State of the Climate in Latin America and the Caribbean

2023

WEATHER CLIMATE WATER

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METEOROLOGICAL
ORGANIZATION

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Cover illustration from Adobe Stock by Gian: Beautiful aerial view of the Panama Canal at sunset

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We need your feedback

This year, the WMO team has launched a process to gather feedback on the *State of the Climate* reports and areas for improvement. Once you have finished reading the publication, we ask that you kindly give us your feedback by responding to this short survey. Your input is highly appreciated.

Key messages

In Latin America and the Caribbean, 2023 was the warmest year on record.

Sea level continued to rise at a higher rate than the global mean around much of the Atlantic part of the region, threatening the coastal areas of several countries and small island developing States.

Hurricane *Otis* made landfall as a Category 5 strength hurricane near Acapulco, Mexico, leading to major losses in life and infrastructure. *Otis* was the strongest landfalling hurricane on record in the eastern Pacific Basin, with one of the most rapid rates of intensification.

Floods and landslides triggered by heavy rainfall led to significant fatalities and economic losses across the region. In São Sebastião, Brazil, 683 mm of rainfall accumulated in 15 hours, triggering a landslide that led to at least 65 deaths.

Climate services are pivotal in enhancing decision-making and action in various sectors. Despite recent developments and successful initiatives, only 38% of WMO Members in the region indicated providing tailored climate products for the health sector.

Extreme heat and heatwaves led to health impacts throughout the year, including excess mortality. Between 2000 and 2019, there was an average of 36 695 heat-related excess deaths in the region per year.

Intense and severe drought, exacerbated by heatwaves, affected large areas of Latin America during 2023. By the end of the year, 76% of Mexico was experiencing some degree of drought.

The Negro River in the Amazon hit a record low level since observations began in 1902. In the Panama Canal, low water levels restricted ship traffic from August onward.

Exceptionally high temperatures and dry conditions also impacted wildlife. In Tefé Lake, in the Brazilian Amazon, water temperature reached a record high and over 150 river dolphins (*Boto-cor-de-rosa*) were reported dead.

Agricultural losses were reported in many countries in the region due to extreme weather and climate events. Such impacts exacerbated food insecurity, especially in communities reliant on agriculture for their livelihoods.

Foreword

The present WMO report is the fourth in an annual series starting with the year 2020. It summarizes the observed climate trends and high-impact events, as well as associated socioeconomic impacts, in Latin America and the Caribbean (LAC). Tropical cyclones, heavy precipitation and flooding events, extreme heat and severe droughts led to significant human and economic losses in the region throughout 2023.

The second half of 2023 was particularly influenced globally by El Niño conditions, which contributed to a record warm year and exacerbated extreme events in the region. This happened on top of well-established long-term climate change and the associated rising frequency and intensity of extreme weather and climate events.

Among many climatic hazards recorded in LAC, Hurricane *Otis* hit Acapulco, in Mexico, as a Category 5 hurricane, devastating the area and leading to dozens of fatalities and billions of dollars in damage. The drought in the Amazon was another noteworthy high-impact event of the year. It was so intense that the Negro River, at Manaus, recorded its lowest level in more than 120 years of observations.

The report highlights the advances made in integrating meteorological data into health surveillance (focusing on disease), reflecting a move towards stronger public health strategies. Despite this improvement, there is still a need for substantial developments and investments in weather services infrastructure and tailored climate services.

There are major gaps in the weather and climate observing networks, especially in the least developed countries and small island developing States; these gaps represent an obstacle to the provision of early warnings, adequate climate services and effective climate monitoring, especially at the regional and national scales. WMO works with its Members and partners to improve climate observations through the Global Climate Observing System (GCOS) and by ensuring adequate financial mechanisms for weather and climate observations through the Systematic Observations Financing Facility (SOFF).

Early warnings are fundamental for anticipating and reducing the impacts of extreme events. WMO is leading the United Nations Early Warnings for All initiative and its Executive Action Plan. The Action Plan, launched by United Nations Secretary-General António Guterres during the World Leaders Summit at the United Nations 2022 Climate Change Conference (COP27), provides a new horizon for strengthening Earth system observations, monitoring and warning capabilities.

I wish to congratulate and thank the lead authors, contributing experts, scientists and organizations for their collaboration and input into the production, review and timely delivery of this publication. I am also grateful to the WMO Member National Meteorological and Hydrological Services, Regional Climate Centres and United Nations agencies for their forefront role in ensuring adequate data and information used in the analysis provided in this report.

(Prof. Celeste Saulo)
Secretary-General

Global climate context

The global annual mean near-surface temperature in 2023 was 1.45 ± 0.12 °C above the 1850–1900 pre-industrial average. The year 2023 was the warmest year on record according to six global temperature datasets. The past nine years, 2015 to 2023, were the nine warmest years on record in all datasets.

Atmospheric concentrations of the three major greenhouse gases each reached new record observed highs in 2022, the latest year for which consolidated global figures are available, with levels of carbon dioxide (CO_2) at 417.9 ± 0.2 parts per million (ppm), methane (CH_4) at 1 923 ± 2 parts per billion (ppb) and nitrous oxide (N_2O) at 335.8 ± 0.1 ppb – respectively 150%, 264% and 124% of pre-industrial (pre-1750) levels (Figure 1). Real-time data from specific locations, including Mauna Loa[1] (Hawaii, United States of America) and Kennaook/Cape Grim[2] (Tasmania, Australia) indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2023.

Over the past two decades, the ocean warming rate has increased, and the ocean heat content in 2023 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 4.77 mm per year between 2014 and 2023, reaching a new record high in 2023. Between 1960 and 2021 (latest available data), the ocean absorbed about 25% of annual anthropogenic emissions of CO_2 into the atmosphere. 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, and threatens food security by endangering fisheries and aquaculture.

