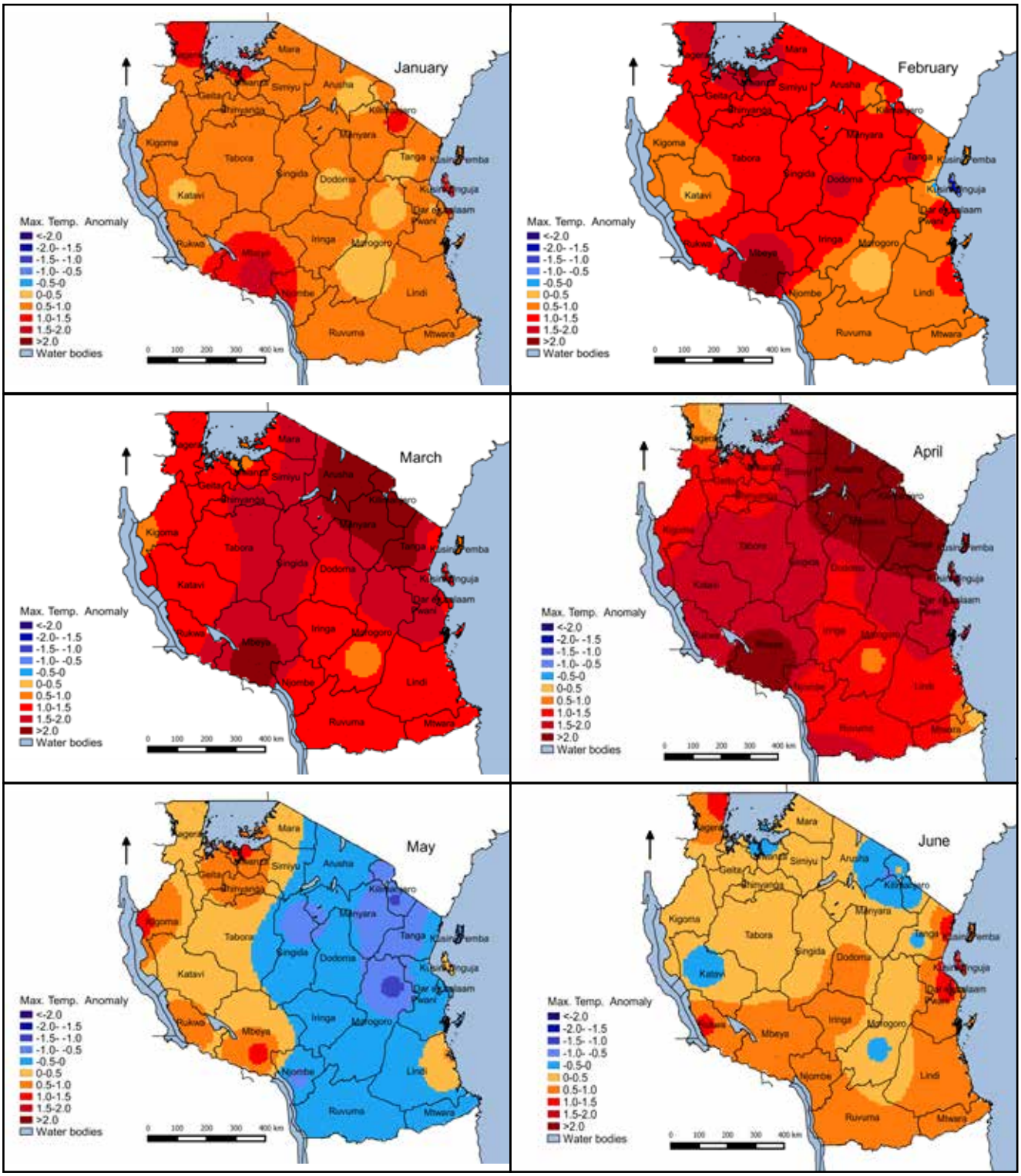

Figure 3a: Monthly maximum temperature departures from long-term average (°C) for January–June 2019.

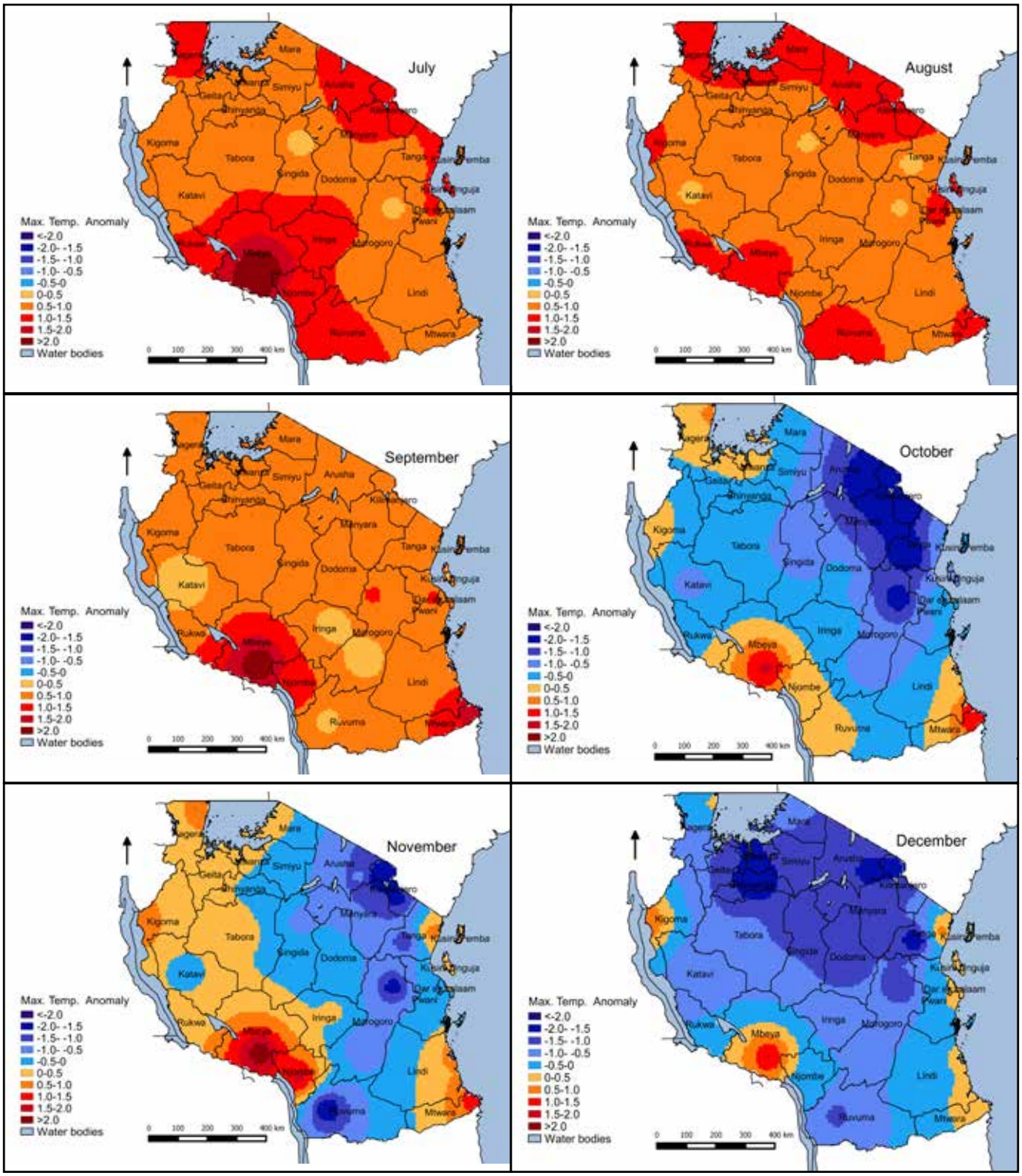

Figure 3b: Monthly maximum temperature departures from long-term average (°C) for July–December 2019.

2.4 Monthly minimum temperature anomalies

The country average minimum temperature anomalies were higher during April and May (anomaly value of 1.4 °C), August, September and October (anomaly value of 1.3 °C). In these months, the highest temperature anomaly exceeding 1 °C was observed over many parts of the country during April and May but mostly over the eastern half of the country during August, September and October (Figures 4a and b).

