State of the Climate in Africa

2022

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

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Cover photo: Sunset at Savannah Plains by Maciej Czekajewski.

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Key messages

In 2022, the African mean near-surface air temperature anomaly was 0.16 °C above the long-term average of 1991–2020 and 0.88 °C above the 1961–1990 average. The average rate of warming in Africa was +0.3 °C/decade during the 1991–2022 period, compared to +0.2 °C/decade between 1961 and 1990.

The average rainfall was generally below normal in most areas in Africa, though extreme rainfall events occurred in some regions, leading to disastrous flooding.

Many parts of the Sahel experienced significant flooding during the monsoon season, with Nigeria, Niger, Chad and the southern half of Sudan particularly affected.

The Horn of Africa faced its worst drought in 40 years, with Ethiopia, Kenya and Somalia particularly hard hit. The “triple-dip” La Niña, in combination with the negative phase of the Indian Ocean Dipole, was a substantial contributor to the ongoing dry conditions in the region.

The South Indian Ocean experienced an active tropical cyclone season despite an unusually late start. The Southern Africa region was hit by a series of tropical cyclones and tropical storms in the first months of 2022, leading to flooding and population displacement.

Five consecutive failures of rainfall seasons have wreaked havoc over large parts of East Africa and contributed to reduced agricultural productivity, food insecurity and high food prices. Flooding in West Africa and Southern Africa in 2022 swept away crop areas and led to food insecurity in those regions.

The rate of coastal sea-level rise in Africa is similar to the global mean value of 3.4 mm/year. It is, however, slightly higher than the global mean along the Red Sea (3.7 mm/year) and along the western Indian Ocean (3.6 mm/year).

Financing African countries’ Nationally Determined Contributions (NDCs) would require an estimated total of US$ 2.8 trillion between 2020 and 2030.

Investing in early warnings and early actions is a priority for saving lives, promoting economic development, valuing development gains and livelihoods, protecting the environment, and reducing the cost of disaster responses.

The level of loss and damage, and therefore the costs incurred, will depend on many factors, including the level of ambition of global mitigation actions and the level of investment in adaptation at the local level. In a 4 °C warming world, with strong regional adaptation, “residual damages” costs equivalent to 3% of Africa’s projected gross domestic product could be incurred annually by 2080.

Foreword

The WMO report on the State of the Climate in Africa 2022 is the fourth annual report on the climate in WMO Regional Association I (Africa). It provides an assessment of past and current climate trends across the African continent using the latest data and information on extreme weather and climate events and their socioeconomic impacts.

Over the past 60 years, Africa has recorded a warming trend that has been more rapid than the global average. In 2022, the continent experienced heatwaves, heavy rains, floods, tropical cyclones, and prolonged droughts. While the Greater Horn of Africa continued to suffer an exceptional multi-year drought which began in the second half of 2020, Southern Africa was battered by a series of cyclones over the first months of 2022, leading to flooding with significant casualties. These extreme events led to devastating impacts on communities, with serious economic implications.

Climate data are critical for the development of climate services that support informed decision-making. Nevertheless, significant gaps in basic weather and climate observations remain over Africa. WMO and its partners initiated the Systematic Observations Financing Facility (SOFF) to close these observational gaps, thereby strengthening the underpinning data required for effective climate services, including early warnings. SOFF is a key element in the push to achieve the ambitious goal of the Early Warnings for All initiative, which was announced by the United Nations Secretary-General last year and which aims to cover the whole world with early warning systems by 2027.

The State of the Climate in Africa 2022 is the result of a multi-agency effort, with contributions from African National Meteorological and Hydrological Services (NMHSs), WMO Regional Climate Centres (RCCs), specialized United Nations agencies, the African Development Bank, the Consultative Group on International Agricultural Research (CGIAR), and numerous experts and scientists.

I take this opportunity to congratulate the authors for the quality of this report and thank the WMO Members, our sister United Nations agencies, and the experts and scientists who have supported its production and review.

Prof. Petteri Taalas
Secretary-General, WMO

Preface

Africa, like other regions, has come to terms with the reality that climate change is already happening. Left untamed, the coming decades and years would easily be characterized by severe climate-induced pressure on the continent's economies, livelihoods and nature. Given Africa's high exposure, fragility and low adaptive capacity, the effects of climate change are expected to be felt more severely. People's health, peace, prosperity, infrastructure, and other economic activities across many sectors in Africa are exposed to significant risks associated to climate change.

Evidence shows that, while the world is exposed to climate threats, Africa is most affected region. Although agriculture is the mainstay of Africa's livelihoods and national economies – supporting 55% to 62% of the labor force in sub-Saharan Africa alone – the continent's agricultural productivity growth has declined by 34% since 1961 due to climate change. This decline is the highest compared to what other regions of the world have experienced.

In recent years, the continent has been hit by extreme weather and climate events, including tropical cyclones, that are negatively affecting efforts to achieve the Goals of Agenda 2063 as well as the Sustainable Development Goals. The 2015 drought in Southern Africa resulted in a 2% reduction in Gross Domestic Product in some countries, with hydropower generation lacking water to operate. The drought situation is the same or even worse in the Horn of Africa. Heavy rains and cyclones have also caused devastating floods resulting in the loss of billions of dollars, damage to property and other infrastructure, water-borne diseases, and fatalities. These extremes and their associated consequences are expected to persist or increase in the near future.

Africa views better monitoring and understanding of the climate as a springboard for climate-informed decision-making, development planning, and actual climate action. This underscores the critical space the State of Africa Climate Report occupies, especially as the continent has made attainment of "*environmental sustainability and climate resilient economies and communities*" a Goal of "The Africa We Want" by 2063. The Report also makes invaluable contribution to the formulation of the African Common Position on Climate Change that guides African Climate Change Negotiators as they engage with their counterparts on the global arena, in line with the vision of Agenda 2063.

Since the adoption of Agenda 2063 in 2013, Africa has made significant advances in the global climate agenda. This is evidenced by the very high ratification rate of the Paris Agreement of over 90%. In addition, the African Union has put in place continental strategies to consolidate and guide its climate action. Key among these are the Africa Climate Change and Resilient Development Strategy and the Integrated African Strategy on Meteorology (Weather and Climate Services).

H.E. Ambassador Josefa Leonel Correia SACKO
Commissioner for Agriculture, Rural Development,
Blue Economy and Sustainable Environment
African Union Commission

Global climate context

The global annual mean near-surface temperature in 2022 was 1.15 °C [1.02 °C to 1.28 °C] above the 1850–1900 pre-industrial average. The year 2022 was either the fifth or the sixth warmest year on record according to six data sets,[1] despite the cooling effect of La Niña. The years 2015 to 2022 were the eight warmest years on record in all data sets.[2]

Atmospheric concentrations of the three major greenhouse gases reached new record observed highs in 2021, the latest year for which consolidated global figures are available, with levels of carbon dioxide (CO_2) at 415.7 ± 0.2 parts per million (ppm), methane (CH_4) at 1 908 ± 2 parts per billion (ppb) and nitrous oxide (N_2O) at 334.5 ± 0.1 ppb – respectively 149%, 262% and 124% of pre-industrial (before 1750) levels (Figure 1). Real-time data from specific locations, including Mauna Loa[3] (Hawaii, United States of America) and Kennaook/Cape Grim[4] (Tasmania, Australia) indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2022.

Over the past two decades, the ocean warming rate has increased, and the ocean heat content in 2022 was the highest on record. Ocean warming and accelerated loss of ice mass from the ice sheets contributed to the rise of the global mean sea level by 4.62 mm per year between 2013 and 2022, reaching a new record high in 2022. Between 1960 and 2021, the ocean absorbed about 25% of annual anthropogenic emissions of CO_2 into the atmosphere,[5] and CO_2 reacts with seawater and lowers its pH. The limited number of long-term observations in the open ocean have shown a decline in pH, with a reduction of the average global surface ocean pH of 0.017–0.027 pH units per decade since the late 1980s. This process, known as ocean acidification, affects many organisms and ecosystem services[6] and threatens food security by endangering fisheries and aquaculture.

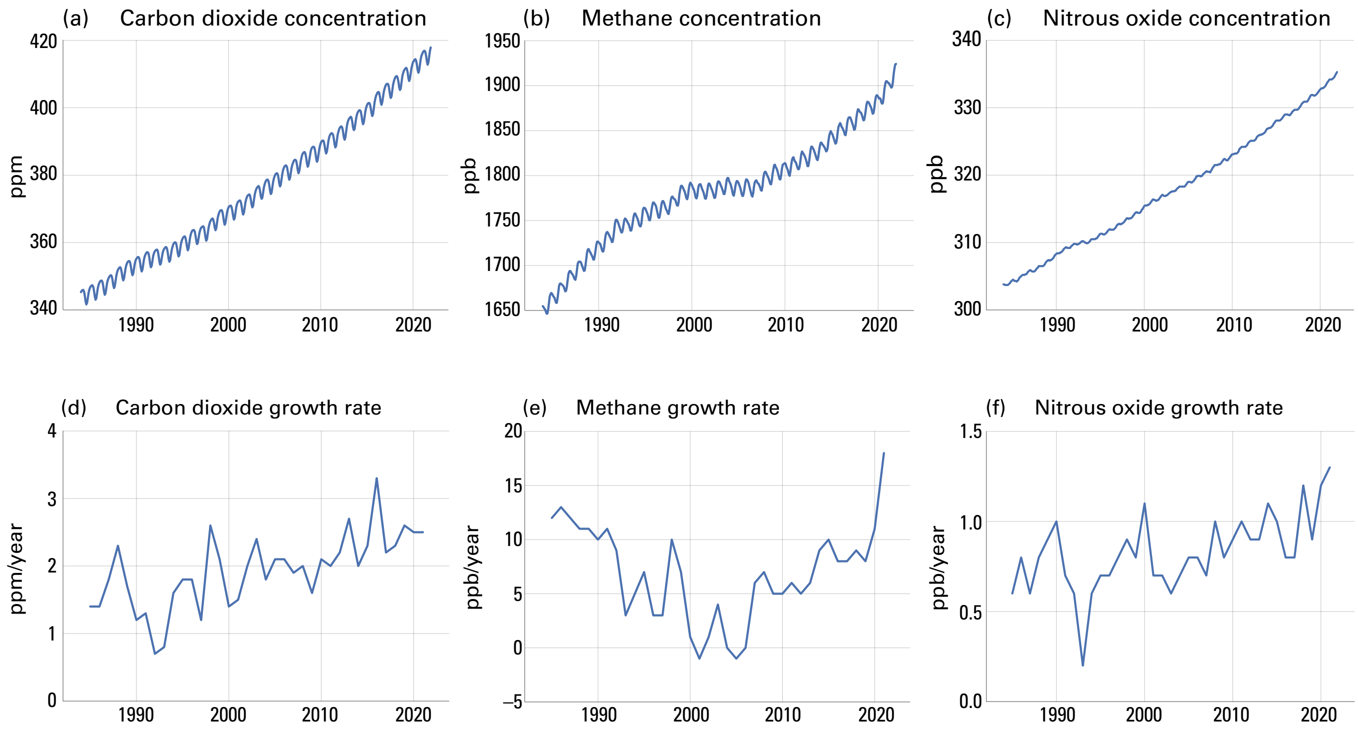


Figure 1. Top row: Monthly globally averaged mole fraction (measure of atmospheric concentration), from 1984 to 2021, of (a) CO_2 in parts per million, (b) CH_4 in parts per billion and (c) N_2O in parts per billion. Bottom row: Growth rates representing increases in successive annual means of mole fractions for (d) CO_2 in parts per million per year, (e) CH_4 in parts per billion per year and (f) N_2O in parts per billion per year.