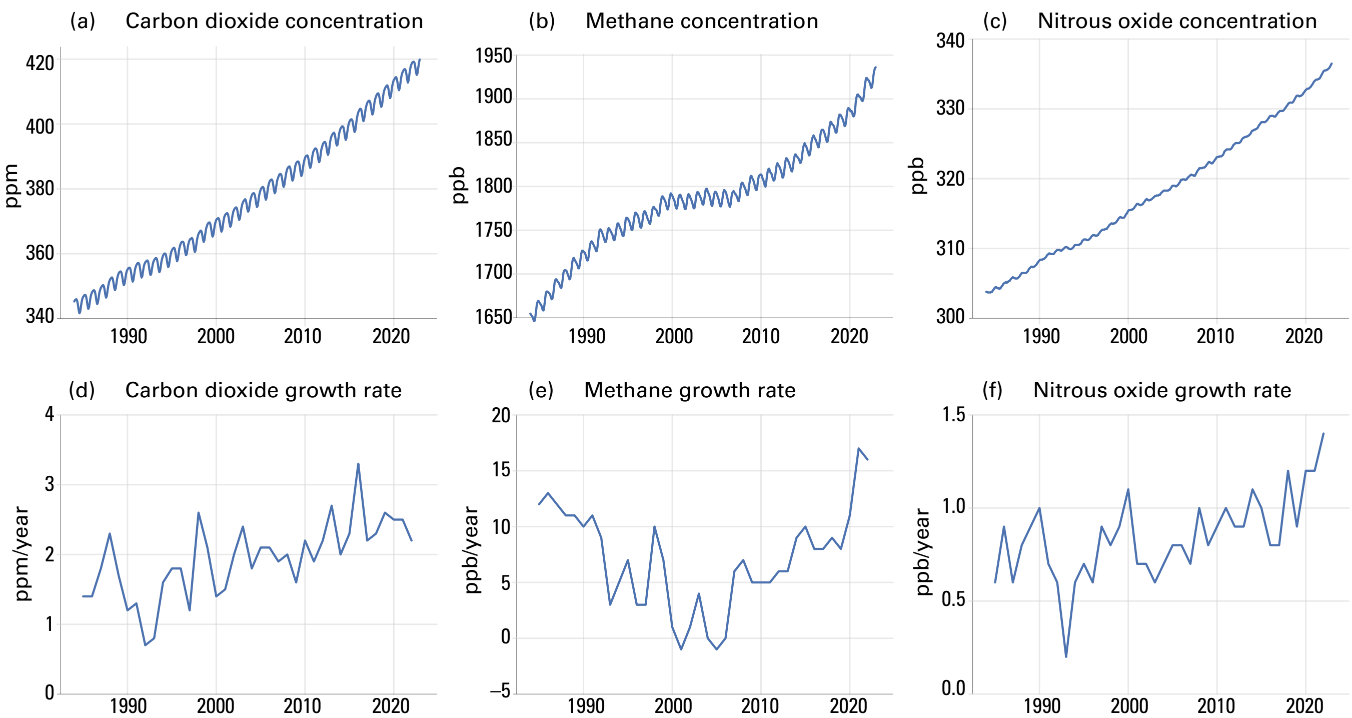

Figure 1. Top row: monthly globally averaged mole fraction (measure of atmospheric concentration), from 1984 to 2022, of (a) CO_2 in parts per million, (b) CH_4 in parts per billion and (c) N_2O in parts per billion. Bottom row: the growth rates representing increases in successive annual means of mole 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 climate in Latin America and the Caribbean (LAC). 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)[3] uses the reference period 1850–1900 for calculating anomalies relative 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 before 1900. Instead, there are two more recent climatological standard average reference periods with sufficient data for computing regional temperature anomalies and other indicators: 1961–1990, which is a fixed reference period recommended by WMO for assessing long-term temperature change, and 1991–2020, which is the most recent climatological standard average reference period. In the present report, exceptions to the use of these baseline periods for calculating anomalies, where they occur, are explicitly noted.

MAJOR CLIMATE DRIVERS

LAC is surrounded by the Pacific and Atlantic Oceans, and the climate in the region is largely influenced by the prevailing sea-surface temperatures (SSTs) and associated large-scale atmosphere–ocean coupling phenomena, such as the El Niño–Southern Oscillation (ENSO). Central and eastern tropical Pacific SST conditions are crucial for identifying the onset of El Niño and La Niña and their influence on climate patterns and extremes, both worldwide and in the LAC region. The tropical Pacific and Atlantic are also essential influences on LAC's climate variability, particularly in areas such as the northern coast of Peru and Ecuador, Amazonia, north-eastern Brazil, south-eastern South America, and, during the hurricane season, the tropical North Atlantic, the eastern coast of Mexico and the Caribbean.

A multi-year La Niña event began in mid-2020 and ended in early 2023. Subsequently, sea-surface temperatures in the eastern tropical Pacific increased, crossing typical El Niño thresholds by June. However, the atmosphere was slower to respond, and it was not until early September that El Niño conditions were well established in both the atmosphere and ocean. By the end of the year, a strong El Niño had developed, with the Oceanic Niño Index (ONI)[4] reaching 2 °C for the November 2023–January 2024 period, the highest value since the 2015/16 El Niño, and indicative of a strong El Niño. Figure 2 shows annual SST anomalies in 2023 in most of the Pacific Ocean, including in the Niño 3.4 region, and part of the Atlantic Ocean. An important aspect was the warming of the eastern equatorial Pacific, but also the North Atlantic and Gulf of Mexico.

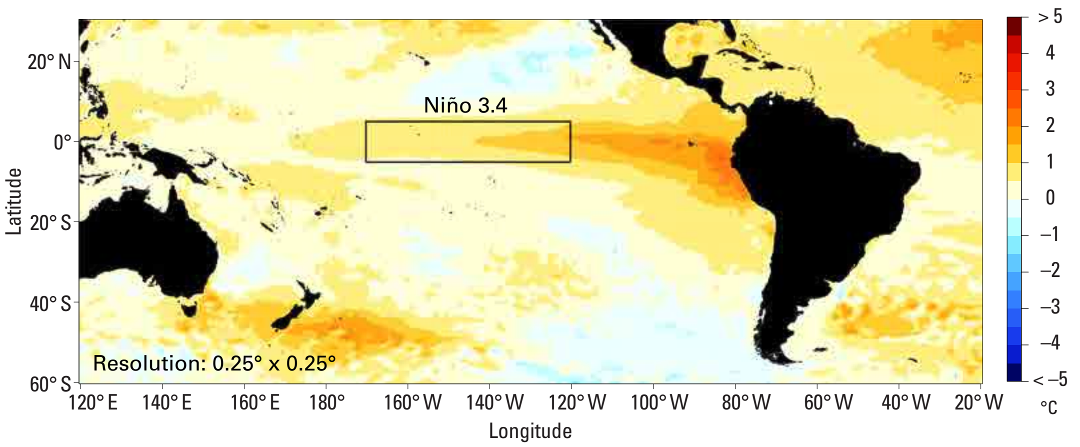

Figure 2. Annual SST anomalies (°C) in 2023 (reference period: 1991–2020). The box "Niño 3.4" represents the Niño 3.4 SST Index region (5°N–5°S, 120°W–170°W).

Source: National Oceanic and Atmospheric Association (NOAA) National Centers for Environmental Prediction (NCEP) Global Ocean Data Assimilation System (GODAS), produced by CIIFEN

The 2023 El Niño event was associated with higher air temperatures and precipitation deficits (see Precipitation) over Mexico, the Peruvian-Bolivian Altiplano and the Amazon, as well as increased rainfall in parts of south-eastern South America. It also prolonged a pre-existing drought over much of the south-western Amazon that, together with higher temperatures, led to extreme low river levels in most of the region during the southern hemisphere spring.[5] As of 31 December, 76% of Mexico was in drought, according to the most recent data from the country's water service (CONAGUA), including extreme drought across much of central and north Mexico.

TEMPERATURE

The 2023 mean temperature in LAC was the highest on record, 0.82 °C above the 1991–2020 average (anomaly of 0.75 °C–0.96 °C, depending on the dataset used). Relative to a 1961–1990 baseline, 2023 was 1.39 °C warmer (anomaly of 1.24 °C–1.62 °C, depending on the dataset used) (Table 1). The annual mean temperature anomalies relative to the 1991–2020 average across the LAC region are shown in Figure 3 and Table 1 (see details regarding the datasets in the Datasets and methods section). Warming was more pronounced in the region in 2023 compared to 2022 due to an El Niño phenomenon. The 1991–2023 period shows the highest warming trend (about 0.2 °C or higher per decade) since 1900 in the LAC region (compared with the previous 30-year periods of 1900–1930, 1931–1960 and 1961–1990). Mexico experienced the fastest rate of warming of the four subregions, about 0.3 °C per decade, from 1991–2023 (Figure 4).