Generally, most parts of the country experienced anomalously warmer minimum temperatures (Tmin) in the range of 0.5 °C and 1.5 °C during June to December, and between 1 °C and 2 °C during April and May. However, temperature anomaly exceeding 2 °C were observed over few areas especially northeastern highlands, southwestern highlands and Lake Victoria during April, May and June (Figures 4a and b). For example, Musoma meteorological station recorded anomalous minimum temperature values of 2.3 °C, 2.4 °C and 2.6 °C during April May and June respectively, while Sumbawanga and Mpanda meteorological stations recorded anomalous minimum temperature values of 2.8 °C and 2.5 °C respectively during May.

On the other hand, near average temperature anomaly (between -0.5 °C and 0.5 °C) were consistently observed over western and southern parts of the country during all months except April and May.

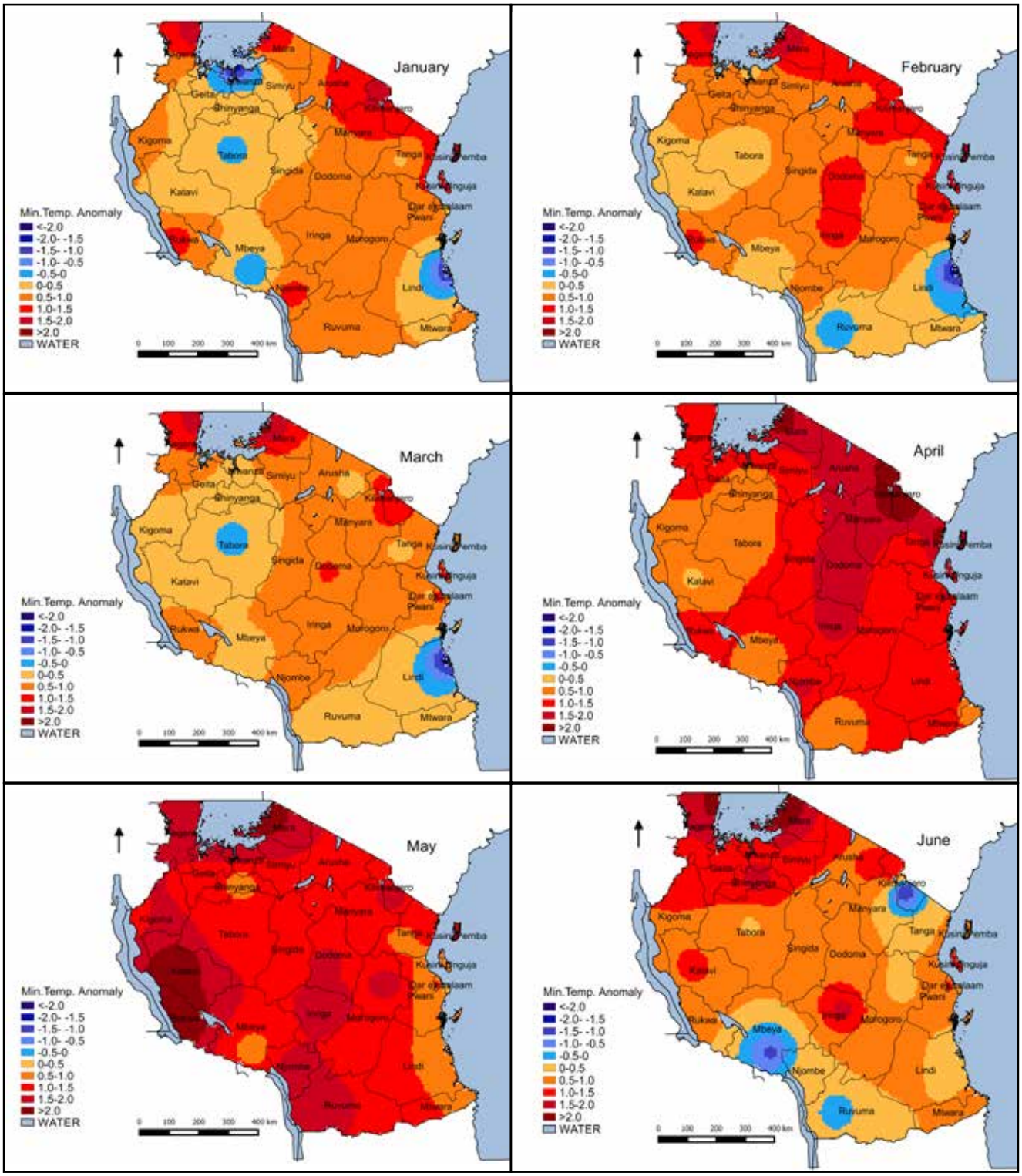

Figure 4a: Monthly minimum temperature departures from long-term average (°C) for January–June 2019.

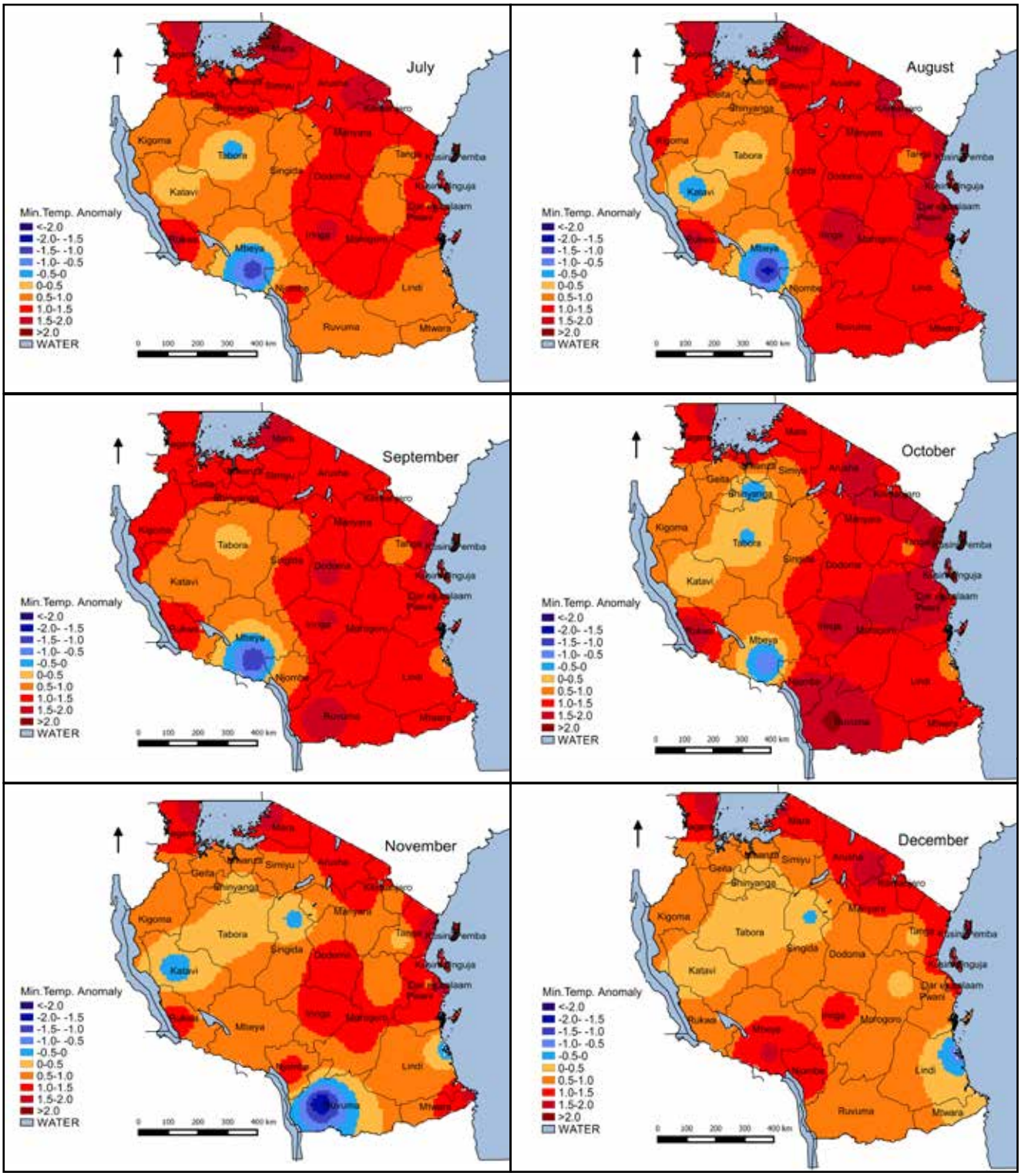

Figure 4b: Monthly minimum temperature departures from long-term average (°C) for July–December 2019.