Regional climate

The following sections analyse key indicators of the state of the climate in Africa during 2022. One such indicator that is particularly important, temperature, is described in terms of anomalies, or departures from a reference period. For global mean temperature, the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC)[7] uses the reference period 1850–1900 for calculating anomalies in relation to pre-industrial levels. However, this pre-industrial reference period cannot be used in all regions as a baseline for calculating regional anomalies due to insufficient data for calculating region-specific averages prior to 1900. Instead, the 1991–2020 climatological standard normal reference period is used for computing anomalies in temperature and other indicators. Regional temperature anomalies can also be expressed relative to the reference period 1961–1990. This is a fixed reference period recommended by WMO for assessing long-term temperature change. In the present report, exceptions to the use of these baseline periods for the calculation of anomalies, where they occur, are explicitly noted.

TEMPERATURE

LONG-TERM TEMPERATURE ANOMALIES IN AFRICA

The African mean near-surface air temperature in 2022 was 0.16 °C [0.06 °C–0.28 °C] above the long-term average of the 1991–2020 climatological standard normal (Figure 2) and 0.88 °C [0.74 °C–1.07 °C] above the 1961–1990 average.

Depending on the data set used, 2022 was between the ninth and the sixteenth warmest year for Africa in the 123-year record.

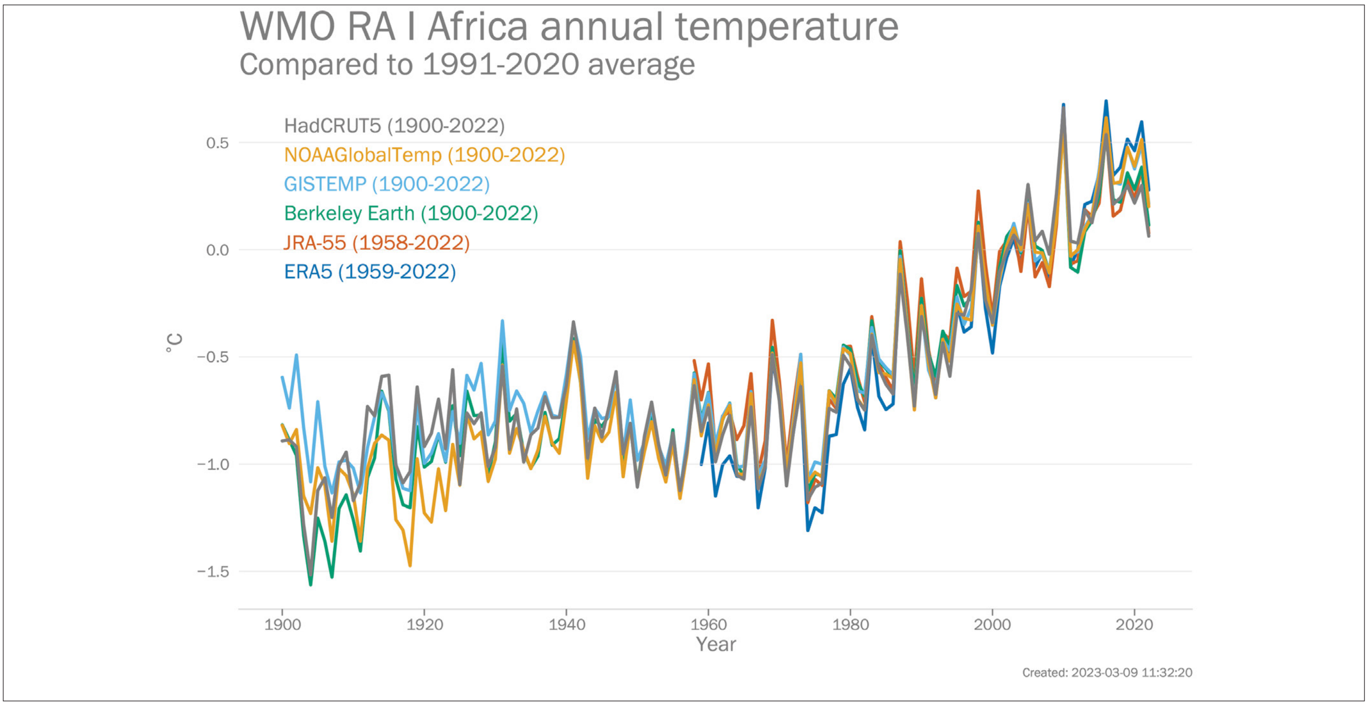


Figure 2. Temperature difference in °C with respect to the 1991–2020 climatological period for Africa (WMO Regional Association I) from 1900 to 2022, based on six data sets, including observational data sets (HadCRUT5 [black], NOAAGlobalTemp [yellow], GISTEMP [light blue], and Berkeley Earth [green]) and reanalyses (JRA-55 [orange] and ERA5 [dark blue])

TEMPERATURE IN THE AFRICAN SUB-REGIONS

Temperature trends are also analysed by sub-region, considering overall geographic and climatic patterns, for North Africa, West Africa, Central Africa, East Africa, Southern Africa, and the Indian Ocean island countries (Figure 3).

Temperature trends

The African continent continued to observe a warming trend, with an average rate of change of around +0.3 °C/decade between 1991 and 2022, compared to +0.2 °C/decade between 1961 and 1990. The recent trend is slightly faster than the global average warming trend of around +0.2 °C/decade for the 1991–2022 period.

All six African sub-regions have experienced an increase in the temperature trend over the past 60 years compared to the period before 1960. The warming has been most rapid in North Africa, around +0.4 °C/decade between 1991 and 2022, compared to +0.2 °C/decade between 1961 and 1990. Southern Africa experienced the slowest warming trend compared to the other sub-regions, around +0.2 °C/decade between 1991 and 2022 (Figure 4).

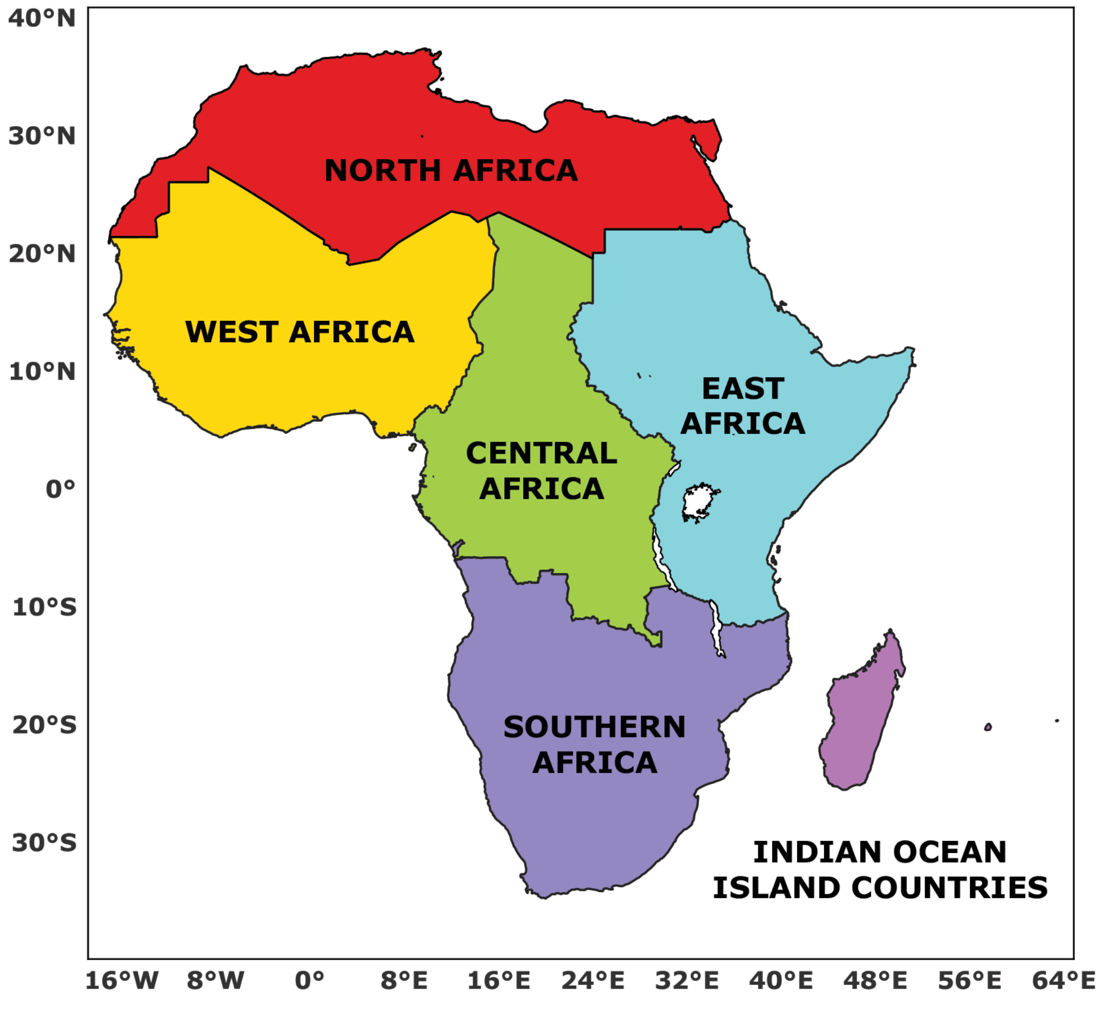


Figure 3. The six African sub-regions referred to in this report: North Africa (red), West Africa (yellow), Central Africa (green), East Africa (light blue), Southern Africa (dark blue), and the Indian Ocean island countries (purple)