Table 1. 2023 temperature ranking (1900–2023) and anomalies for LAC (°C, difference from the 1991–2020 and 1961–1990 averages)

Subregion/region	*Temperature ranking*	*Anomaly (°C)*	
		1991–2020	*1961–1990*
Mexico	1st warmest	0.88 [0.81–1.06]	1.58 [1.24–1.83]
Central America	1st warmest	0.85 [0.67–0.97]	1.31 [1.16–1.54]
Caribbean	1st warmest	0.71 [0.60–0.79]	1.21 [0.93–1.42]
South America	1st warmest	0.81 [0.72–0.97]	1.37 [1.17–1.62]
LAC	1st warmest	0.82 [0.75–0.96]	1.39 [1.24–1.62]

Source: Data are from six datasets used in this assessment: Berkeley Earth, ERA5, GISTEMP, HadCRUT5, JRA-55 and NOAAGlobalTemp. Five datasets were used in the assessment relative to 1961–1990. For details regarding the datasets, see Temperature in the Datasets and methods section.

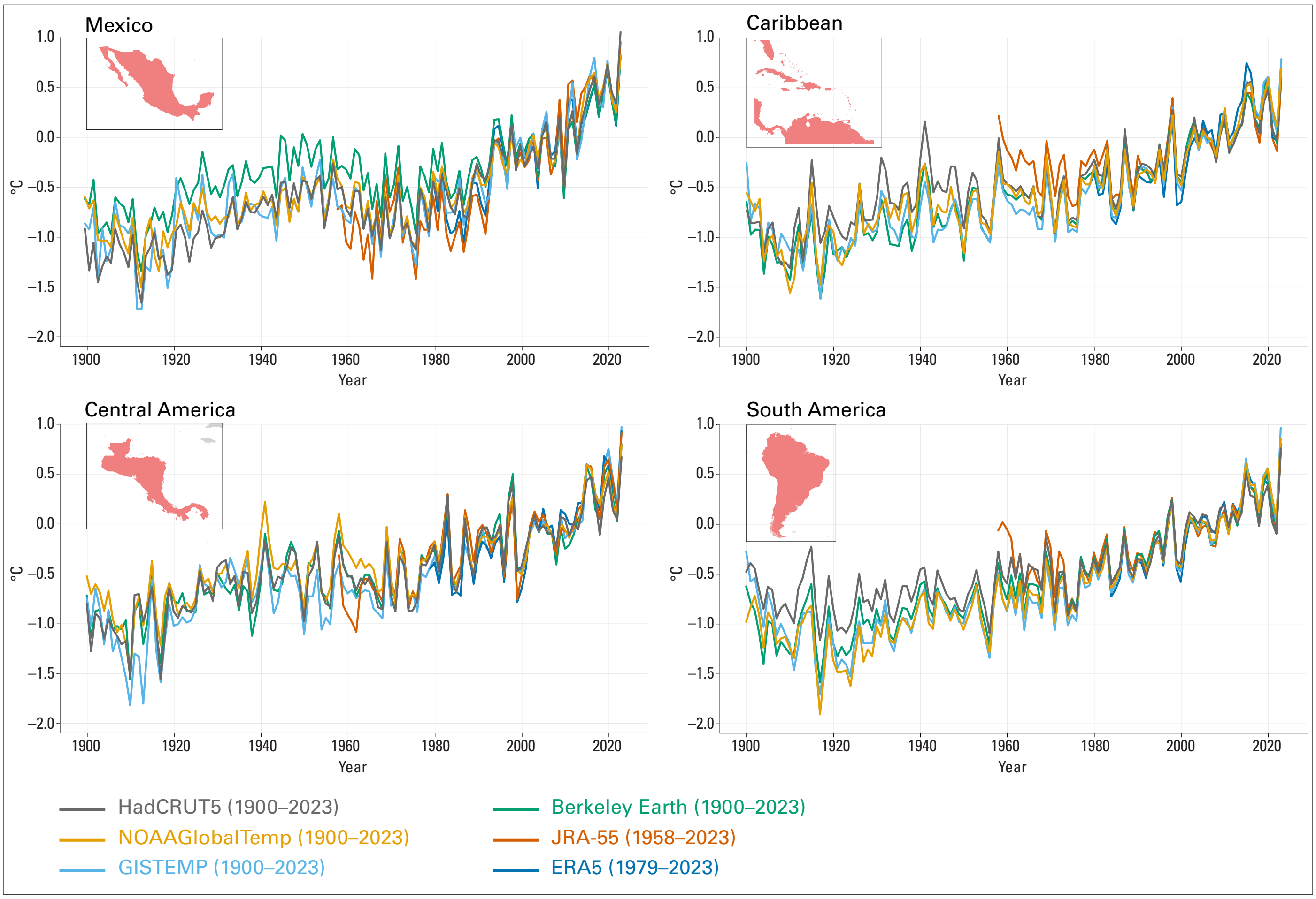

Figure 3. Annual mean near-surface temperature anomalies, 1900–2023, difference relative to the 1991–2020 average for four subregions in the LAC region: Mexico, Central America, the Caribbean and South America. Data are from six different datasets, as indicated in the legend: Berkeley Earth, ERA5, GISTEMP, HadCRUT5, JRA-55 and NOAAGlobalTemp. The inset maps show the subregions for which the averages are calculated.

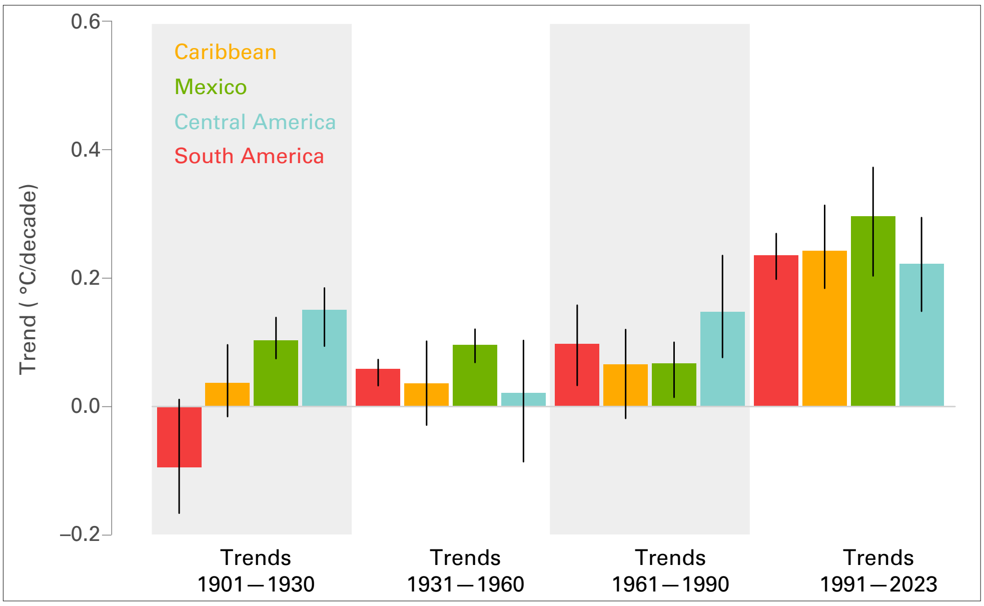

Figure 4. Temperature trends for the Caribbean, Mexico, Central America and South America subregions, for 30-year periods. The coloured bars show the average trend calculated over each period for the six datasets: Berkeley Earth, ERA5, GISTEMP, HadCRUT5, JRA-55 and NOAAGlobalTemp. The black vertical lines indicate the ranges of the six estimates.