3. Rainfall distribution

Normal to below normal rainfall was observed during November 2018–April 2019 rainy season (NDJFMA), whereas normal rainfall and above normal rainfall was observed during March–May (MAM) rainy season and October–December (OND) season respectively. On average May, October, November and December were the wettest among other months with some parts of the country receiving rainfall amount exceeding 200% of the 1981–2010 long-term average. In contrary, March and April, were the driest months especially for bimodal areas.

3.1 Annual rainfall distribution

The country average annual total rainfall for 2019 was 1283.5 mm, which is higher than the long-term average (1981-2010) rainfall by 256.5 mm and equivalent to 125% of the long-term average. This makes 2019 to be the fourth wettest year on record since 1970. The spatial distribution of rainfall (Figure 5) expressed in percentage of average indicates that, most parts of the Lake Victoria basin, north eastern highlands, central, entire coast and parts of southwestern highlands received above normal rainfall (rainfall amount between 125% and 150% of average), and the remaining parts of the country received normal rainfall (rainfall amount between 100% and 125% of long-term average).

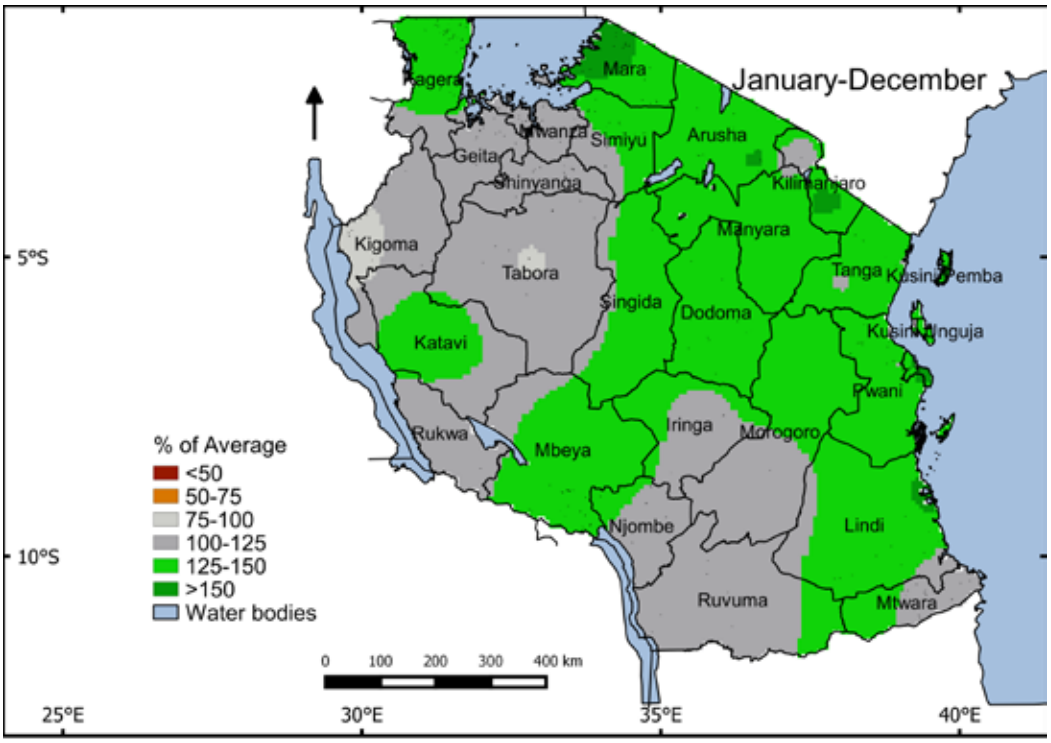

Figure 5: Annual rainfall anomalies for 2019 expressed as a percentage of the long-term average.

3.2 Seasonal rainfall distribution

Normal rainfall in the range of 75% and 100% of average was mainly observed over Lake Victoria regions, central, and some parts in the western Tanzania, southwestern highlands, and southern coast, whereas below normal rainfall (rainfall amount between 50% and 75% of average) was observed over the rest of the country during 2018-2019 NDJFMA rainfall season. (Figure 6 top panel left). During the transition period January-February (Figure 6 top panel right), many parts of the country received normal rainfall in the range of 75% and 100%, of average except northern coast and parts of Kigoma which received below normal rainfall (rainfall amount between 50% and 75% of average), and parts of Lake Victoria which received above normal rainfall (rainfall amount between 125% and 200% of average, but exceeding 200% over few areas of Mara region). The 2019 MAM rainfall season was observed to be mainly normal for most parts of the country (rainfall amount between 75% and 125% of average) with patches of above and below normal rainfall over few areas (Figure 6 bottom panel left).

On the other hand wetter than normal rainfall was observed over most parts of the country during OND rainfall season. Rainfall amounts ranging from 125% to 200% of average were mainly observed over the western parts of the country while rainfall exceeding 200% over the eastern parts of the country (Figure 6 bottom panel right). This marks 2019 OND rainfall season to be the second wettest year on record from 1970, after the 1997 strong El Ñino year.

3.3 Monthly rainfall distribution

October was the wettest month in 2019 with rainfall amount exceeding 200% of the long-term average across the country. Likewise, November and December were the wetter months but with rainfall amounts ranging between 125% and 200% of long-term average mainly over the western half of the country extending to southern parts while eastern half of the country especially northeastern highlands, northern coast and eastern parts of Lake Victoria received over 200% of the long-term average (Figure 7b). Wetter than normal condition in the range between 125% and larger than 200% of the long-term average was also observed over the eastern half of the country during May (Figure 7a). In general, October was the wettest month on record while December being the second wettest and May being the third wettest on record since 1970.

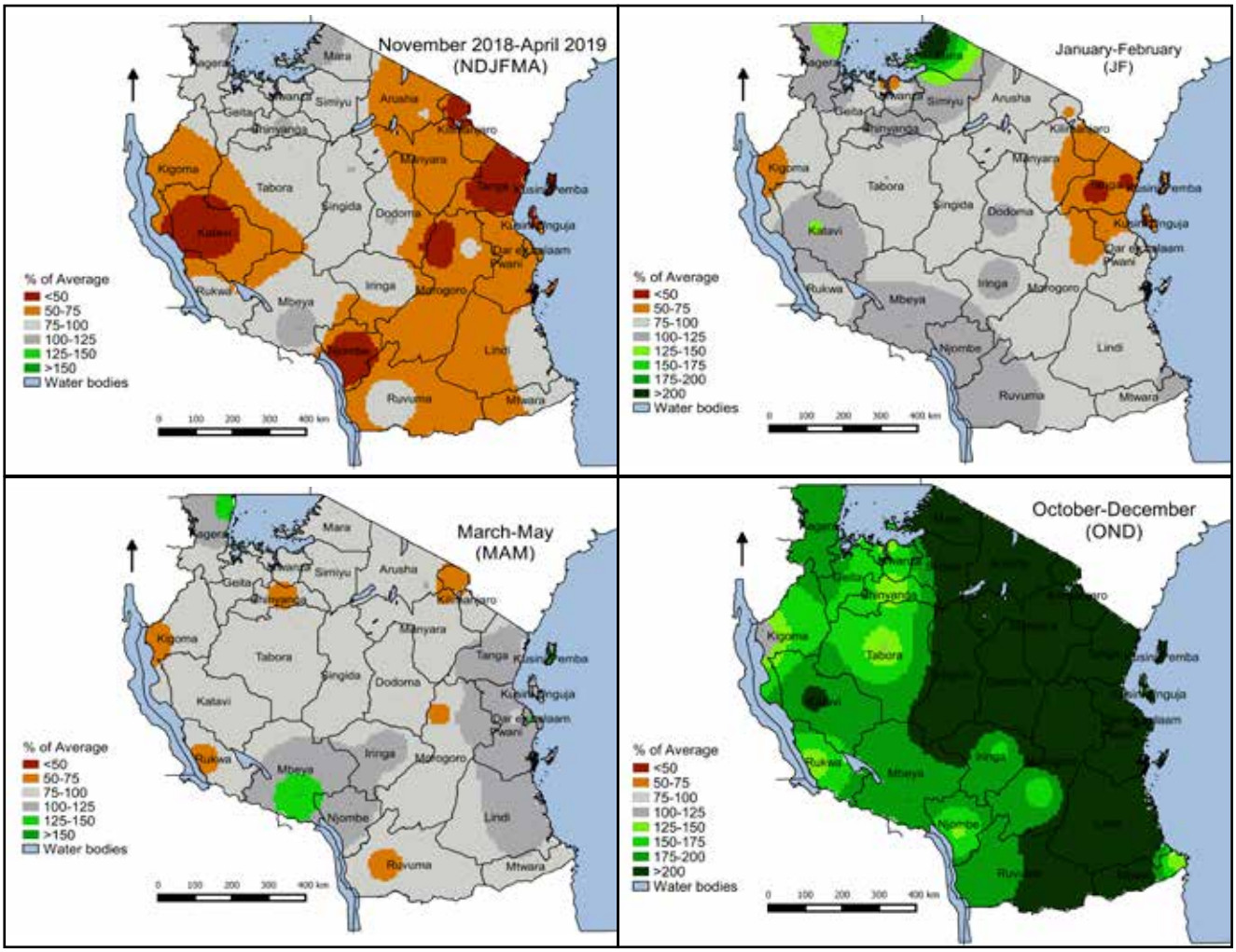

Figure 6: Seasonal rainfall distribution during 2019, expressed as percentage of long term average for November 2018–April 2019 (top panel left), January–February 2020 (top panel right), March–May 2020 (bottom panel left) and October–December 2020 (bottom panel right)