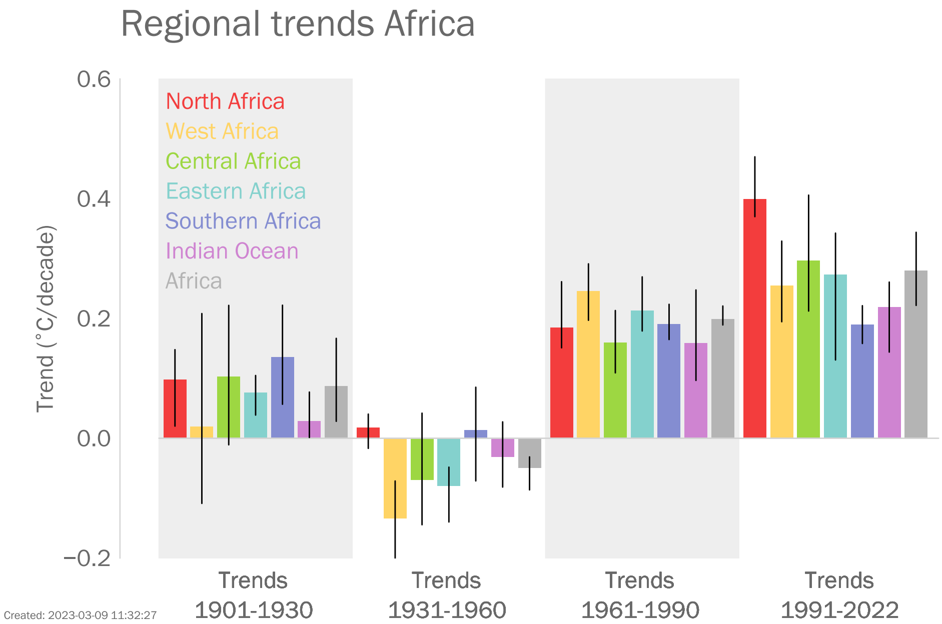


Figure 4. Trends in the area average temperature in °C/decade for the six African sub-regions: North Africa (red), West Africa (yellow), Central Africa (green), East Africa (light blue), Southern Africa (dark blue), the Indian Ocean island countries (purple), and the whole of Africa (grey) over four 30-year sub-periods: 1901–1930, 1931–1960, 1961–1990, and 1991–2022. The trends were calculated using different data sets, including observational data sets (HadCRUT5, NOAAGlobalTemp, GISTEMP, and Berkeley Earth) and reanalyses (JRA-55 and ERA5). The black vertical lines indicate the range of the six estimates.

Temperature anomalies

In 2022, most of Africa recorded temperatures above the 1991–2020 average. The exceptions were the desert areas of North and Southern Africa (Figure 5, left). However, these are also data-sparse regions in the continent, where uncertainties are relatively higher (Figure 5, right). The highest temperature anomalies

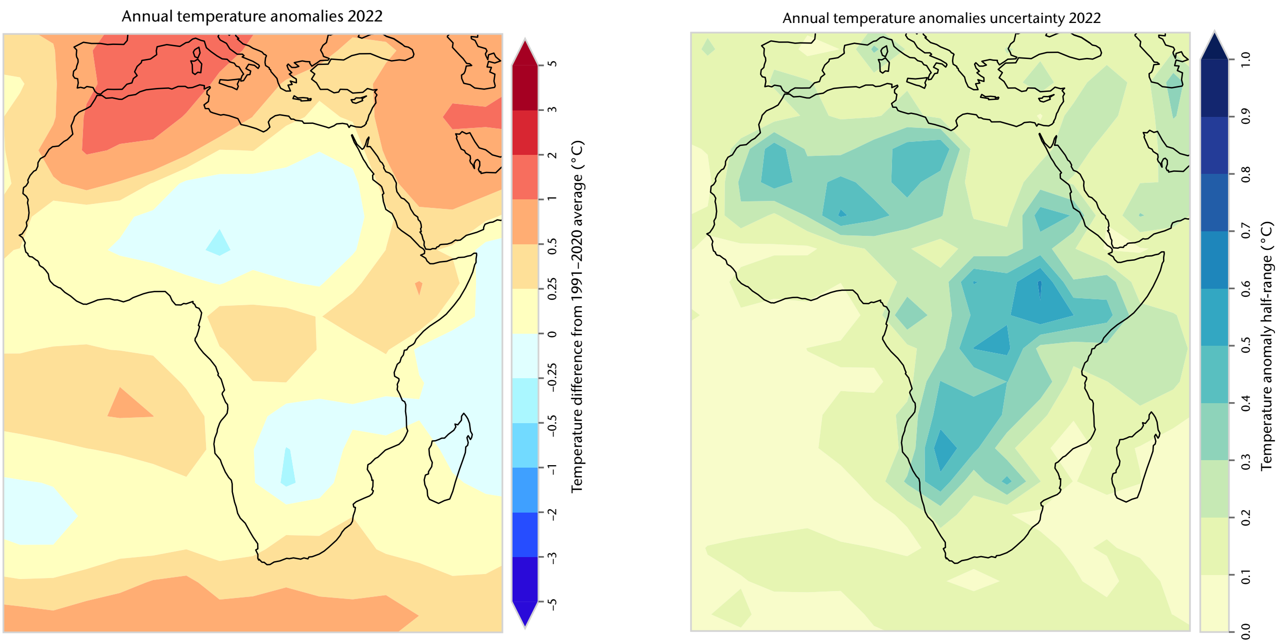


Figure 5. Near-surface air temperature anomalies for 2022 relative to the 1991–2020 average (left) and estimated uncertainty in temperature anomalies for 2022 (right). Anomalies are calculated as the median of six data sets, including observational data sets (HadCRUT5, NOAAGlobalTemp, GISTEMP, and Berkeley Earth) and reanalyses (JRA-55 and ERA5). Each data set has been averaged onto a consistent 5° latitude by 5° longitude grid then plotted using a standard contouring algorithm that interpolates between the grid averages.

were recorded across north-western Africa, especially in Morocco and northern Algeria. North Africa recorded the highest 2022 temperature anomaly compared to the other African sub-regions: 0.50 °C above the 1991–2020 average and 1.40 °C above the 1961–1990 average (Table 1).

The regional averages mask some notable averages in individual countries, such as South Africa, which had a mean temperature in 2022 that was about 0.4 °C above the average of the 1991–2020 reference period, making 2022 approximately the fourth hottest year on record for that country since 1951. In contrast, Cameroon experienced one of its coldest years in the past twenty years in 2022, with a temperature anomaly of -0.24 °C compared to the 1991–2020 average.

Table 1. Near-surface air temperature anomalies in °C for 2022 relative to the 1991–2020 and 1961–1990 reference periods. Anomalies for the whole African continent and for each of the African sub-regions have been calculated using six different data sets, including observational data sets (HadCRUT5, NOAAGlobalTemp, GISTEMP, and Berkeley Earth) and reanalyses (JRA-55 and ERA5). The range of anomalies among these data sets is given in the brackets.

	1991–2020	1961–1990
North Africa	**0.50 °C** [0.41 °C–0.65 °C]	**1.40 °C** [1.24 °C–1.64 °C]
West Africa	**0.03 °C** [–0.18 °C–0.14 °C]	**0.71 °C** [0.39 °C–0.87 °C]
Central Africa	**0.13 °C** [–0.04 °C–0.37 °C]	**0.80 °C** [0.60 °C–1.11 °C]
East Africa	**0.14 °C** [–0.02 °C–0.28 °C]	**0.90 °C** [0.69 °C–1.12 °C]
Southern Africa	**0.01 °C** [–0.17 °C–0.12 °C]	**0.61 °C** [0.42 °C–0.75 °C]
Indian Ocean island countries	**0.03 °C** [–0.04 °C–0.10 °C]	**0.60 °C** [0.49 °C–0.70 °C]
Africa	**0.16 °C** [0.06 °C–0.28 °C]	**0.88 °C** [0.74 °C–1.07 °C]

PRECIPITATION

Precipitation anomalies were above the 1991–2020 average in north-eastern Africa, large parts of West Africa, the eastern Sahel region, Sudan, and parts of South Africa. Regions with a marked rainfall deficit included the western part of North Africa, the Horn of Africa, portions of Southern Africa, and Madagascar (Figure 6, right).

Below-normal annual rainfall prevailed over much of North and north-western Africa, especially Morocco, Algeria, Tunisia, and western Libya (Figure 6, left), where the precipitation deficits exceeded 150 mm (the lowest 10% of the observed totals during the 1991–2020 climatology period). Conversely, the area around the Gulf of Sidra and northern Egypt experienced above-average precipitation, with excesses of over 50 mm (the highest 10% of the observed totals during the climatology period).

West Africa experienced a delayed onset of its monsoon rainy season for the second consecutive year, while later in the West African monsoon season, rainfall totals were higher than normal. Southern Mauritania, western Senegal, central Mali, western Burkina Faso, south-eastern Niger, southern Ghana, southern Togo, eastern Benin and parts of Nigeria received enhanced rainfall (the highest 10% of the observed totals during the climatology period). Conversely, northern Mali, south-eastern Guinea, parts of Côte d'Ivoire and portions of Nigeria observed suppressed precipitation (the lowest 10% of the observed totals during the climatology period) (Figure 6, right).

In Central Africa, large positive precipitation anomalies (more than 200 mm above average) were recorded in central and southern Chad, northern Cameroon, the Central African Republic, and parts of Congo and the Democratic Republic of the Congo. Negative precipitation anomalies of over 350 mm were observed across south-western Cameroon, Equatorial Guinea, Gabon and portions of the southern part of the Democratic Republic of the Congo (Figure 6, left).

In East Africa, much of Sudan and pocket areas in southern Tanzania recorded wetter-than-normal conditions, with rainfall in some areas above the highest 10% of the observed totals during the climatology period. Conversely, Ethiopia, northern Uganda, Somalia and Kenya recorded drier-than-normal conditions, with rainfall in some areas below the lowest 10% of the observed totals during the climatology period (Figure 6, right). Most of Ethiopia, Kenya and Somalia have experienced five consecutive below-average rainfall seasons, leading to an exceptional multi-seasonal drought (see Major drivers of climate variability affecting the region).

In Southern Africa, positive rainfall anomalies of over 200 mm were found across central and western Angola (Figure 6, left). The central part of South Africa and portions of Mozambique observed enhanced rainfall, with some areas in the highest 10% of the observed totals during the climatology period. Conversely, remarkable rainfall deficits of over 200 mm were observed across eastern Angola, Zambia, Zimbabwe and pocket areas in the southern part of South Africa, with some areas in the lowest 10% of the observed totals during the climatology period (Figure 6, right).