The year 2023 was the warmest on record in many parts of the region, which is reflected by the high temperature anomalies at the country level. Station data for 2023 relative to 1991–2020 (Figure 5a to Figure 5d) show that positive anomalies of +1 °C to +3 °C were recorded in central Mexico and the Yucatán Peninsula, and negative anomalies of –1 °C to –2 °C in parts of northern Mexico and Baja California. Anomalies of +1 °C to +2 °C were recorded in Central America (Figure 5b). Positive temperature anomalies of +1 °C to +2 °C were recorded in many areas across the Caribbean region (Figure 5c). In South America, above-normal temperature anomalies of around +2 °C, up to +3 °C in some locations, were observed in central and northern Argentina, the central and southern Andes of Peru, Bolivia, northern Chile and Paraguay, the Peruvian and Bolivian Amazon, and the entire tropical zone of South America, some of them reflecting the heatwaves that affected the region (see Heatwaves section). Negative temperature anomalies of –0.5 °C to –1.0 °C were observed in the extreme south of Argentina and Chile (Figure 5d).

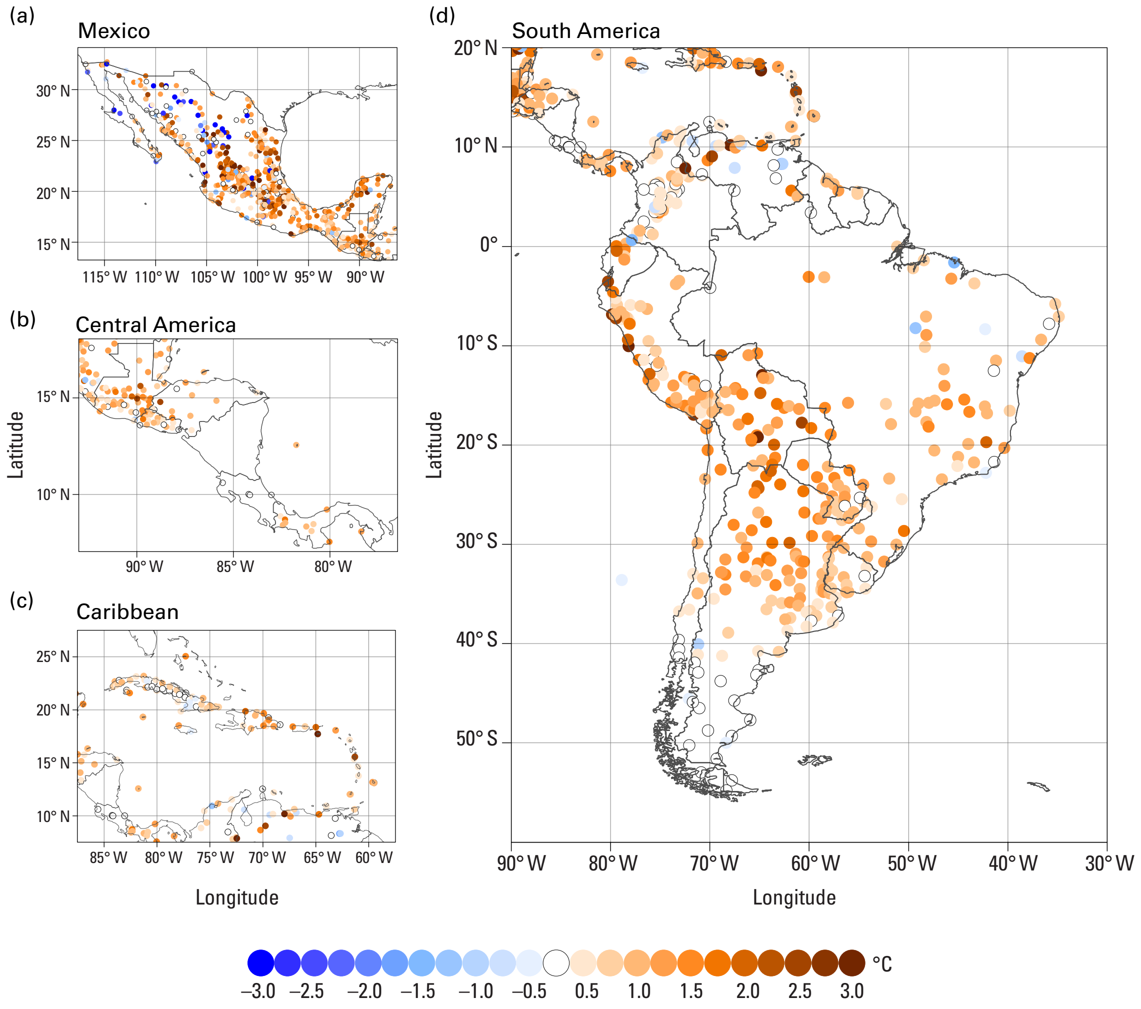

Figure 5. In situ mean air temperature (2 m) anomalies for 2023 (relative to 1991–2020) for (a) Mexico, (b) Central America, (c) the Caribbean and (d) South America, in °C. The colour scale is shown below the figure.

Source: International Research Centre on El Niño (CIIFEN), from National Meteorological and Hydrological Services' data

PRECIPITATION

Annual rainfall anomalies for 2023 (relative to the 1991–2020 climatological standard normal) are shown in Figure 6. Rainfall was below normal in most of Mexico (around 20%–60%); some exceptions were Baja California and the Yucatán Peninsula (Figure 6a). In most of Central America, rainfall was generally between 20%–40% below normal, including in Panama and Honduras. Rainfall in Costa Rica and parts of Guatemala was about 10%–40% above normal (Figure 6b). In the Caribbean, above-normal rainfall was recorded in parts of the Dominican Republic and eastern Cuba. In the Eastern Caribbean islands, negative rainfall anomalies were predominant (around 20% below normal) (Figure 6c).