In contrast, most parts of the country received normal rainfall ranging between 75% and 125% of average during January, February and April, but areas in the northern coast, northeastern highlands received below normal rainfall in the range of 50% to 75% of average during February and April. However, below normal rainfall in the range of 50% to 75% was observed over many parts of the country during March (Figure 7a). The deficiency of rainfall during these months makes April to be the second driest month on record since 1970.

Notably, below normal rainfall (rainfall amount below 50%) was observed over most areas of the country during June, July and few areas during August and September (Figures 7a and 7b). This should not be interpreted as being drier than normal condition, because these months are climatologically dry, although occasional rains do occur.

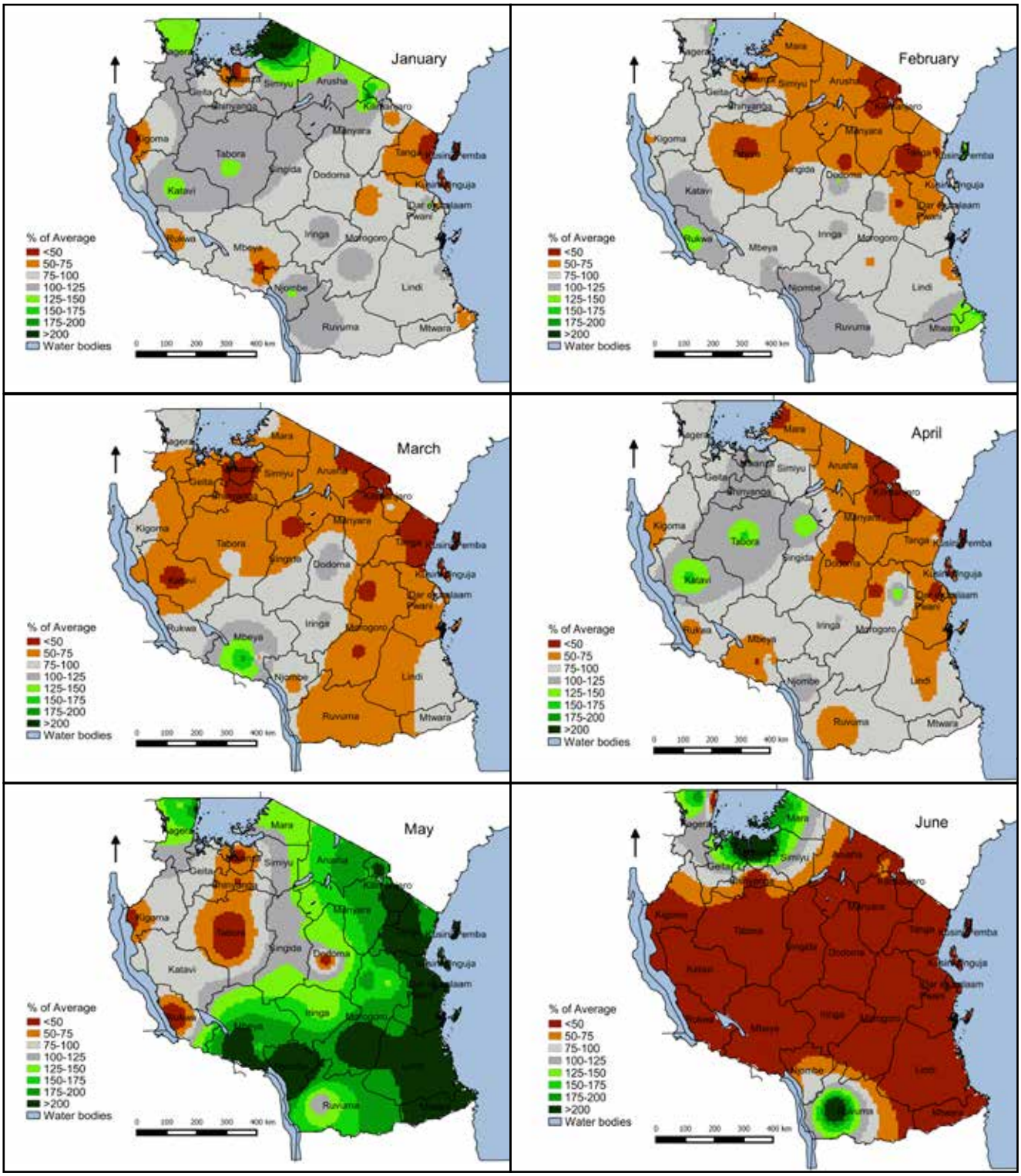

Figure 7a: Monthly rainfall distribution as percentage of long-term average for January–June 2019.