In the West Indian Ocean, suppressed rainfall resulted in negative anomalies of over 200 mm in eastern Madagascar and Seychelles. On the other hand, a rainfall surplus was recorded in Comoros and some local areas in Madagascar (Figure 6, left). Intense rainfall as a result of the tropical weather systems at the beginning of the year allowed some easing of the long-term drought that affected the southern part of Madagascar.

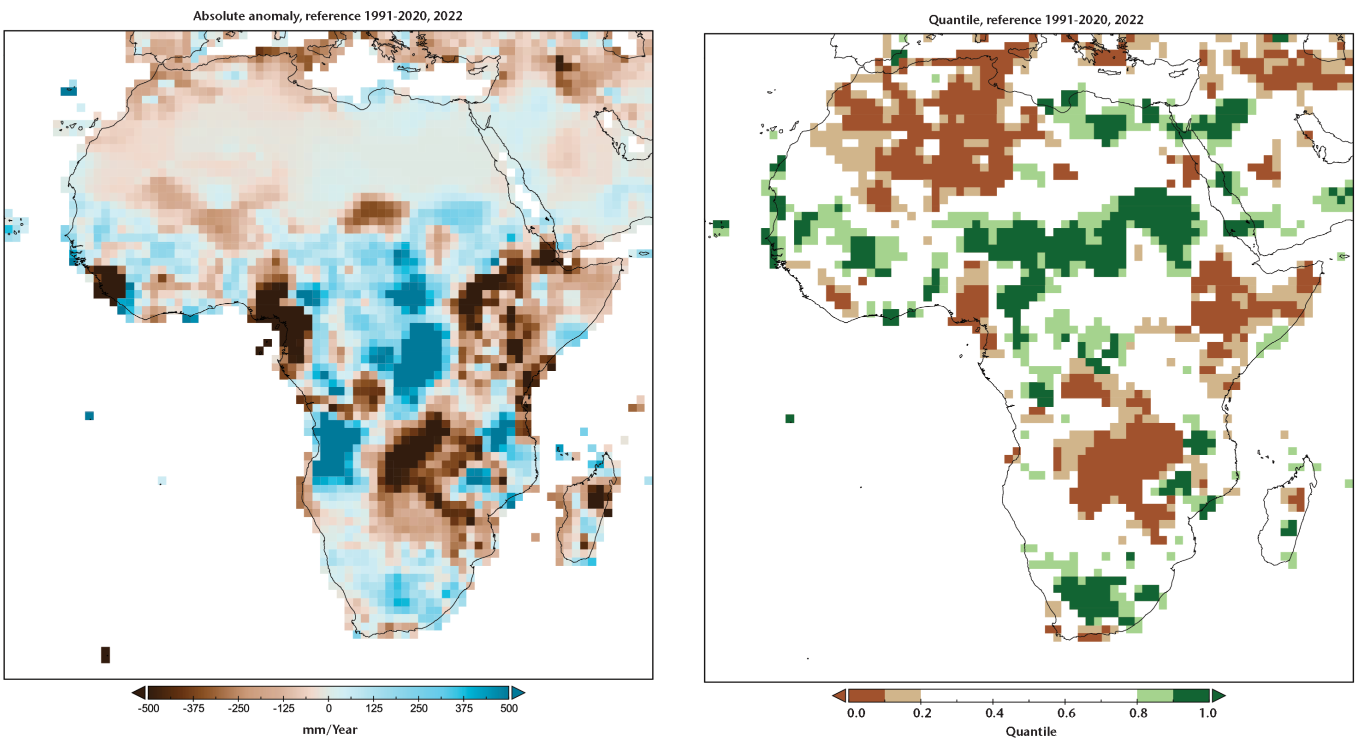


Figure 6. Precipitation anomalies in mm for 2022 (left): Blue areas indicate above-average precipitation, and brown areas indicate below-average precipitation. The reference period is 1991–2020. Precipitation quantiles for 2022 (right): Green areas indicate unusually high precipitation totals (light green indicates the highest 20%, and dark green indicates the highest 10% of the observed totals). Brown areas indicate abnormally low precipitation totals (light brown indicates the lowest 20%, and dark brown indicates the lowest 10% of the observed totals). The reference period is 1991–2020. *Source:* Global Precipitation Climatology Centre (GPCC), Deutscher Wetterdienst (DWD), Germany

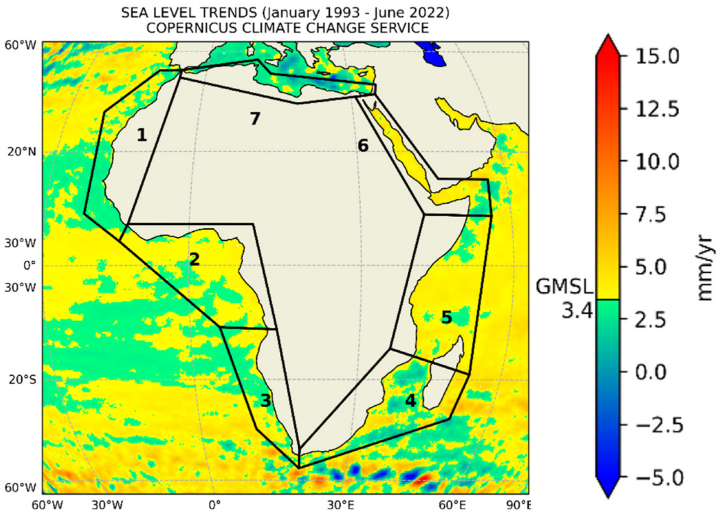
SEA LEVEL

Since the early 1990s, sea level has been routinely measured globally and regionally by high-precision altimeter satellites. Over the past three decades, the global mean sea level has risen at an average rate of 3.4 mm ± 0.3 mm/year and has accelerated in response to ocean warming and land ice melt.

Sea-level rise was measured in the seven African coastal regions[8] from January 1993 to June 2022 (Figure 7). The rate of sea-level rise in these coastal regions does not differ significantly from the global mean over the same period.

The highest rate of sea-level rise around Africa, 3.7 mm/year, has been observed along the coastal areas of the Red Sea (Box 6), followed by the coastal areas of the western Indian Ocean (Box 5), where the rate exceeds 3.6 mm/year. The rate of sea-level rise is lower than the global mean along the coastal areas of the southern Mediterranean Sea (Box 7), where the rate is about 2.4 mm/year.

The coastal areas of the western Indian Ocean and the Red Sea (Boxes 4, 5 and 6) are subject to significant interannual variability. For instance, significant variations occur during El Niño–Southern Oscillation (ENSO) events.



Box number	Ocean	Rate of sea level rise (mm/year)
1	North-east Atlantic	3.2 ± 0.1
2	Tropical Atlantic	3.4 ± 0.1
3	South-east Atlantic	3.3 ± 0.1
4	South-west Indian Ocean	3.2 ± 0.1
5	Western Indian Ocean	3.6 ± 0.2
6	Red Sea	3.7 ± 0.2
7	Southern Mediterranean Sea	2.4 ± 0.2
-	Global	3.4 ± 0.3

Figure 7. Left: Sea-level trends in the seven coastal regions of Africa covering the period from January 1993 to June 2022: Northeast Atlantic (1), Tropical Atlantic (2), Southeast Atlantic (3), South-west Indian Ocean (4), Western Indian Ocean (5), Red Sea (6), and Southern Mediterranean Sea (7). Right: Table indicating the sea-level rise in mm/year for the seven coastal regions of Africa and the global ocean.
Source: Copernicus Climate Change Service (C3S). See C3S Climate Data Store for more information on the data sets and methodology used to measure sea-level rise.

Major drivers of climate variability affecting the region

The phases of ENSO and the sea-surface temperature (SST) anomaly patterns in the tropical Atlantic Ocean and Indian Ocean usually constitute the main drivers of rainfall variability in Africa.

La Niña conditions emerged in mid-2020 and continued for a third consecutive year into 2022. It is the third time that such an event, referred to as a “triple-dip” La Niña, has occurred in the last 50 years. Despite a brief break in the boreal summer 2021, La Niña evolved to moderate strength through the end of 2022 (Figure 8a). The Tropical Northern Atlantic (TNA) index was positive for most of 2022, reflecting positive SSTs in the eastern tropical North Atlantic Ocean, except during the months of March and July (Figure 8b). The Tropical Southern Atlantic (TSA) index was positive for most of the year (Figure 8c). The South-western Indian Ocean (SWIO) index fluctuated and was close to neutral during the first four months of 2022. It became strongly positive in May and July and from October onwards (Figure 8d). The Indian Ocean Dipole (IOD) was negative during most of 2022, except from March to April and in December. 2022 was the second consecutive year in which a negative IOD phase developed during the austral winter (Figure 8e).

Positive TNA and TSA indices were favourable for above-average summer rainfall over West Africa. The positive SWIO index favoured well-above-average austral summer precipitation in many parts of South Africa and southern Madagascar. Drier-than-normal conditions, with five below-average rainy seasons in a row in East Africa, were largely driven by the combined effect of La Niña and a negative IOD.