In South America (Figure 6d), below-normal rainfall was recorded in central Chile (about 40% below normal), in the central and south-western Andes of Peru, in the Plurinational State of Bolivia, in the western Amazon (about 40%–70% below normal) and in the rest of tropical Brazil (20%–40% below normal). As in 2022, below-normal rainfall was dominant over

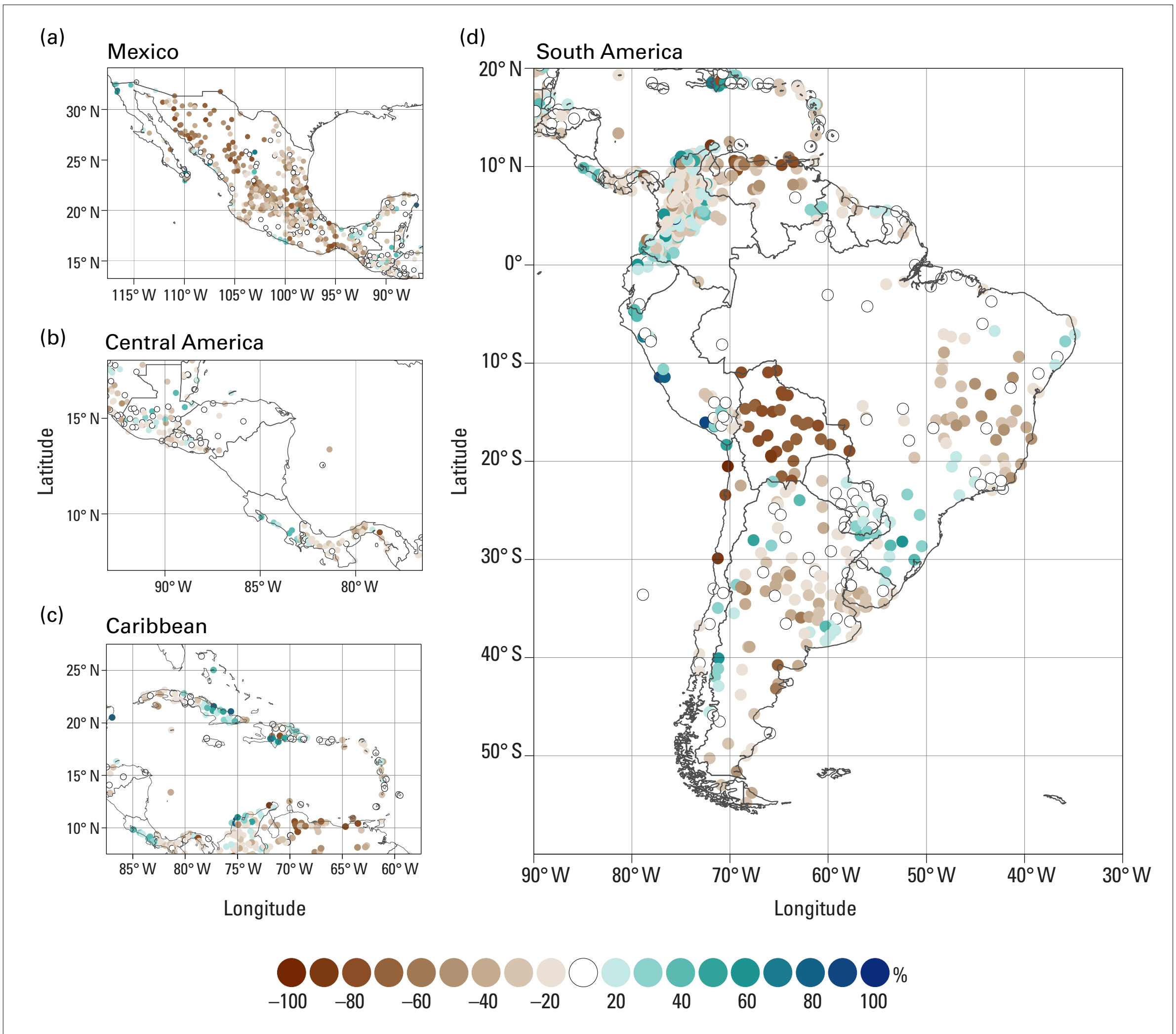

Figure 6. In situ rainfall anomalies for 2023 (percentage relative to the 1991–2020 reference period) in (a) Mexico, (b) Central America, (c) the Caribbean and (d) South America. The colour scale is shown below the figure.

Source: CIIFEN, from National Meteorological and Hydrological Services' data the Paraná–La Plata Basin in Uruguay and northern Argentina, suggesting a late onset and weak South American monsoon. Above-normal precipitation anomalies (40%–50%) dominated parts of southern and south-eastern Brazil, the northern coast of Peru, central and coastal Colombia and Ecuador, and eastern Bolivarian Republic of Venezuela and Guyana. Positive precipitation anomalies in south-eastern Brazil were related to heavy precipitation events concentrated over a few days (see Extreme events). Some of the observed rainfall patterns were consistent with the typical rainfall patterns associated with La Niña conditions during the first half of 2023, and with El Niño in the second half (see Major climate drivers), especially intense rainfall in southern Brazil and drought in the western Amazon (see Extreme events).

GLACIERS

In the Andes, the greatest number of glaciers are found along the border between Chile and Argentina (approximately 4 000). A smaller number are found in the tropical Andes, which constitute more than 95% of the world's tropical glaciers.[6] In the dry Andes, the longest series of data relating to glacier mass reported by the World Glacier Monitoring Service (WGMS) comes from the Echaurren Norte glacier (Figure 7), which lost about 31 m water equivalent (m w.e.) from 1975 to 2023 (0.65 m w.e. per year).The largest part of the loss, about 22 m w.e. (0.96 m w.e. per year), occurred since 2000.[7]

The O'Higgins Glacier in Chile, one of the largest of southern Patagonia, has been experiencing a rapid calving retreat (an important process of mass loss) since 2016. The recession from 2016 to 2023 has been 7 km^2, with 4 km^2 occurring from 2019 to 2023. The retreat since 2016 has been 3 000 m on the northern margin, 3 700 m in the centre and 3 500 m on the southern margin.[8,9]

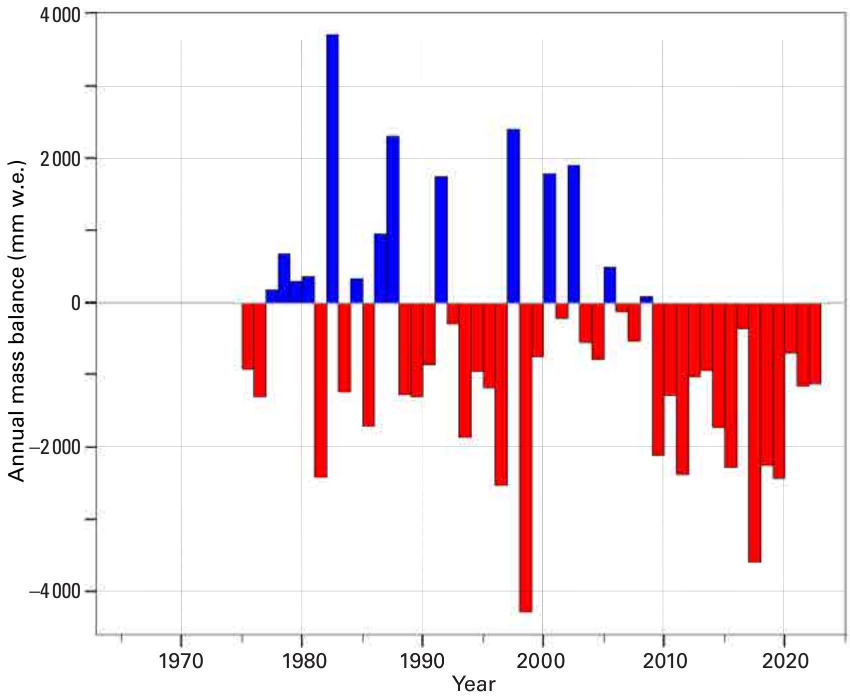

Figure 7. Annual mass balance of the Echaurren Norte reference glacier, Andes (Chile), 1975–2022

Source: World Glacier Monitoring Service (WGMS) *Fluctuations of Glaciers Database*; WGMS FoG database version: 2024-01-23, https://doi.org/10.5904/wgms-fog-2024-01.