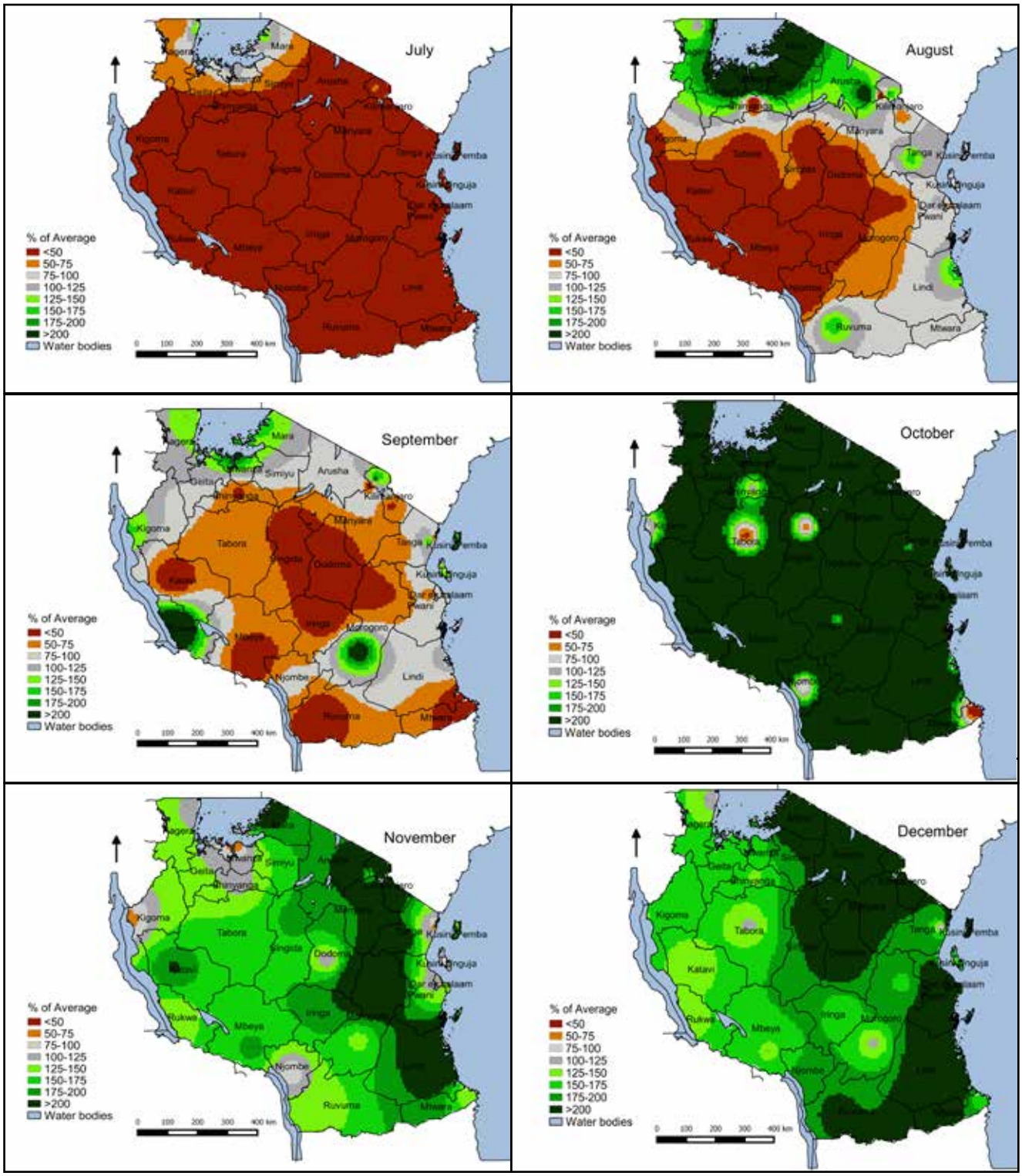

Figure 7b: Monthly rainfall distribution as percentage of long-term average for July–December 2019.

3.4 Cumulative rainfall

In this report 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 has hydrologic meaning in the short term as a generalized evaluation of either insufficient or abundant rainfall.

During November 2018–April 2019 (NDJFMA) season, the seasonal rainfall accumulation for most stations in the unimodal areas (west, central and southern parts of the country), were nearly comparable to 1981–2010 long-term average of NDJFMA season rainfall. However, higher than average seasonal total rainfall was observed over Mbeya and below average seasonal total was observed over Tabora and Kigoma (Figure 8a). This has an indication that, insufficient rains were observed over the western parts of the country during NDJFMA season while sufficient rains were observed over central and southern parts of the country also as depicted in (Figure 6)

In the MAM season, the rainfall accumulations for most stations in the bimodal areas (Morogoro, Arusha, Musoma, Shinyanga and Zanzibar) were nearly comparable to 1981–2010 long-term average. However, lower than average seasonal total was observed over Moshi, Mwanza and Tanga, while higher than average rainfall was observed over Bukoba and JNIA (Dar es salaam) (Figure 8b). Generally, sufficient rains were observed over many parts during MAM season, same as depicted in (Figure 6). However, the temporal evolution of rainfall during the season indicates that, even for stations that received sufficient rains, rainfall was mainly lower than long-term average in the beginning of the season (March and April) but picked up in the end of the season (May).

In contrast to MAM season, the OND 2019 season was observed to be wetter over many parts of the bimodal areas. Most stations in the bimodal areas (Dar es Salaam, Zanzibar, Arusha, Moshi, Morogoro, Mwanza, Bukoba, Tanga and Musoma) received higher than average seasonal total rainfall except Shinyanga which experienced near normal rainfall that is comparable to 1981–2010 long-term average (Figure 8c). In addition, the rains were fairly distributed within the season.

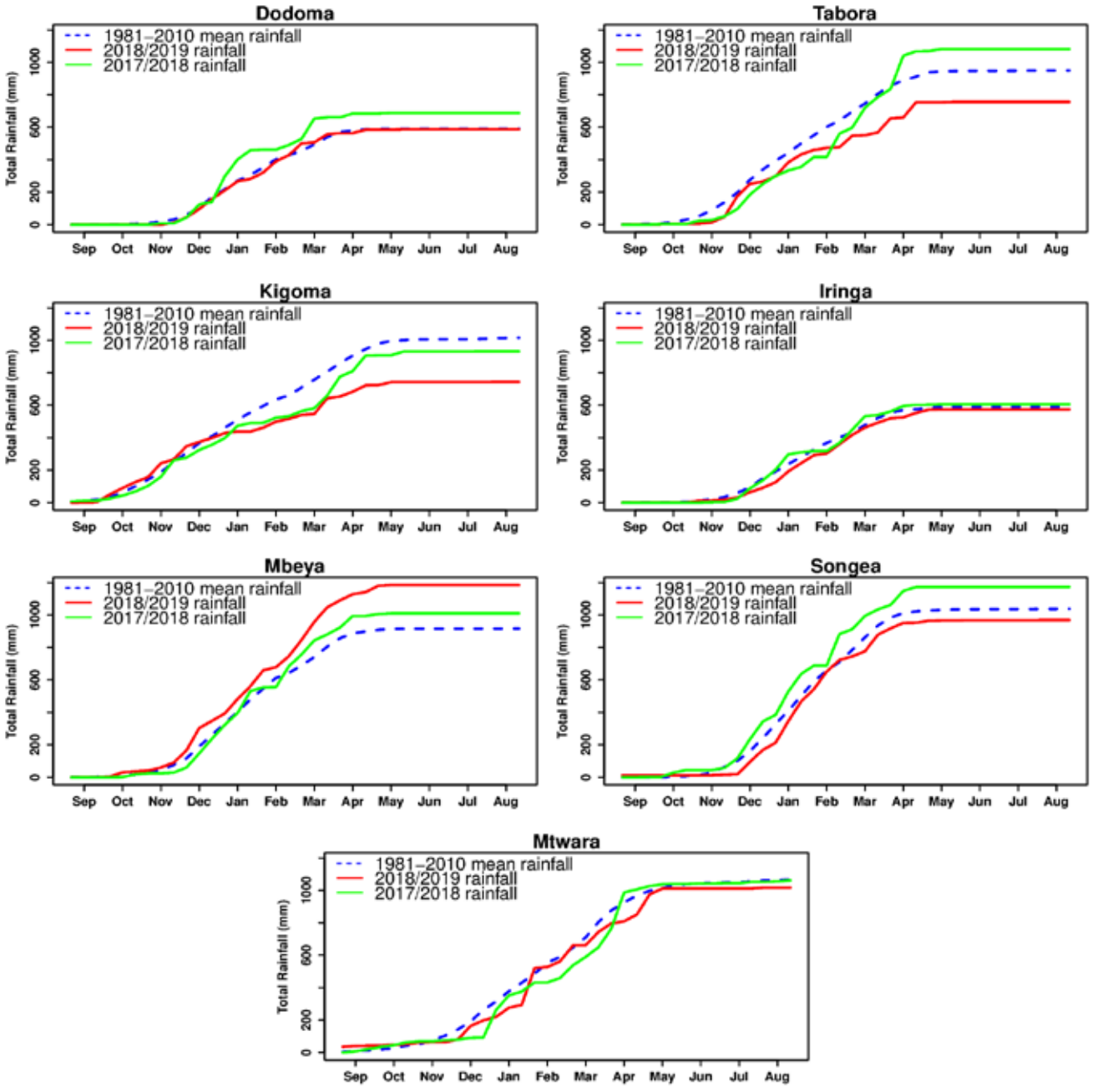

Figure 8a: Cumulative rainfall plots for NDJFMA season for Dodoma, Tabora, Kigoma, Iringa, Mtwara, Mbeya and Songea meteorological stations presented as accumulation of dekadal rainfall totals for each month starting from September 2018 to August 2019.