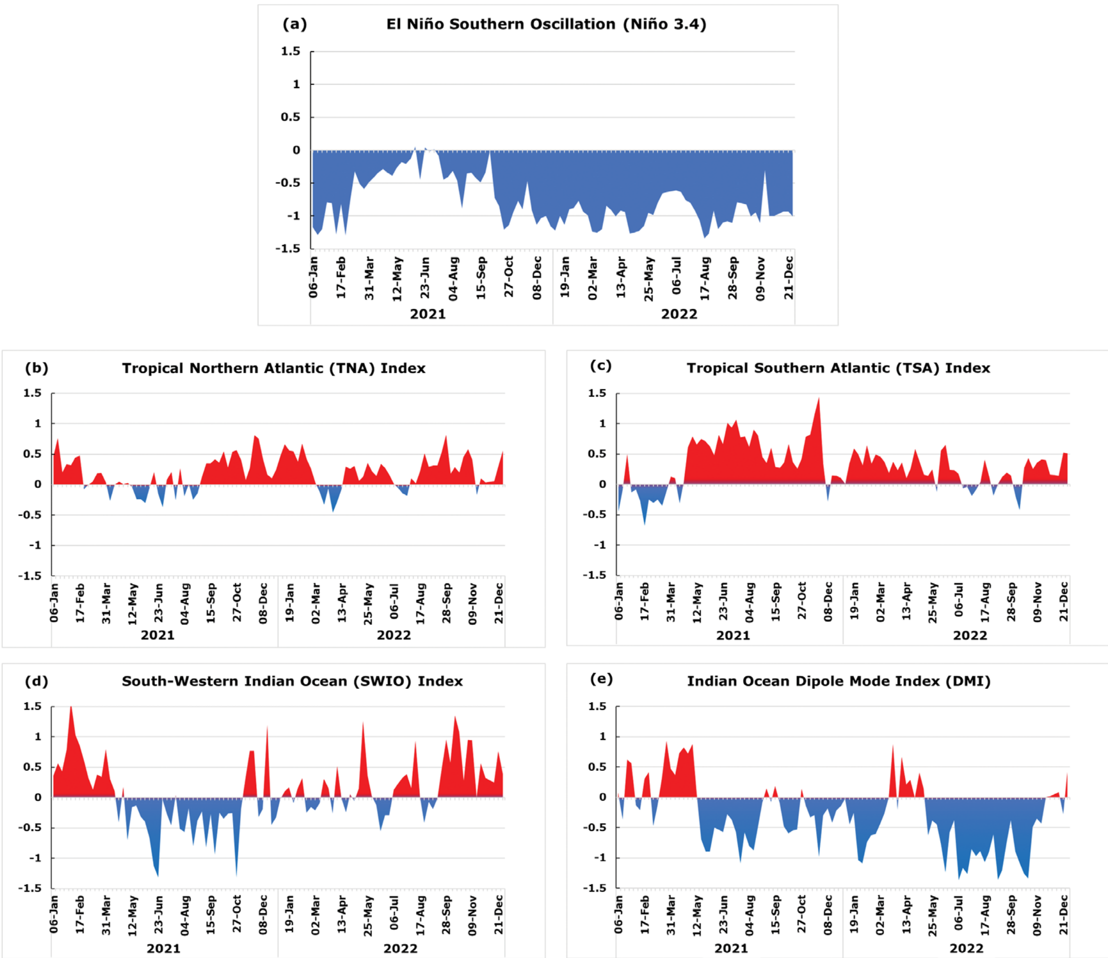


Figure 8. Time series of climate indices for 2021 and 2022 relative to 1982–2005: (a) Niño 3.4 index [5°S–5°N; 170°W–120°W]; (b) Tropical Northern Atlantic index [5.5°N–23.5°N; 15°W–57.5°W]; (c) Tropical Southern Atlantic index [0–20°S; 10°E–30°W]; (d) South-western Indian Ocean index [32°S–25°S; 31°E–45°E]; (e) Indian Ocean Dipole Mode index (DMI) – the difference between the SST anomalies over the tropical western Indian Ocean [10°S–10°N; 50°E–70°E] and the tropical eastern Indian Ocean [10°S–0; 90°E–110°E]

Extreme events

In 2022, many extreme events were reported across Africa. The continent was affected by heavy rainfall, floods, tropical cyclones, droughts, heatwaves, wildfires, and sandstorms. The extreme events in this section are described according to the sub-regions they affected: North Africa, West and Central Africa, East Africa, and Southern Africa and the South-west Indian Ocean. The rationale behind dividing the continent in this manner for extreme events was twofold: first, it divides the continent in terms of economic groupings, and second, it groups sub-regions together in terms of their apparent climate variability coherence, especially with regard to the influence of the major climate drivers described in the previous section.

NORTH AFRICA

Consistent with the high temperature anomalies in Figure 5, western North Africa recorded the highest increase in the number of heatwave days.

For the second consecutive year, wildfires were associated with major loss of life in Algeria, with 44 deaths reported in August.[9]

Morocco was affected by four heatwaves, each lasting between five and eight days between May and July. The country recorded its driest agricultural year (from September 2021 to August 2022) in the last 40 years. Dry conditions associated with high temperatures were favourable for forest fires in the northern region of Morocco (Larache, Tetouan, Ouezzane and Taza), ravaging an area of 10 000 hectares.

In Tunisia, the summer of 2022 was the second hottest since 1950 (after the summer of 2021), with an average temperature anomaly of +2.0 °C compared to 1991–2020. The month of June was the hottest month since 1950 and was marked by heatwaves, with some locations setting all-time record highs. The cities of Beja and Medenine each recorded a maximum temperature of 47.8 °C on 27 June, corresponding to temperature anomalies of +13.2 °C and +12.5 °C, respectively. Tunisia was also affected by more than 200 fires that ravaged 5 900 hectares of forests and maquis in different governates. These forest fires, some of which spread to densely populated areas, caused significant damage.

On 25 January, the northern regions of Libya were affected by a cold air mass accompanied by heavy rains and snowfall of 10–20 cm. The snow blanketed the Al-Jabal Al-Akhdar regions of Sidi AlHamri, Al-Faydiya, Shahat, Al-Bayda, Qandula and Belqes; some roads were closed due to the accumulation of snow (Figure 9, left). A significant decrease in visibility to less than 1 km due to a sandstorm was observed in Tripoli from 19 to 20 March 2022, with strong winds ranging between 55 and 85 km/hr (Figure 9, right).

Figure 9. Snow accumulation on 25 January 2022 over buildings and roads (left). Sandstorm in Tripoli on 20 March 2022 (right)
Source: Archives of the Libyan National Meteorological Centre

WEST AFRICA AND CENTRAL AFRICA

Many parts of the Sahel, particularly its eastern half, saw significant flooding during the monsoon season, especially towards the end of the season. Nigeria, Niger, Chad and the southern half of Sudan were particularly affected. The flooding was exacerbated in Nigeria when heavy local rains fell in October as floodwaters arrived from upstream. The flooding in Nigeria was the worst since the 2012 floods and resulted in the deaths of more than 600 people.[10]

In 2022, Chad recorded its heaviest rainfall in the past 30 years, resulting in rivers overflowing and damage to houses and agricultural land in the capital, N'Djamena, and the surrounding provinces.[11]

Starting in August, the Far North Region of Cameroon experienced flooding as a result of heavy rainfall, river overflows and dike breaches (Figure 10). As of September 2022, over 37 000 people were affected by floods, more than 95 were injured, more than 9 000 houses were destroyed, and a dozen health facilities and 88 schools were flooded, depriving over 26 600 children of education.[12]

Figure 10. Floods in the Far North Region of Cameroon in October 2022
Source: United Nations Office for the Coordination of Humanitarian Affairs (OCHA) and Office of the United Nations High Commissioner for Refugees (UNHCR)/Moise Amedje Peladai

EAST AFRICA

In 2022, drought intensified in the Greater Horn of Africa, primarily in southern Ethiopia, Kenya and Somalia. Rainfall was well below average across the region in the March–May and October–December rainy seasons,[13] the fourth and fifth consecutive poor wet seasons, the longest such sequence in 40 years,[14] with major impacts on agriculture and food security.

Sudan was severely impacted by heavy rains and flash floods during the June–September rainy period. More than 340 000 people were affected, more than 24 800 homes were destroyed, and more than 48 200 homes were damaged in 16 of Sudan's 18 states.[15]

South Sudan was marked by its fourth consecutive year of abnormally high flooding. Over 1 million people were affected by the floods in 36 counties.[16]

SOUTHERN AFRICA AND THE SOUTH-WEST INDIAN OCEAN

Despite the late start of the tropical cyclone season, the South Indian Ocean had one of the season's highest-impact cyclonic systems. In the first months of 2022, Southern Africa was battered by a series of tropical cyclones and tropical storms that affected more than 2.8 million people and resulted in more than 800 people losing their lives in the region.[17] In January, Tropical Storm *Ana* affected more than 1.3 million people in Madagascar, Mozambique, Malawi and Zimbabwe. In February, Tropical Cyclones *Batsirai* and *Emnati* affected more than 423 800 people in Madagascar, and Tropical Storm *Dumako* affected more than 33 700 people in Madagascar and Mozambique. In March, Tropical Cyclone *Gombe* affected more than 900 000 people in Mozambique and Malawi. In April, Tropical Storm *Jasmine* affected nearly 5 000 people in southern Madagascar (Table 2).

Table 2. Tropical storms/cyclones that affected Southern Africa during the 2022 cyclone season

Month	Tropical storm/cyclone	Country affected	Number of people affected and deaths
January	Tropical Storm *Ana*	Madagascar, Mozambique, Malawi and Zimbabwe	171 deaths and 1.3 million affected
February	Tropical Cyclones *Batsirai* and *Emnati*	Madagascar	136 deaths and 423 800 affected
February	Tropical Storm *Dumako*	Madagascar and Mozambique	14 deaths and 33 700 affected
March	Tropical Cyclone *Gombe*	Mozambique and Malawi	103 deaths and 900 000 affected
April	Tropical Storm *Jasmine*	Madagascar	5 000 affected

Source: OCHA

Subtropical Depression *Issa*, in combination with a cut-off low-pressure system, caused extreme flooding in April in the KwaZulu-Natal province of eastern South Africa, with rainfall totals of up to 311 mm in 24 hours on 11–12 April. Over 400 deaths were attributed to the flooding[18] and 40 000 people were displaced.

Climate-related risks and socioeconomic impacts

HIGH-IMPACT HYDROMETEOROLOGICAL DISASTERS

The increasing occurrence and intensity of extreme weather and climate events is reducing agricultural productivity, driving agricultural expansion, and threatening biodiversity and ecosystems. Climate change and the diminishing natural resource base could fuel conflicts for scarce productive land, water, and pastures, where farmer-herder violence has increased over the past 10 years due to growing land pressure, with geographic concentrations in many sub-Saharan countries.[19]

Based on data provided in the Emergency Event Database (EM-DAT),[20] in Africa, 80 meteorological, hydrological and climate-related hazards were reported in 2022; of these 56% were flood-related events. These natural hazard events resulted in around 5 000 fatalities, of which 48% were associated with drought and 43% were associated with flooding. Overall, more than 110 million people were directly affected by these disaster events, causing a total of over US$ 8.5 billion in economic damages. While drought was the leading cause of death and people affected, flooding was the leading cause of economic damages (Figure 11). The true figures related to the impacts of extreme events are presumed to be greater because of underreporting.