SEA LEVEL

In 2023, global mean sea level (GMSL) continued to rise. GMSL rise is estimated to be 3.43 mm ± 0.3 mm per year, averaged over the 31 years (1993–2023) of the satellite altimeter record. The decadal average rate of sea-level rise has more than doubled since the start of the satellite record, increasing from 2.13 mm per year between 1993 and 2002 to 4.77 mm per year between 2014 and 2023.[10]

The mean sea level has increased at a higher rate than the global mean in the South Atlantic and the subtropical and tropical North Atlantic, and at a lower rate than the global mean in the eastern Pacific over the last three decades. Sea-level rise threatens a large portion of the Latin American and Caribbean population who live in coastal areas, by contaminating freshwater aquifers, eroding shorelines, inundating low-lying areas and increasing the risks of storm surges.[11]

High-precision satellite altimetry data covering the period from January 1993 to May 2023 indicate that during this period, the rates of sea-level change on the Atlantic side of South America were higher than those on the Pacific side (Figure 8 (right) and Table 2). In the South American Pacific zone, the rate of change was 2.43 mm ± 0.12 mm per year, and along the

Table 2. Rate of area-averaged sea-level change over the period from January 1993 to May 2023 based on satellite altimetry. Zones are defined in Figure 8.

Subregion	*Zone number (see Figure 8)*	*Area*	*Trends in rate of sea-level rise (in mm per year)*
Mexico, Central America and the Caribbean	1	Central America Pacific	2.22 + 0.27
	2	Subtropical North Atlantic and Gulf of Mexico	4.23 + 0.12
	3	Tropical North Atlantic	3.56 + 0.10
South America	1	South America tropical North Atlantic	3.68 + 0.08
	2	South Atlantic	3.96 + 0.06
	3	South America Pacific	2.43 + 0.12

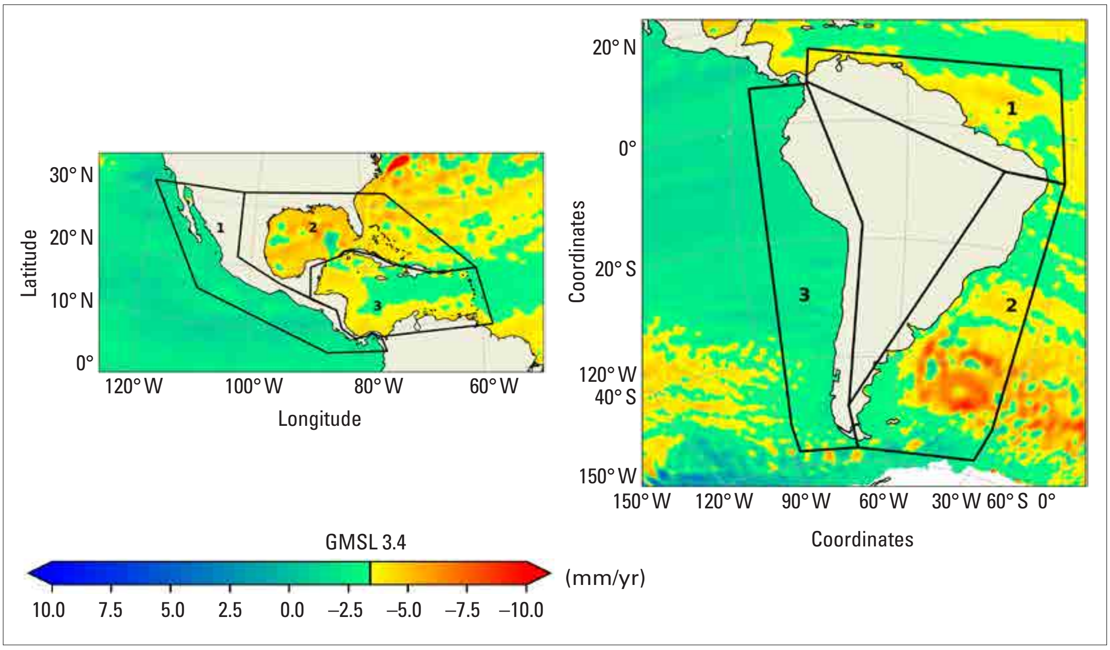

Figure 8. Sea-level trends based on satellite altimetry, in the LAC subregions of Mexico, Central America, the Caribbean (left), and South America (right), over the period from January 1993 to May 2023. The transition from green to yellow corresponds to the 3.4 mm per year global mean averaged trend. The numbered boxes represent the zones where the rates of area-averaged sea-level change are provided in Table 2.

Source: Copernicus Climate Change Service (C3S)

Pacific coast of Mexico and Central America, it was 2.22 mm ± 0.27 mm per year, both lower than the global average. Along the Atlantic coast of South America, south of the equator, the rate of change from January 1993 to July 2023, namely 3.96 mm ± 0.06 mm per year, was higher than the global average. A comparable rate was also observed in the subtropical North Atlantic and the Gulf of Mexico (4.23 mm ± 0.12 mm per year). In the tropical North Atlantic, around Central America and the southern Caribbean, the rate was 3.56 mm ± 0.10 mm per year during this period (Figure 8 (left) and Table 2).

The Guna Yala, an archipelago of over 300 islands off the north-east coast of Panama, are home to the Guna people, an Indigenous community. The islands are highly vulnerable to climate change impacts, especially sea-level rise.
Credit: Silvia Markli (United States of America)

Extreme events

The Sixth Assessment Report (AR6) of IPCC Working Group I[12] states that global warming is altering the intensity and frequency of many extreme weather events, leading to or exacerbating other high-impact events such as flooding, landslides, wildfires and avalanches. The wider socioeconomic risks and impacts associated with these events are described in the Climate-related impacts and risks section. The IPCC AR6 also states that for Central and South America, the observed trends indicate a *likely* increase in the intensity and frequency of hot extremes, and a *likely* decrease in the intensity and frequency of cold extremes, as well as an increase in mean and heavy precipitation in south-eastern South America. The following sections only highlight the most extreme weather- and climate-related events of 2023; details on all reported extreme weather- and climate-related events can be found in an interactive online map.

TROPICAL CYCLONES

The 2023 Atlantic hurricane season had an above-average number of storms, ending with 20 named storms (compared to an average of 14 named storms for 1991–2020).[13] El Niño usually favours low hurricane activity in the Atlantic Basin due to the increased vertical wind shear mainly in the western portion of the main development region, where most tropical storms develop. However, that was not the case in 2023, due to several inter-related conditions including the anomalously warm SSTs in the tropical and subtropical Atlantic and the Gulf of Mexico.[14] Some storms affected land areas in the LAC region (Table 3), including two tropical storms and two major hurricanes.