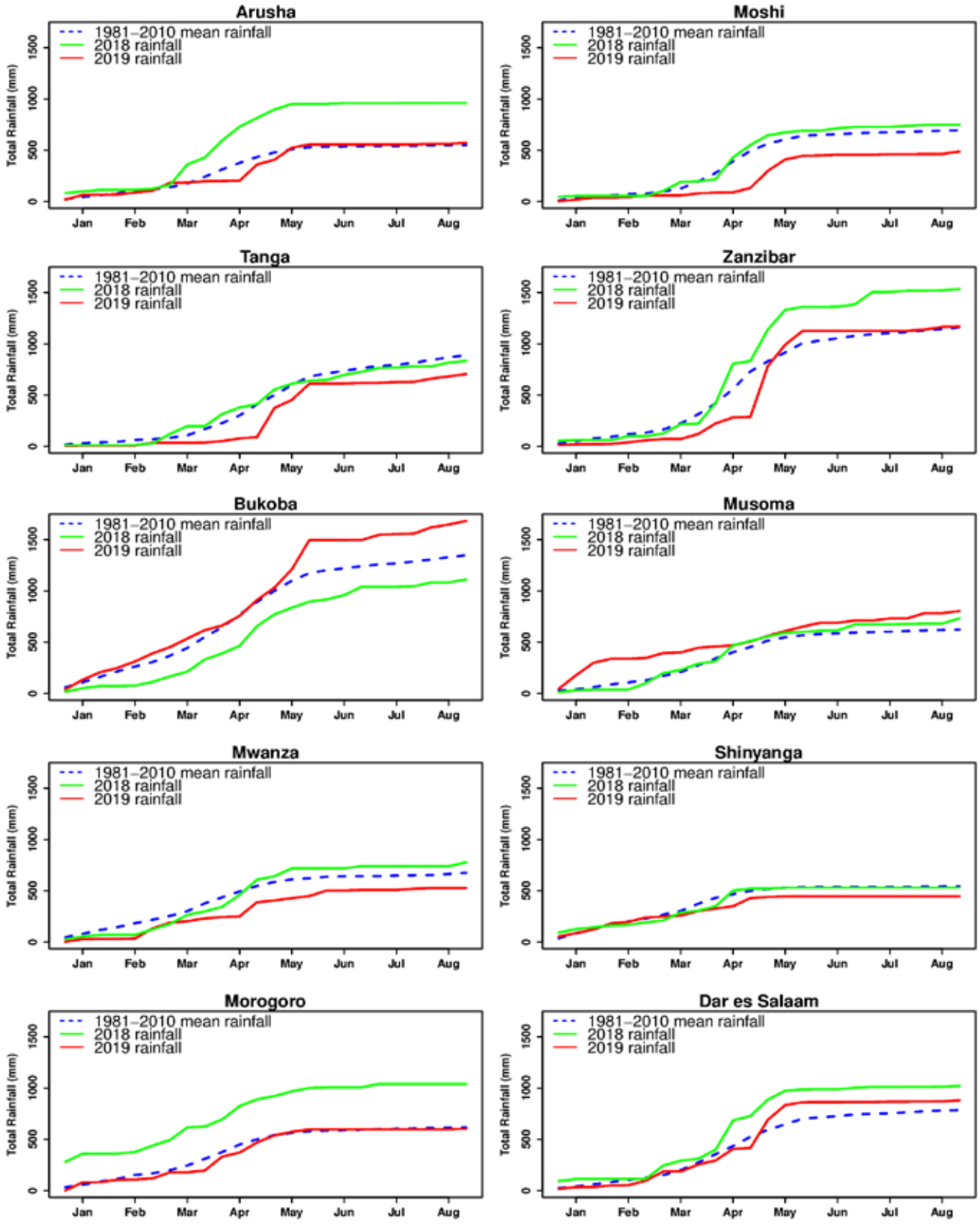

Figure 8b: Cumulative rainfall plots for MAM season for Bukoba, Mwanza, Musoma, Shinyanga, Dar es Salaam, Morogoro, Tanga, Zanzibar, Arusha and Moshi meteorological stations presented as accumulation of dekadal rainfall totals for each month starting from January to August 2019

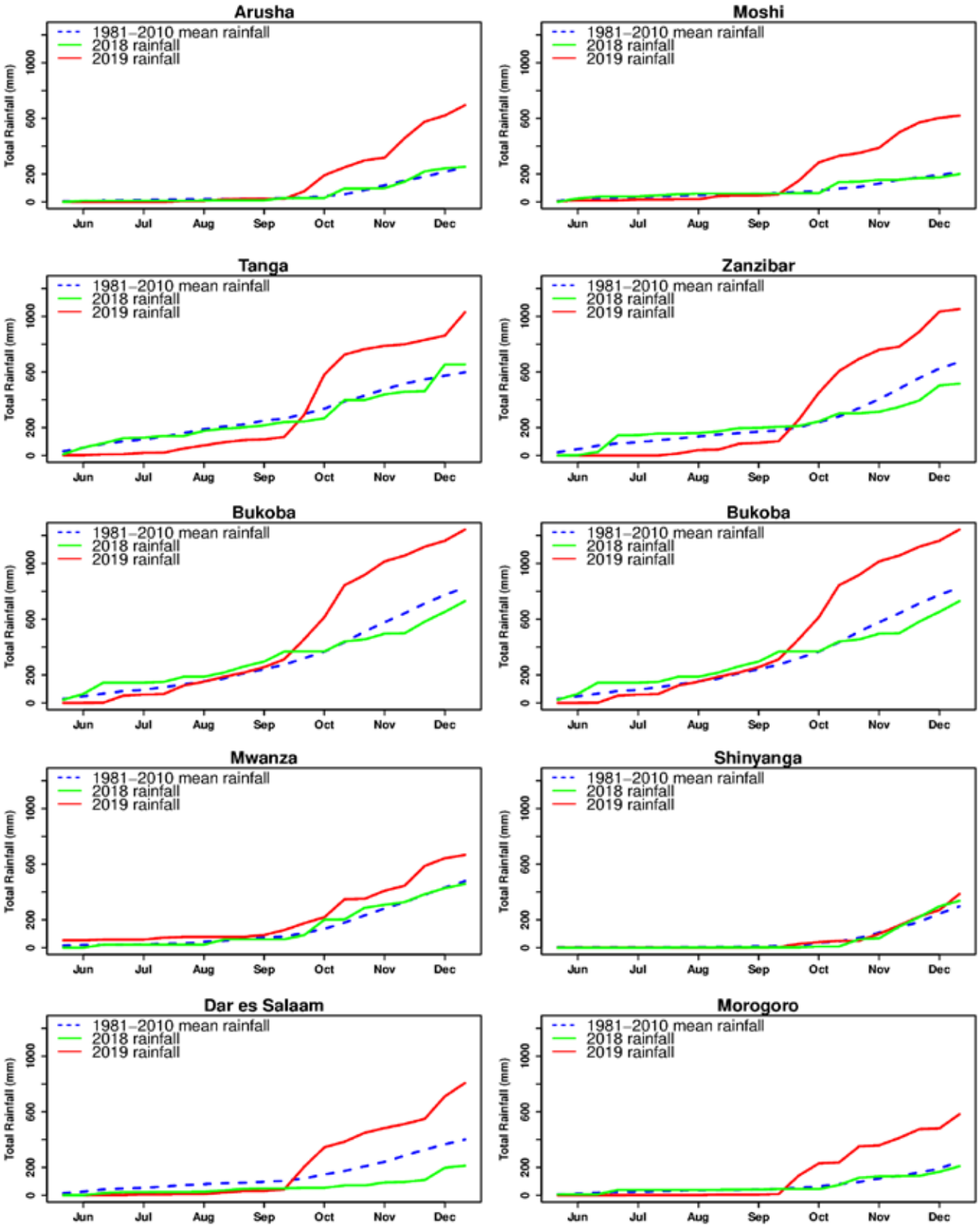

Figure 8c: Cumulative rainfall plots for OND season for Bukoba, Mwanza, Musoma, Shinyanga, Dar es Salaam, Morogoro, Tanga, Zanzibar, Arusha, and Moshi meteorological stations presented as accumulation of dekadal rainfall totals for each month starting from June to December 2019.

4. Extreme weather and climatic events

The 2019 was a year with quite number of devastating extreme weather events particularly heavy rains associated with significant flooding. In October, some of the meteorological stations in the northern coast and northeastern highlands observed five to ten times its October long-term average rainfall. The strong Indian Ocean Dipole phenomena during October-December is linked to the above normal rainfall over the most regions in the bimodal and some regions in the unimodal rainfall regime.

4.1 Extreme rainfall and flood events

In the year 2019 heavy rainfall and flood events continued to manifest and affected many parts of the country. Noteworthy events related to heavy rainfall or continuous rainfall occurred in the areas of Lake Victoria, northeastern highlands, northern coast, central, western and southern parts of the country during October, November and December but significant events occurred also during April and May. At least 20 deaths were attributed to heavy rainfall in Tanga region in October including flooded rivers and destructed bridges.

Some of the extreme rainfall events observed in 2019 include: On 15th January 2019, Morogoro meteorological station recorded 77.6 mm of rainfall which caused floods at Dumila Bridge. Mtwara meteorological station recorded 177.6 mm of rain in two days (7th and 8th February 2019). There were few events with rainfall exceeding 50 mm, reported during this month especially for unimodal areas. Heavy rainfall with hail (95.7mm) was also reported at Kibondo on 18th February 2019 while light rains associated with strong winds and hail was observed in Arusha town on 25th Feb 2019.