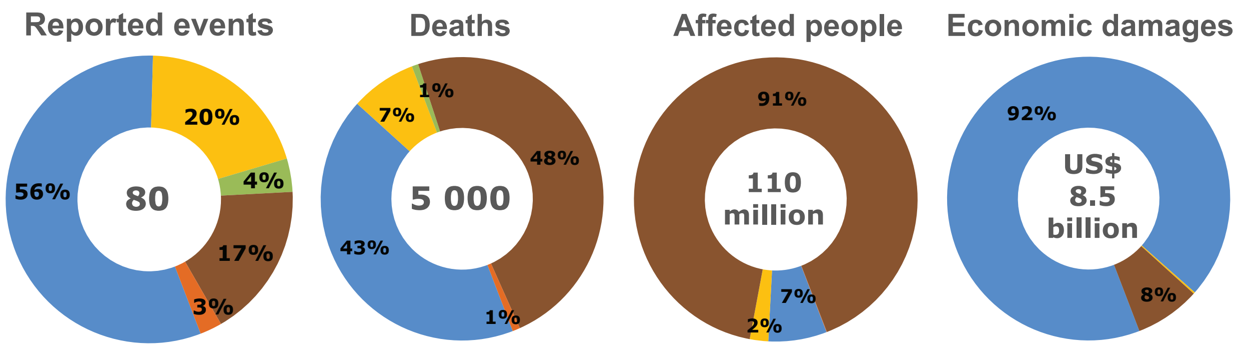


Figure 11. Weather-, climate- and water-related disasters in Africa in 2022. Note: The economic damages of some disaster occurrences are not presented in the figure due to data unavailability.
Source: Data as of June 2023 from EM-DAT

AGRICULTURE AND FOOD SECURITY

The aggregate cereal production in North Africa in 2022 was estimated to be 33 million tons, about 10% below the previous five-year average (2017–2021) and 14% down from 2021. Conversely, in West Africa, the aggregate cereal production in 2022 was estimated to be 76.4 million tons, which is above average and around 7% higher than the estimated output in 2021, due to good rains during the crop season.[21]

The pastureland and cropland areas in East Africa were negatively impacted by continuous drought-stressed conditions. In the northern and eastern pastoral and marginal agricultural areas of Kenya, the number of acute food insecure people was estimated to be 4.4 million between October and December 2022, almost 90% higher on a yearly basis. By September 2022, the prices of coarse grains were exceptionally high in Somalia, South Sudan, and Sudan. In Somalia, the prices of maize and sorghum were up to 45% and 75% higher, respectively, than the prices in the previous year due to low production after four consecutive below-average harvests.[22]

The 2022 total cereal output in Southern Africa was estimated to be 38.5 million tons, around 5% higher than the previous five-year average (2017–2021), but about 10% lower than the record high in 2021.[23] Above-average cereal outturns were estimated in Madagascar, Malawi and South Africa, thanks to conducive weather conditions in the main producing areas. Conversely, substantial production downturns were registered in Zambia and Zimbabwe, with below-average harvests, due to an unfavourable rainfall distribution. Elsewhere in the subregion, harvests were close to the five-year averages.[24]

The wide-ranging macroeconomic consequences of food insecurity brought on by climate change usually begin with shortages of food or agricultural inputs, which raise food prices.[25] Consequently, the projected annual food imports by African countries are expected to increase by about a factor of three, from US$ 35 billion to US$ 110 billion by 2025.[26]

POPULATION DISPLACEMENT

The Horn of Africa faced its worst drought in 40 years in 2022, with Ethiopia, Kenya and Somalia particularly hard hit.[27] In Somalia, almost 1.2 million people[28] became internally displaced by the catastrophic impacts of drought on pastoral and farming livelihoods and hunger during the year.[29] Over 60 000 people fleeing the combined impacts of drought and conflict crossed into Ethiopia and Kenya during the same period.[30] Concurrently, Somalia was hosting almost 35 000 refugees and asylum seekers in drought-affected areas, including over 2 600 new arrivals from Ethiopia.[31] A further 512 000 internal displacements associated with drought were recorded in Ethiopia.[32] As a result of funding shortfalls and the global increase in food prices, more than 3.5 million refugees in the region (75% of the total refugee population) were affected by major cuts in food assistance.[33]

Some high-impact weather events in 2022 happened consecutively, leaving little time for recovery between shocks and compounding repeated and protracted displacements. The Southern Africa region was hit by a series of cyclones in the first months of 2022, leading to a surge in the need for protection and shelter. Hundreds of thousands of people were affected, including pre-existing refugees and people internally displaced. More than 190 000 people in Malawi who lost or fled their homes during Tropical Storm *Ana* in late January were still displaced in April.[34] In Mozambique, two months after *Ana*, impacts included the destruction of the homes and shelters of over 20 000 pre-existing internally displaced households.[35] Tropical Cyclone *Gombe* compounded the impacts of *Ana*, affecting over 736 000 people, damaging or destroying some 142 000 homes in many of the same areas, and forcing over 23 000 to take refuge in official shelters.[36] An assessment of existing shelter sites for internally displaced people in Nampula found that around 40% of the temporary shelters had been destroyed.[37] Meanwhile, displacement continued for over 129 000 people in Sofala province who had been forced to flee by Tropical Cyclone *Idai* in 2019.[38]

Climate policy

FINANCING REQUIREMENTS

There is a need to continue supporting climate governance in Africa and to continue ensuring that sustainable development incorporates climate adaptation strategies. Climate governance frameworks in Africa have led to the development of national and regional climate governance frameworks, such as Nationally Determined Contributions (NDCs), the National Adaptation Programme of Actions (NAPAs) and Nationally Appropriate Mitigation Actions (NAMAs), in line with the United Nations Framework Convention on Climate Change (UNFCCC). However, there have been serious challenges in the implementation required by these frameworks.

The continent generally needs considerable investments to build climate-resilient economies, in particular for agriculture, food security and infrastructure. This would require significant financing from governments, the private sector and international donors.[39]

The African continent suffers from the long-standing problem of a lack of weather and climate observations. This persistent limitation of information affects the capacity of African nations to predict and adapt to extreme events. The Systematic Observations Financing Facility (SOFF) is a financing mechanism that seeks to close the major gaps in observations in least developed countries and small island developing States. By strengthening the underpinning data required for weather forecasts, early warning systems and climate services, SOFF will contribute to strengthening climate adaptation and resilient development in Africa based on sound scientific evidence and robust early warning services.

OPPORTUNITIES AND NEEDS FOR FINANCING AFRICAN NATIONALLY DETERMINED CONTRIBUTIONS

As of February 2023, a total of 53 parties from Africa had submitted their NDCs, and over 90% had submitted an updated NDC. Agriculture and food security, water, disaster risk reduction, and health are the top priorities for adaptation (Figure 12, left). Energy, waste and agriculture are the top priority areas for reducing greenhouse gas emissions (Figure 12, right), even though Africa accounts for only 2%–3% of the world's carbon dioxide emissions, mainly from energy and industrial sources.[40] Africa's per capita emissions of carbon dioxide in 2021 were 1.04 metric tons per person, compared with the global figure of 4.69 metric tons per person.[41] Nevertheless, African countries are pursuing win-win policies that will better minimize their greenhouse emissions while tackling urban pollution.

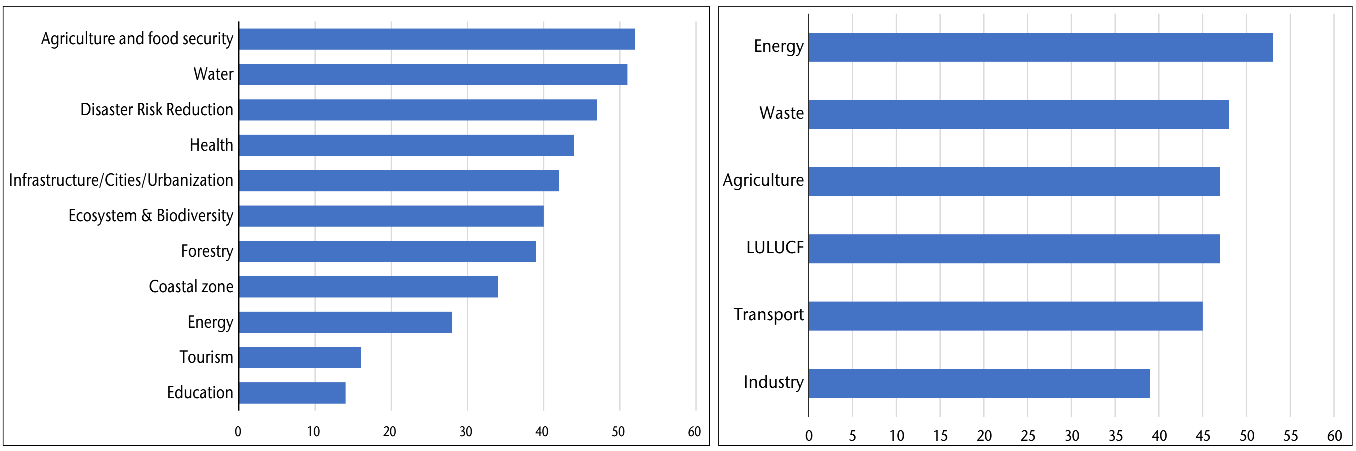


Figure 12. Priority areas for adaptation (left) and priority sectors for mitigation (right) in African countries' NDCs.
LULUCF = land use, land-use change and forestry.

Implementing Africa's NDCs will require up to US$ 2.8 trillion between 2020 and 2030.[42] The African Development Bank (AfDB) has doubled its climate finance to US$ 25 billion by 2025 and devoted 67% of its climate finance to adaptation,[43] in addition to its effort to raise up to US$ 13 billion for its Africa Development Fund.[44,45]

Significant progress on climate adaptation was achieved at the twenty-seventh session of the Conference of the Parties of the UNFCCC (COP 27), where governments agreed to move forward on the Global Goal on Adaptation to improve resilience among the most vulnerable.[46] New pledges, totalling more than US$ 230 million, were also made to the Adaptation Fund. Parties also agreed on the institutional arrangements to operationalize the Santiago Network for Loss and Damage to catalyse technical assistance to developing countries that are particularly vulnerable to the adverse effects of climate change. Moreover, the United Nations Climate Change's Standing Committee on Finance was requested to prepare a report on doubling adaptation finance for consideration at COP 28 in 2023.

CLIMATE SERVICES CAPACITIES

According to the data available, more than 60% of Members in the region provide basic climate services to the disaster risk reduction sector, including data services, climate monitoring, climate analysis and diagnostics and climate prediction. However, fewer than 30% of Members reported providing climate projections and fewer than 40% reported providing tailored products (Figure 13). This is a significant gap considering that disaster risk reduction is one of the region's top priority areas for adaptation and considering that the disaster risk reduction sector needs long-term climate projections and tailored products to address long-term strategies as well as medium- and short-term activities and interventions.