In the eastern Pacific, the hurricane season was slightly more active than normal, with 17 named storms (compared to an average of 15 named storms for 1991–2020).[15] Six of these storms

Table 3. Summary of the 2023 hurricane season in the Atlantic and Eastern Pacific Basins. The table includes only tropical storms, hurricanes and major hurricanes that most affected land areas in the LAC region (in chronological order). Some of these also had significant impacts outside the LAC region. Major hurricanes are identified with the acronym MH.

Hurricane or tropical storm	*Period*	*Affected areas*
Tropical Storm *Bret*	19–24 June	Barbados, Dominica, Saint Vincent and the Grenadines, and Saint Lucia
Hurricane *Hilary* (MH)	16–21 August	Baja California (Mexico)
Hurricane *Franklin* (MH)	20 August–1 September	Dominican Republic and parts of the Greater Antilles, Bermuda Hispaniola
Hurricane *Idalia* (MH)	26–31 August	Yucatán Peninsula (Mexico), Cayman Islands, western Cuba
Tropical Storm *Philippe*	23 September–6 October	Barbuda
Hurricane *Lidia* (MH)	03–11 October	Jalisco (Mexico)
Hurricane *Norma* (MH)	17–23 October	South Baja California (Mexico)
Hurricane *Otis* (MH)	22–25 October	Acapulco (Mexico)

Source: Based on data from NOAA/National Hurricane Center (NHC): https://www.nhc.noaa.gov/tafb_latest/tws_atl_latest.gif and https://www.nhc.noaa.gov/tafb_latest/tws_pac_latest.gif, last accessed on 11 January 2024 affected Mexico, namely four major hurricanes (*Hilary*, *Norma*, *Lidia* and *Otis*), one hurricane (*Beatriz*) and one tropical storm (*Max*). Major Hurricanes *Lidia* and *Otis* rapidly intensified in the hours leading up to their landfall.

Otis was the strongest hurricane to make landfall on Mexico's west coast, and *Lidia* was the fourth strongest. *Lidia* made landfall in the state of Jalisco, on 10 October, with sustained winds of 220 km/h (120 knots). *Otis* reached hurricane intensity at 1200 UTC on 24 October, and within 15 hours had intensified to a Category 5 system. *Otis* made landfall near Acapulco (Mexico) on 25 October, with maximum sustained winds estimated to be 260 km/h (140 knots). This is the first time on record (since the NHC assumed operational forecast responsibility for the basin in 1988) that the eastern Pacific had a hurricane at Category 5 through landfall.[16] *Otis* caused at least 48 deaths and an estimated 12 billion US dollars (USD) of damage.[17] In Acapulco, a city that depends heavily on tourism, *Otis* damaged 80% of the hotel infrastructure and 96% of businesses (Figure 9).[18]

Hurricane *Idalia* impacted Cuba on 28 August with tropical storm-force winds, damaging agriculture plantations. Hurricane *Idalia* crossed the Gulf of Mexico and made landfall near Keaton Beach, Florida, around 1145 UTC on 29 August, leading to significant impacts in portions of the south-eastern United States.[19]

Tropical Storm *Franklin* (later Major Hurricane *Franklin*) made landfall in the Dominican Republic on 23 August, bringing flooding and mudslides to the island. Rain in Santo Domingo exceeded 330 mm. In the Dominican Republic, at least 749 homes were damaged by the storm. Two people were killed, and one other was reported missing. More than 1.6 million people were left without water the following day.

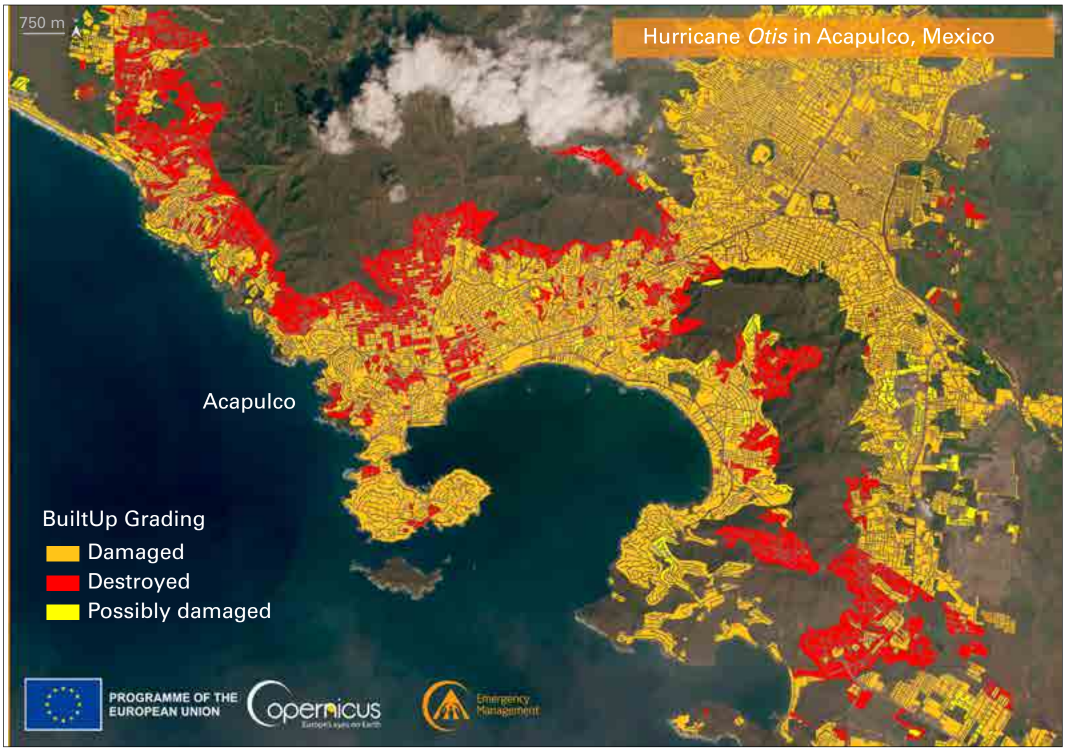

Figure 9. Buildings damaged and destroyed by Hurricane *Otis*, on 25 October 2023, in Acapulco, Mexico: situation as of 26 October at 1713 UTC

Source: European Union, Copernicus Emergency Management Service (CEMS) Rapid Mapping, activation code #EMSR70

HEAVY PRECIPITATION, FLOODS AND LANDSLIDES

In Latin America and the Caribbean, heavy rainfall events and subsequent flooding and landslide episodes were reported in 2023. In this region, El Niño is typically associated with above-normal rainfall in southern Brazil, southern Argentina, central Chile, eastern Plurinational State of Bolivia and along the coast of Peru and Ecuador.