Between 28th and 29th April 2019, Arusha meteorological station recorded a total amount of 126.4 mm of rainfall in 24 hours. This amount is the fourth highest on record but second highest in April for this station since its establishment in 1949. The highest amount was 190.5 mm recorded on 15/4/1949 while the second highest was 188.7 mm recorded on 23/3/1990, and the third highest was 148.8 mm recorded on 18/11/1963. However, very high amounts of rainfall were recorded in the neighborhood locations on the same day; rainfall amount of 215.5 mm were recorded at Themi secondary, while 206.3 mm was recorded at Arusha DC. Rainfall amounts of 148.3 mm and 124.5 mm were also recorded over Tukuyu and Mlingano respectively in the same day.

In May 2019, northern coast of Tanzania especially Zanzibar, Pemba and the vicinity areas including Dar es salaam received unusual rain for 10 consecutive days from 3rd to 12th May. Rainfall total amounts reaching 330 mm and 286.3 mm were recorded in two days (between 5th and 6th May 2019) over Zanzibar and Pemba stations respectively. The later got 181 mm on 5th and 105 mm on 6th May 2019 while the former got 167.2 mm on 5th and 163.4 mm on 6th May 2019. In addition, a neighbour station in Dar es Salaam reported 143.7 mm in two days (64.7 mm on 5th and 79 mm on 6th May 2019). The 181 mm of rainfall recorded over Pemba is the seventh on record since the station started operation in 1940 but the third highest on record for the month of May. The first highest amount ever recorded in this station was 450.7 mm, recorded on 27/4/1978. The amounts recorded in Zanzibar on 5th and 6th are the fifteenth and seventeenth on record respectively but third and fourth on record

for the month of May respectively. Another heavy rainfall of 100.7 mm was reported on 12th May 2019 and 110.8 mm on 22nd May 2019 at Pemba Island. Generally, the recorded monthly rainfall amount for these stations were at least three times the May normal rainfall.

Likewise, between 25th and 26th May 2019, unusual rain fell in Bukoba town. A total amount of 110.1 mm was recorded at Bukoba meteorological station in a range of 8 hours. This rainfall amount is the third highest for the recent two decades (from 2000). Nearly same amount, 112.0 mm and 110.3 mm was recorded on 11/5/2017 and on 1/5/2005 respectively. However, the event is the 17th highest on record for this station since its establishment in 1922, but the 7th on record for the month of May. The highest amount ever recorded in this station is 248.2 mm recorded on 30/4/1994. While the highest amount for May was 138.4 mm recorded on 21/5/1942.

Several meteorological stations in the northern coast and few in northeastern highlands and Lake Victoria reported very high amount of rainfall reaching up to eight times the long-term average rainfall in October 2019. There were 34 records of rainfall amount exceeding 50 mm of which 7 events recorded rainfall amount exceeding 100 mm. For example, Mlingano station recorded 345.8 mm of rains for five consecutive day from 9th to 13th October 2019, and 134.7 mm for two consecutive days between 17th and 18th October 2019. Tanga station recorded 102.6 mm on 12th October 2019, Handeni station recorded 123.7 mm on 24th October 2019, Zanzibar 100.2 mm on 23rd October 2019, Lyamungo 209.8 mm in two consecutive day between 17th and 18th October 2019 but 126.3 mm was recorded on 17th October 2019 only. In addition, Bukoba station recorded 119.1 mm on 10th October 2019 and Matangatuani station recorded 103.6 mm on 13th October 2019.

Rainfall events exceeding 50 mm continued to be reported in November and December 2019 with large number of events confined over the bimodal areas. There were 12 events reported in November and 24 events in December. Specifically, Julius Nyerere International airport station (Dar es Salaam) reported 136.6 mm of rain in 24 hours that occurred between 16th and 17th December 2019, Singida reported 103.4 mm on 20th December 2019 while Pemba reported 141.7 mm of rainfall on 21st Dec 2019. 23rd and 29th December 2019, Sofi Secondary (Mahenge) reported 103.1 mm and 181.5 mm respectively. However, on 16th December, Julius Nyerere International airport station (Dar es Salaam) recorded rainfall amount of 95.5 mm in eight hours.

4.2 Extreme temperature events

In the year 2019, large number of higher daily maximum temperature (Tmax) events exceeding 35 °C occurred during March (159 events) followed by February (76 events), January (22 events), and April (18 events). The extreme hot temperatures were mostly experienced over the northern parts of the country especially the northeastern highlands and the northern coast extending to the hinterland. The highest daily maximum temperature of 38.4 °C, was observed at Mlingano meteorological station on 17th April 2019, and is ranked the 4th position in April but overall in the 9th position in the station record since it started operation in 1950. The second highest daily maximum temperature in the country was 37.5 °C observed at Kilimanjaro international Airport meteorological station, on 22nd March 2019. This

temperature record is ranked 3rd on record for March but overall the 17th position since the station was established. In general, the extreme maximum temperatures for this year are slightly higher than last year's (2018) extreme temperature by at least one-degree Celsius.

The southwestern highlands and southern region were the coldest parts during June, July and August. Large number of lower daily minimum temperature events less than 5 °C (32 events) occurred during July, followed by June (22 events) and August (12 events). The lowest minimum temperature of 1.5 °C was observed at Uyole meteorological station on 26th June 2019 while the second lowest temperature value (2 °C) was observed at Mbeya meteorological station on 28th July 2019. This is the second lowest observed temperature in this decade since 2011, but lower temperatures up to -8 °C has been observed at this station in the past years.

In contrast, higher minimum temperatures exceeding 25 °C were observed in January through April and in November and December for some stations, especially along the coastal areas. Due to its proximity to the Indian Ocean, the Port meteorological station was leading by recording higher number of minimum temperature events exceeding 25 °C for all mentioned months, and the highest value of 29.5 °C was recorded on 28th December 2019.

5. Major drivers of observed weather and climate events in 2019

There is no single indicator that can usefully summarize and adequately characterize the observed weather and climate events. Indeed, some of the projected changes in precipitation in response to climate change affect the frequency and intensity of rainfall that are not well captured by observed weather and climate systems. Two main factors in particular that can help to understand the climate of 2019 are the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). The two-oceanic conditions are normally associated with above or below average rainfall condition over East Africa, because the ocean plays important roles in the climate. Other factors occurring at regional scale and even local scale also contributed to the observed climate, severe weather and extreme climatic events in different parts of the country.

The 2019 started with weak El Niño conditions and went through June when temperatures turned to ENSO neutral conditions from July and persisted through December 2019. However, the usual effects of El Niño to precipitation at global and even regional scale was absent throughout the event. The El Niño condition was expected to bring normal rainfall condition over the country especially to bimodal areas during MAM season. However, the presence of tropical cyclones in the Indian Ocean during March and April caused deficiency of rainfall over many areas during these months. In addition, other factors including the SSTs evolution over the Indian Ocean basin dominated the weather during May.

The IOD on the other hand started weakly positive and progressively became more positive from May to December. The strongest positive IOD event was observed in October 2019 (the IOD index = 2 °C) ranking the largest value since 1950. The strong positive IOD event continued in November 2019 (the IOD index = 1.9 °C), ranking the second largest value since 1950. The positive phase of dipole

mode weakened in December 2019 (the IOD index ≈ 0.9 °C). The positive phase of the IOD has been associated with higher rainfall than normal observed in many parts of the East Africa in the end of the year especially during October-December rainfall season. Thus, convection was enhanced over the western Indian Ocean and suppressed over the eastern Indian Ocean. In addition, anomalous easterlies (Lower and upper levels) prevailed over the equatorial Indian Ocean during October, November and December.

From September-November 2019, the Madden Julian oscillations (MJO) signal remained mostly stationary over the Africa continent and the adjacent Indian Ocean and was constructively interfering with the positive phase of the IOD which resulted to strong upper-level divergence over Africa and the eastern Indian Ocean. This condition favored much development of enhanced convective activities over most parts of the country.

The tropical cyclone season over the Indian Ocean that started from November 2018 to April 2019 modulated weather patterns over the country, causing dry and wet conditions especially during MAM season. For example, the cyclone, Idai which brought severe impacts over Mozambique and neighboring countries was associated with dry condition that was observed over some parts of the country especially northern coast and northeastern highlands during March. The Idai was responsible for the deflection of moist winds away from the country to the southern Africa. Other tropical cyclones that influenced rainfall activities and intensities in the country are Desmund, Eketsang and Kenneth. These cyclones were associated with induced westerly winds that drag moisture from Congo forest towards the country and even deflecting winds away from the country.