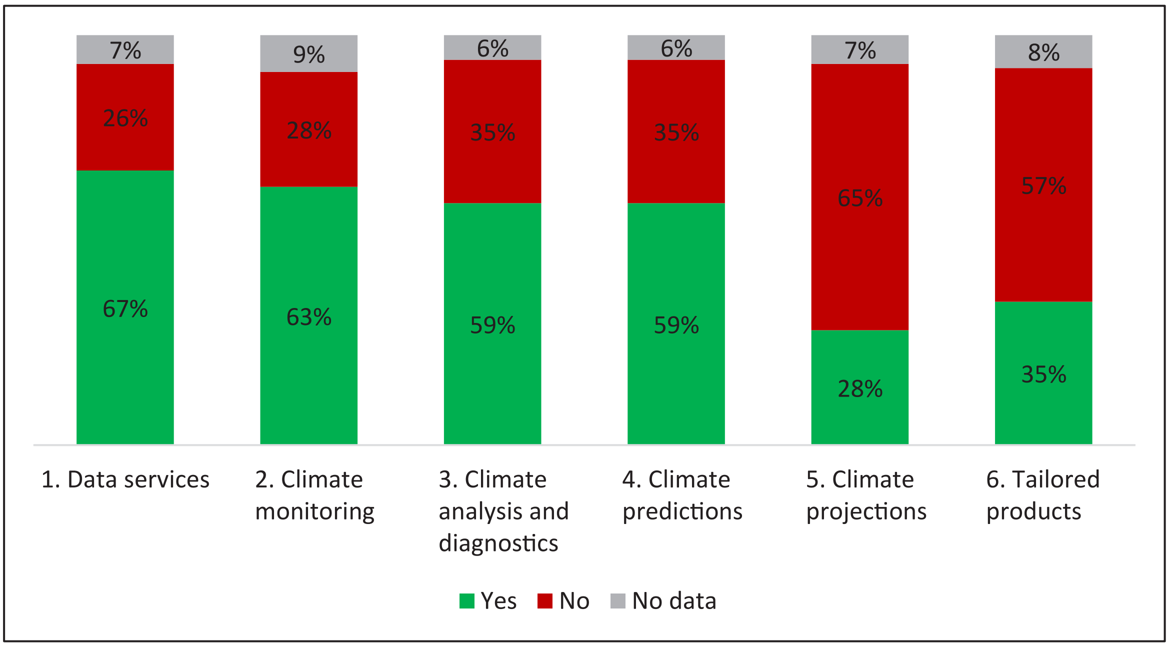


Figure 13. Percentage of Meteorological Services providing climate services for the disaster risk reduction sector

Strategic perspectives

EARLY WARNING SYSTEMS AND EARLY ACTIONS

About one-third of the world's people, mainly in least developed countries and small island developing States, are not covered by early warning systems. In Africa, the situation is precarious: 60% of people lack coverage. Following the call of the United Nations Secretary General for WMO to lead the Early Warnings for All (EW4All) initiative, a ministerial meeting on the Integrated Early Warning and Early Action System Initiative in Southern Africa was held in September 2022 in Maputo, Mozambique.[47] The meeting provided a ministerial declaration in support of the acceleration of the implementation of Sendai Target G[48] to substantially increase the availability of and access to early warning systems in the continent in addition to other mechanisms already put place.

Furthermore, an EW4All Action Plan for Africa (2023–2027), based on Executive Action Plan 2023–2027,[49] has been initiated and will be launched at the Africa Climate Summit in September 2023. This plan aims to implement a coherent programme and activities that will significantly contribute to operationalizing effective multi-hazard early warning systems across Africa. The plan leverages various ongoing regional efforts and is aligned with the African Union Climate Change and Resilient Development Strategy and Action Plan (2022–2032)[50] and the Integrated African Strategy on Meteorology (Weather and Climate Services) (2021–2030).[51] This is in addition to the Africa Institutional and Operational Framework for Multi-Hazard Early Warning and Early Action, which has been adapted to become the Africa Multi-hazard Early Warning and Early Action System (AMHEWAS) Programme of the African Union, which aims to substantially reduce continental disaster losses by ensuring that the African public has access to multi-hazard early warnings and risk information by 2030.

Warnings can only be effective if they are received in a timely manner by those required to act, and if those required to act know what to do. Effective implementation of the EW4All initiative will require inputs from a wide range of actors, including actors in academia, national disaster agencies, non-governmental organizations (NGOs), the private sector, climate finance institutions and the United Nations system.

The EW4All initiative for Africa is designed to support existing organizations and capacity building initiatives by establishing a more structured process for the exchange of data and information among all involved, ensuring the effective sharing of best practices, identifying opportunities to reduce costs and attracting investments through various partnerships.

Some partnerships have already been created through existing and new initiatives to implement the EW4All plan, including AMHEWAS, SOFF, the Risk-informed Early Action Partnership (REAP), Climate Risk and Early Warning Systems (CREWS), and the Anticipation Hub. Implementing the African EW4All plan also requires a scaling up of climate fund investment programmes, such as the Green Climate Funds (GCFs) and the Adaptation Fund, and the participation of key multilateral development banks, as well as the use of innovative new financial instruments by stakeholders across the entire early warning value chain.

LOSS AND DAMAGE

The United Nations Economic Commission for Africa (UNECA)/African Climate Policy Centre (ACPC) report on Loss and Damage in Africa states, "*Under all mitigation and adaptation scenarios, Africa will continue to experience residual loss and damage. The level of loss and damage and therefore the costs incurred will depend, among others, on the level of ambition of global mitigation actions and the level of investment in adaptation at the local level*".[52] For example, in a 4 °C world, with strong regional adaptation, "residual damages" costs equivalent to 3% of Africa's projected gross domestic product could be incurred annually by 2080. Residual losses and damages are impacts of climate change that cannot be avoided through mitigation and adaptation efforts.

According to the report, the response to loss and damage must address three challenges: (i) the ex-ante potential for reducing losses through resilience building, (ii) the ex-post challenges of recovery and rehabilitation from the loss and damage where possible and (iii) the challenges of having to cope with permanent losses. The report further proposes four key components to help address loss and damage, namely, building preventative resilience, managing risk, assisting in rehabilitation, and providing redress in the event of permanent loss. Preventative resilience includes hazard mapping, measures to make assets more resistant to damages (for example, building flood protection walls), and temporarily moving vulnerable assets out of harm's way via the implementation of early warning systems and the dissemination of timely and accurate weather information at the local level.

ACPC applied the AD-RICE model[53] to assess damage costs for Africa in relation to mitigation and adaptation efforts and concludes that "*if global mitigation efforts remain inadequate, damages for Africa increase strongly, even with increased adaptation efforts. Damages for Africa also increase strongly if adaptation falls short, even under strong global mitigation efforts*". It should be noted that the model does not adequately cater for non-economic losses, such as losses of, inter alia, life, health, displacement and human mobility, territory, cultural heritage, indigenous/local knowledge, biodiversity and ecosystem services.

The model used for the projection of losses and damages in Africa requires an update, since it was developed before the Sixth IPCC Assessment Report. It is recommended that the model be adopted and broadened as a basis for assessing and quantifying losses and damages.

The loss and damage costs in Africa due to climate change are projected to range between US$ 290 billion (in a 2 °C warming scenario) and US$ 440 billion (in a 4 °C warming scenario).[54] African states need more tools, capacity and knowledge generation mechanisms to provide details and specifics about national loss and damage. In addition, although most of the 2021 and 2022 African NDCs provide a quantification of the estimated adaptation costs, they give little prominence to loss and damage due to a lack of standard methodologies for assessing climate-related risks.[55]

In this regard, UNECA/ACPC's modelling-based assessments on loss and damage in Africa can be contextualized to generate useful results regarding the linkages between mitigation, adaptation, and loss and damage costs at the national level.

INNOVATIVE FINANCING MECHANISMS

Exploring innovative financing mechanisms could help to accelerate the implementation of the NDCs. The implementation of climate actions under the Paris Agreement as well as the Loss and Damage Fund, decided at COP 27, will help African countries to deal with the impacts of climate change and create an enabling environment for the realization of the United Nations Sustainable Development Goals (SDGs). There are opportunities to leverage the continent's vast nature-based ecosystems to attract innovative financing,[56] such as green and blue bonds and loans, sustainability or sustainability-linked bonds and loans, debt-for-climate swaps, and more efficient and better-priced carbon markets.

Observational basis for climate monitoring

Climate monitoring is performed by a system of observing systems covering the atmosphere, the ocean, hydrology, the cryosphere, and the biosphere. Each of these areas is monitored in different ways by a range of organizations. Cutting across all these areas, satellite observations provide major contributions to global climate monitoring.

In 1992, the Global Climate Observing System (GCOS) was established by WMO, the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Science Council (ISC) to coordinate and facilitate the development and improvement of global climate observations. GCOS has identified a set of Essential Climate Variables (ECVs) that together provide the information necessary to understand, model and predict the trajectory of the climate as well as plan mitigation and adaptation strategies (Figure 14). The status of the observational basis for these ECVs is published in regular status reports. GCOS also identifies what is needed in implementation reports to improve the system.

In 2022, GCOS released its latest Implementation Plan[57] in response to the findings of the 2021 GCOS Status Report, to the implications arising from the IPCC Sixth Assessment Report and to recent scientific studies on the climate cycles. The publication provides recommendations for a sustained and fit-for-purpose Global Climate Observing System.