Another primary synoptic feature during May 2019 was an easterly wave over the Indian Ocean. This wave produced anomalously wet conditions across the coastline in the first dekad, including some late-season rainfall for the southern coast. In addition, the western Indian Ocean was relatively warmer that influenced formation and persistence of near equatorial trough and easterly wave which in turn brought heavy rainfall over the coast of Tanzania.

Apart from global and regional factors the existence of quasi-stationary systems near or within the country are responsible for the occurrence of individual severe events (heavy rainfall) that occurred during 2019, especially those in May, October, November and December. These systems, such as near equatorial troughs, easterly wave and the Inter Tropical Convergence Zone (ITCZ) were in most cases associated with well-developed thunderstorms.

6. Weather and climate related impacts

In 2019, several weather and climate related effects and associated impacts were reported ranging from heavy rainfall and floods, severe thunderstorm, strong winds and extreme higher temperatures. Several deaths related to floods and strong winds were reported, in addition, destruction of roads, bridges and farm fields were reported across the country. Generally, many parts of the northern coast received heavy rainfall during May and October through December which in turn caused a lot of destruction of infrastructure and loss of lives.

On 25th February 2019, severe thunderstorms associated with strong winds and hails was observed in Arusha Town. This rare event did not cause severe damage to community and their properties, except, the event disrupted social and economic activities like transport, shop services and communication for some hours before the condition was brought back to normal.

Figure 9: Students walking on hailstones in Arusha on 25/02/2019

Over 100 residents fled their flooded homes following heavy rainfall in Arusha district on 29th April 2019. Furthermore, loss of properties by flooded water, damage of properties and infrastructures was reported in various location including roads connecting Arusha and neighboring districts and regions.

Heavy rainfall events over northeastern parts of the country (Zanzibar, Dar es Salaam, Pemba and Pwani regions) that occurred between 5th and 12th May 2019 caused serious flooding in Dar es Salaam and Zanzibar. At least five people were reported dead in Dar es Salaam city and several houses were flooded, resulting in the displacement of over 1,000 households and the destruction of more than 1,500 residences and infrastructure. In Zanzibar, 3 people were injured; two by falling house and one by a falling coconut tree and over 2000 houses were flooded and destroyed. The overall impacts to this event include destruction of infrastructures, shut down of public transport especially in Dar es Salaam (Jangwani) because of flooded Msimbazi River and schools were closed in Dar es Salaam, Unguja and Pemba islands. Furthermore, some social and economic activities were delayed or completely closed for over six hours.

One person was reported dead and over 100 houses flooded by water due to heavy rain and by the flooded river Kanoni in Bukoba town on 26th May 2019.

Figure 10: Houses surrounded by flooded water in Bukoba town after heavy rainfall that lasted for eight hours between 25th and 26th May 2019.

About 29 people lost lives in Handeni district due to severe floods. Most victims were swept by flood waters and others hit by falling debris as houses fell under the impact of the downpour. The heavy rain caused economic activities like transport, communication and power services to a standstill. Up to 15 bridges in the roads managed by the Tanzania Rural and Urban Roads Agency (TARURA)

in Handeni district were damaged. The situation was equally felt by the highways operated by the Tanzania National Roads Agency (TANROADS) which include a portion of the Dar es Salaam-Arusha road, Korogwe-Handeni-Mkata section, Mandera Bridge between Korogwe and Segera.

On 26th October 2019, Dar es Salaam–Arusha highway was closed following floods from heavy rains in Tanga Region which also swept away the Mandera Bridge in Korogwe District. More than 2,000 bus passengers and motorists from various regions were stranded at Mandera in Korogwe District following the collapse of the bridge. Until 27th October 2019 about 40 houses were damaged and 70 surrounded by water in Handeni district and more than 300 families were left without shelter. Furthermore, hundreds of hectares of the agricultural fields were flooded, and crops destroyed.

The flood in Handeni was attributed to heavy rains which hit the neighbouring upstream districts of Kilindi, Kiteto and Simanjiro where many seasonal rivers cutting through Handeni originated. It left a trail of destruction of infrastructure and properties on a scale that has never been seen in recent years.

Figure 11: The Handeni/Korogwe road section was washed away following the ongoing heavy rains at Sindeni in Handeni District in Tanga Region on Saturday 26th October 2019 (Source https://www.thecitizen.co.tz/news/1840340-5328818-9slyoo/index.html)

The heavy rains on 16th and 17th December 2019 caused businesses and transport to a standstill in Dar es Salaam city, most businesses remained closed throughout the day as transport to the city center was suspended after most of the roads were submerged by flash floods.

7. Summary and conclusion

According to the meteorological observations, the year 2019 was marked the fourth warmest on record since 1970. Most parts of the country experienced anomalously warmer air temperatures in all months with higher positive anomalies observed for minimum temperatures compared to maximum temperatures. March and April were the warmest months of year especially over the northeastern highlands and northern coast, while May, October, November and December were slightly warm with respect to long term average. Large number of events with higher daily temperatures exceeding 35 °C were observed in February and March especially over northern coast and northeastern highlands. In addition, the highest daily maximum temperature of 38.4 °C was observed at Mlingano meteorological station in April 2019.

The annual records of rainfall across the country showed 2019 to be the fourth wettest year on record since 1970. On average, normal rainfall was mainly observed over many areas of the country during MAM rainfall season, and below normal rainfall was observed during NDJFMA rainfall season. On the other hand, wetter than normal rainfall was observed over most parts of the country during OND rainfall season. May, October, November and December were the wettest month in 2019 due to existence of persisting easterly wave in May and the presence of strong positive Indian Ocean Dipole from October through December. Most stations in northeastern highlands and northern coast received rainfall amount reaching up to eight times the normal rainfall. However, deficiency of rainfall was observed during March and April, consequently, April was found to be the second driest month on record since 1970.

Unusual rains were observed over many parts of the country especially during OND season. Most of observed extreme weather events especially heavy rainfall and floods, posed significant impacts to socio-economic activities across the country. The impacts include loss of lives and properties, damage to infrastructures and destruction of farm fields and settlements. In many parts the impacts left a trail of destruction of infrastructure and properties on a scale that has never been seen in recent years.

The impacts of severe weather could be much reduced if weather forecast and warnings issued by TMA were closely followed and effectively utilized by the public and government sectors in their day-to-day planning.

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, continuing through February or March, 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 are among the main factors affecting distribution and variability of rainfall in Tanzania and the entire East Africa. The migration of ITCZ lags the overhead sun by 3-4 weeks over the region. The ITCZ migrate to southern regions of Tanzania in October to December, reaching southern part of the country in January-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 basin, and the Islands of Zanzibar (Unguja and Pemba). These regions receive two distinct rainfall seasons; the long rain 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 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 that between 75 and 125 is normal rainfall. The percentage value less than 75 is below normal.

8.3 Temperature anomaly

Temperature anomaly is calculated by taking the difference between the observed values (monthly/seasonal/annual) 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 see how much rain has fallen in the region within the prescribed period such as previous week, month or year. The concept has 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 seasons and the presence of wet or dry spells in the season.

In this report, cumulative rainfall is an accumulation of observed dekadal rainfall from a selected reference point. Dekadal rainfall for 2019 was calculated by observing the following procedures:

- for unimodal areas, rainfall from September 2018 to August 2019 was accumulated, because rainfall season over these areas starts from November in the previous year to April in the following year. While,
- for bimodal areas accumulated rainfall from January to August 2019 was used to characterize rainfall for MAM season and rainfall from June to December 2019 was used to characterize rainfall for OND seasons
- dekadal baseline climatology from 1981-2010 was calculated by following same procedure as it is done in calculating dekadal values for individual season.

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 27 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 weights the points closer to the processing cell greater than those far away. The IDW algorithm effectively is a moving average interpolator that is usually applied to highly variable data.

8.6 Severe weather definition and indicators

Severe weather is defined as any aspect of the weather that poses risks to life, property or requires the intervention of authorities. Types of severe weather phenomena vary, depending on the latitude, altitude, topography, and atmospheric conditions. Strong winds, hail, excessive precipitation, and wildfires are forms and effects of severe weather. According to WMO, severe weather can be categorized in to two groups; general severe weather (e.g. windstorms and accompanied phenomena), and localized severe weather (e.g. downbursts and tornadoes). Extreme weather is described as unusual weather events that are at the extreme of historical distribution for a given area.

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 climatic 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.