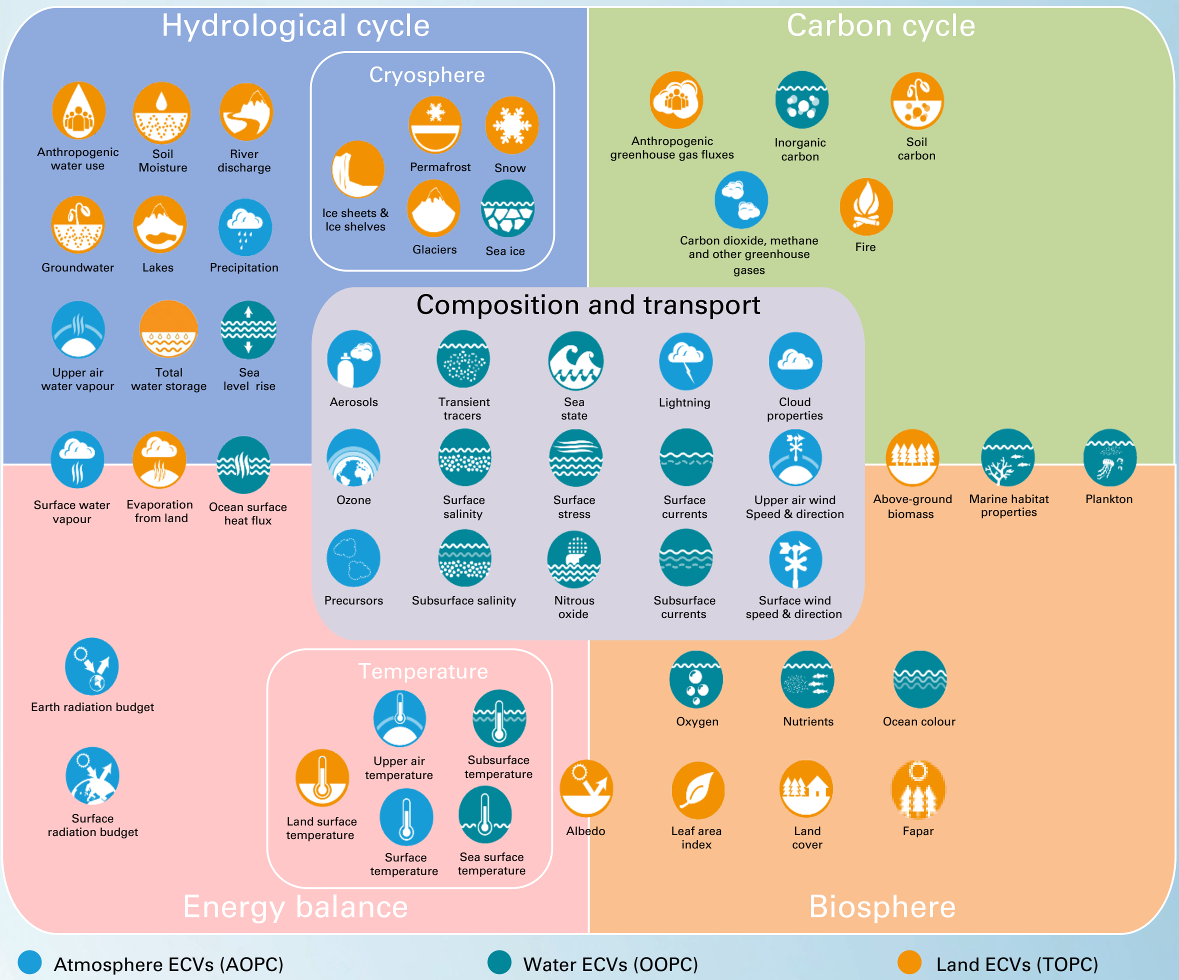


Figure 14. ECVs identified by GCOS and the climate cycles. Many ECVs contribute to understanding several different cycles – this figure only indicates the main links.

In addition to observations provided by the GCOS-coordinated Global Surface Network (GSN) and Global Upper-Air Network (GUAN), National Meteorological and Hydrological Services (NMHSs) of WMO Members provide a more comprehensive and widespread network of observations, acquired primarily for operational weather prediction. The WMO Global Basic Observing Network (GBON), a globally-designed network with prescribed capabilities and observing schedules, and for which international data exchange is mandatory, will provide critically needed observations for numerical weather prediction and will help substantially strengthen climate reanalysis.

In situ observations of a large majority of ECVs are deficient in some areas of Africa, notably in the central part of the continent. These large data gaps are often due to a scarcity of financial and technical resources that hamper the capacity of African countries to implement effective weather and climate services.

In order to provide the necessary financial and technical assistance for the implementation and operation of GBON in the poorest and most poorly observed areas of the globe, WMO, the United Nations Development Programme (UNDP) and UNEP have established the Systematic Observations Financing Facility (SOFF). SOFF has raised significant funds for supporting observations in least developed countries and small island developing States and commenced its implementation phase in 2023.

Complementing the observations of the physical and dynamic properties of the atmosphere, WMO's Global Atmospheric Watch (GAW) coordinates atmospheric composition measurements, ensuring that reliable and accurate data are obtained from measurements made by WMO Members, research institutions and/or agencies and other contributing networks.

Observations of ocean physics, biogeochemistry, biology, and ecosystems are coordinated through the Global Ocean Observing System (GOOS). The GOOS Observations Coordination Group (OCG) monitors the performance of these observations[58] and produces an annual Ocean Observing System Report Card. Ocean observations are generally made widely available to international users.

In the terrestrial domain, there is a wider group of observing networks. Hydrological observations are generally operated by NMHSs and coordinated through WMO. A number of specialized Global Terrestrial Networks (GTNs), for example, on hydrology (including lakes and rivers), permafrost, glaciers, land use, and biomass, also contribute to GCOS. Data exchange agreements are generally less developed for the terrestrial networks, and many important observations are not made available to international users.

The Committee on Earth Observation Satellites/Coordination Group for Meteorological Satellites (CEOS/CGMS) Joint Working Group on Climate (WGClimate) bases the development of satellite observations for climate on the ECV requirements established by GCOS. It has produced an ECV Inventory that includes records for 766 climate data records for 33 ECVs covering 72 separate ECV products, with more planned. WGClimate is also working on actions arising from the Implementation Plan. Satellite observations have near-global coverage. Used with ground-based observations, either as complementary data sets, or for validation and calibration, they form an invaluable part of the global observing system.

Data sets and methods

All data sets and their use are subject to licence or permission even if from an open source. Please consult the data download pages for appropriate support.

TEMPERATURE

Gridded data

Six data sets (cited below) were used in the calculation of regional temperature. Regional mean temperature anomalies were calculated relative to 1961–1990 and 1991–2020 baselines using the following steps:

1. Read the gridded data set;
2. Regrid the data to 1° latitude × 1° longitude resolution. If the gridded data are higher resolution, take a mean of the grid boxes within each 1° × 1° grid box. If the gridded data are lower resolution, copy the low-resolution grid box value into each 1° × 1° grid box that falls inside the low-resolution grid box;
3. For each month, calculate the regional area average using only those 1° × 1° grid boxes whose centres fall over land within the region.
4. For each year, take the mean of the monthly area averages to obtain an annual area average;
5. Calculate the mean of the annual area averages over the periods 1961–1990 and 1991–2020;
6. Subtract the 30-year period average from each year to obtain anomalies relative to that base period.

Note that the range and mean of anomalies relative to the two different baselines are based on different sets of data.

The following six data sets were used:

BERKELEY EARTH

Rohde, R. A.; Hausfather, Z. The Berkeley Earth Land/Ocean Temperature Record. *Earth System Science Data* **2020**, *12*, 3469–3479. https://doi.org/10.5194/essd-12-3469-2020. The data are available here.

ERA5

Hersbach, H.; Bell, B.; Berrisford, P. et al. The ERA5 Global Reanalysis. *Quarterly Journal of the Royal Meteorological Society* **2020**, *146* (730), 1999–2049. https://doi.org/10.1002/qj.3803. The data are available here.

Bell, B., Hersbach, H., Simmons, A. et al. The ERA5 Global Reanalysis: Preliminary Extension to 1950. *Quarterly Journal of the Royal Meteorological Society* **2021**, *147* (741), 4186-4227. https://doi.org/10.1002/qj.4174.

GISTEMP V4

GISTEMP Team, 2022: *GISS Surface Temperature Analysis (GISTEMP)*, version 4. NASA Goddard Institute for Space Studies, https://data.giss.nasa.gov/gistemp/. Lenssen, N.; Schmidt, G.; Hansen, J. et al. Improvements in the GISTEMP Uncertainty Model. *Journal of Geophysical Research: Atmospheres* **2019**, *124* (12), 6307–6326. https://doi.org/10.1029/2018JD029522.

HADCRUT5 ANALYSIS

Morice, C. P.; Kennedy, J. J.; Rayner, N. A. et al. An Updated Assessment of Near-Surface Temperature Change From 1850: The HadCRUT5 Data Set. *Journal of Geophysical Research: Atmospheres* **2021**, *126* (3), e2019JD032361. https://doi.org/10.1029/2019JD032361.

HadCRUT.5.0.1.0 data were obtained from http://www.metoffice.gov.uk/hadobs/hadcrut5 on 09 March 2023 and are © British Crown Copyright, Met Office 2023, provided under an Open Government License, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/.

JRA-55

Kobayashi, S.; Ota, Y.; Harada, Y. et al. The JRA-55 Reanalysis: General Specifications and Basic Characteristics. *Journal of the Meteorological Society of Japan*. Ser. II **2015**, *93* (1), 5–48. https://doi.org/10.2151/jmsj.2015-001. The data are available here.

NOAAGLOBALTEMP

Huang, B.; Menne, M. J.; Boyer, T. et al. Uncertainty Estimates for Sea Surface Temperature and Land Surface Air Temperature in NOAAGlobalTemp Version 5. *Journal of Climate* **2020**, *33* (4), 1351–1379. https://doi.org/10.1175/JCLI-D-19-0395.1.

Zhang, H.-M.; Lawrimore, H.; Huang, B. et al. Updated Temperature Data Give a Sharper View of Climate Trends. *Eos*, 19 July 2019. https://doi.org/10.1029/2019EO128229.

In situ data

Temperature in situ data are provided by National Meteorological and Hydrological Services.

PRECIPITATION

Gridded data

Schneider, U.; Becker, A.; Finger, P. et al. GPCC Monitoring Product: Near Real-Time Monthly Land-Surface Precipitation from Rain-Gauges based on SYNOP and CLIMAT data; Global Precipitation Climatology Centre (GPCC), 2020. http://dx.doi.org/10.5676/DWD_GPCC/MP_M_V2020_100.

In situ data

Precipitation in situ data are provided by National Meteorological and Hydrological Services.

SEA-SURFACE TEMPERATURE

Reynolds, R. W.; Rayner, N. A.; Smith, T. M. et al. An Improved In Situ and Satellite SST Analysis for Climate. *Journal of Climate* **2002**, *15* (13), 1609–1625. https://doi.org/10.1175/1520-0442(2002)015<1609:AIISAS>2.0.CO;2.

Data: NOAA NCEP EMC CMB GLOBAL Reyn_SmithOIv2 monthly sst (columbia.edu).

SEA LEVEL

Guérou, A., Meyssignac, B., Prandi, P. et al. Current Observed Global Mean Sea Level Rise and Acceleration Estimated from Satellite Altimetry and the Associated Uncertainty, *EGUsphere* **2022** [preprint]. https://doi.org/10.5194/egusphere-2022-330.

EM-DAT DATA

EM-DAT data were used for historical climate impact calculations: www.emdat.be. EM-DAT is a global database on natural and technological disasters, containing essential core data on the occurrence and effects of more than 21 000 disasters around the world, from 1900 to the present. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université catholique de Louvain, located in Brussels, Belgium.

The indicators used for mortality, number of people affected, and economic damage are total deaths, number affected and total damages ('000 US$), respectively.

CLIMATE SERVICES

WMO analysis of NDCs

Checklist for Climate Services Implementation (Members' climate services capacities, based on responses to this Checklist, can be viewed here)

WMO Climates services dashboard

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WMO RCC-Intergovernmental Authority on Development (RCC-IGAD)
WMO RCC-Network-North Africa (RCC-Network-NA)
RCC for West Africa and the Sahel (RCC-WAS)
Southern African Development Community–Climate Services Centre (SADC-CSC)
Indian Ocean Commission (IOC)

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Endnotes

1 Data are from the following data sets: Berkeley Earth, ERA5, GISTEMP v4, HadCRUT.5.0.1.0, JRA-55, NOAAGlobalTemp v5. For details regarding these data sets, see the Data sets and methods section in the *State of the Global Climate 2022* (WMO-No. 1316).

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