Flash floods in the Mexican state of Jalisco on 25 September resulted in eight fatalities after a sudden rise of a river in Autlán de Navarro. Another notable event took place on 3 November, when the Aguadulcita and Tancochapa Rivers in Veracruz overflowed due to a combination of record-breaking precipitation (400 mm in San José del Carmen, Veracruz, on 1 November) and strong winds.[20]

A tropical disturbance moved across the Caribbean on 17 November, bringing torrential rainfall to Jamaica, Haiti and the Dominican Republic, with at least 21 people losing their lives in the Dominican Republic. Arroyo Hondo Viejo (Dominican Republic) recorded a daily rainfall amount of 431.0 mm on 18 November, the highest on record in the country. Comparable amounts were also recorded in the Renacimiento neighbourhood in Santo Domingo (426.0 mm), and in Paraiso in Barahona Province (394.7 mm).[21]

In central Chile, significant rainfall totals were recorded from 18–23 August. The General Freire station in Curicó (Maule Region) recorded 150.2 mm in 24 hours, the highest amount since 1950.

In Brazil, in the coastal areas of the state of São Paulo, at least 65 people lost their lives after torrential rain caused floods and landslides in the city of São Sebastião; on 18–19 February, 683 mm of rain fell in 15 hours in the city (Figure 10).

In the state of Acre in the Brazilian Amazon, heavy rain and the overflowing of the Acre River flooded vast areas of Rio Branco on 23 March. The city recorded 124.4 mm of rainfall in 24 hours.[22] On 23 March, the Acre River level at Rio Branco jumped from around 8 m to 15.8 m in 24 hours (flood level is 14 m). In the Plurinational State of Bolivia, on 27 March, the Acre River stood at 12.13 m above normal. The Santa Cruz Department reported rising levels

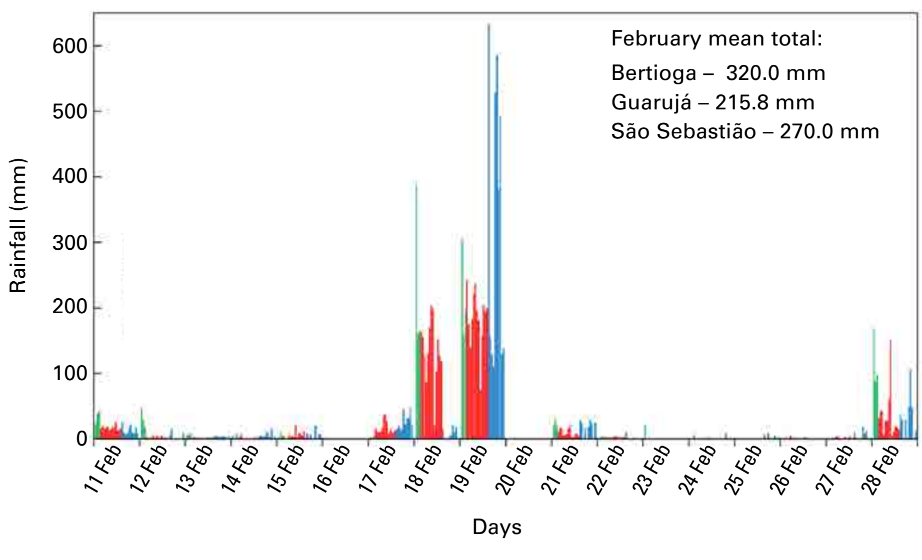

Figure 10. Daily variability of rainfall between 11 and 28 February for São Sebastião (blue bars), Bertioga (green bars) and Guarujá (red bars) in the northern coastal state of São Paulo (Brazil) (each city has several stations, represented by different bars for each day). Units in mm/day. The 2013–2023 monthly mean for the three locations is provided in the upper right "February mean total".

Source: Marengo, J. A; Cunha, A. P.; Seluchi, M. E. et al. Heavy Rains and Hydrogeological Disasters on February 18th–19th, 2023, in the City of São Sebastião, São Paulo, Brazil: From Meteorological Causes to Early Warnings. *Natural Hazards* **2024**. https://doi.org/10.1007/s11069-024-06558-5.

of the Pirai and Rio Grande Rivers from around 20 March and two persons died in the Pirai River. In Brazil, heavy rainfall on 21 April led to flooding and landslides in south Bahía, forcing thousands to leave their homes. As much as 92.9 mm of rain fell in Santa Cruz Cabrália in the 24 hours leading up to 22 April. The following day, the city of Belmonte recorded 216.0 mm, and Porto Seguro 87.9 mm.

The state of Rio Grande do Sul in southern Brazil was affected by intense rain events in 2023. In one of these events the torrential rain, brought by an extra-tropical cyclone, triggered flooding and landslides on 16 June. In total, 49 municipalities in the state were affected by heavy rainfall and strong winds. As much as 300 mm of rain fell in 24 hours in Maquiné. On 4 September, heavy rainfall and flooding led to at least 48 fatalities, 20 978 people displaced and 4 904 homeless. It also caused widespread damage in the state, where several stations reported more than 100 mm of rain in 24 hours, leading to a rise of 12 m in the level of the Taquari River on 6–7 September.[23] Heavy rain continued to affect the state throughout September and early October. On 10 October, 136 out of the 295 municipalities in Santa Catarina were affected by the rains and floods, 89 of which declared a state of emergency.

In late October, intense rain in Foz do Iguaçu, Paraná (Brazil) disrupted the city. The station near the airport recorded approximately 239 mm over three days (27–29 October).[24] Iguaçu Falls had a flow of 24 200 m^3/s on 30 October. According to the Iguaçu National Park administration, this is the highest value recorded in recent years. Usually, the flow of the Falls ranges from 500 m^3/s to 1 000 m^3/s.[25]

In Peru, at least eight people lost their lives in seven departments after heavy rain and flooding associated with Cyclone *Yaku*, starting on 8 March. In Cajamarquilla, a new record daily rainfall amount of 57.4 mm was observed on 10 March. Six fatalities were reported in the department of Piura and over 200 people were displaced.

In Paraguay, heavy rain led to flooding in at least four departments from 25 February. Thousands of families were affected by floods in Concepción, where about 200 mm of rain were measured between 25 and 26 February.[26]

In Argentina, in western Patagonia, rainfall events led to accumulations ranging from around 100 to 800 mm during July. The south-eastern part of the province of Buenos Aires was affected by abundant and intense rains between 2 and 4 July; the city of Mar del Plata accumulated 120 mm throughout the period. On 11 July, Gualeguaychú, in the province of Entre Ríos, recorded 90 mm, a new 24-hour rainfall record for that location. The intense rain raised the level of the Uruguay River, and ferry crossings between Brazil and Argentina were suspended because the safe level was exceeded. Crossings between Brazil and Argentina at the Porto Xavier international port were also suspended due to the rise in the Uruguay River. On 16–17 December, a severe storm affected the city of Bahía Blanca, and later that night the same storm arrived in Buenos Aires, producing strong wind gusts (more than 150 km/h). These gusts were destructive, causing hundreds of trees to fall and massive power outages.

DROUGHTS

Drought affected several countries in the LAC region during 2023. La Niña-related impacts during the first quarter of 2023, and El Niño in the second half of the year, contributed to precipitation deficits, above-average temperatures and recurrent heatwaves, leading to severe droughts in various countries in the region. The Integrated Drought Index (IDI), which combines a

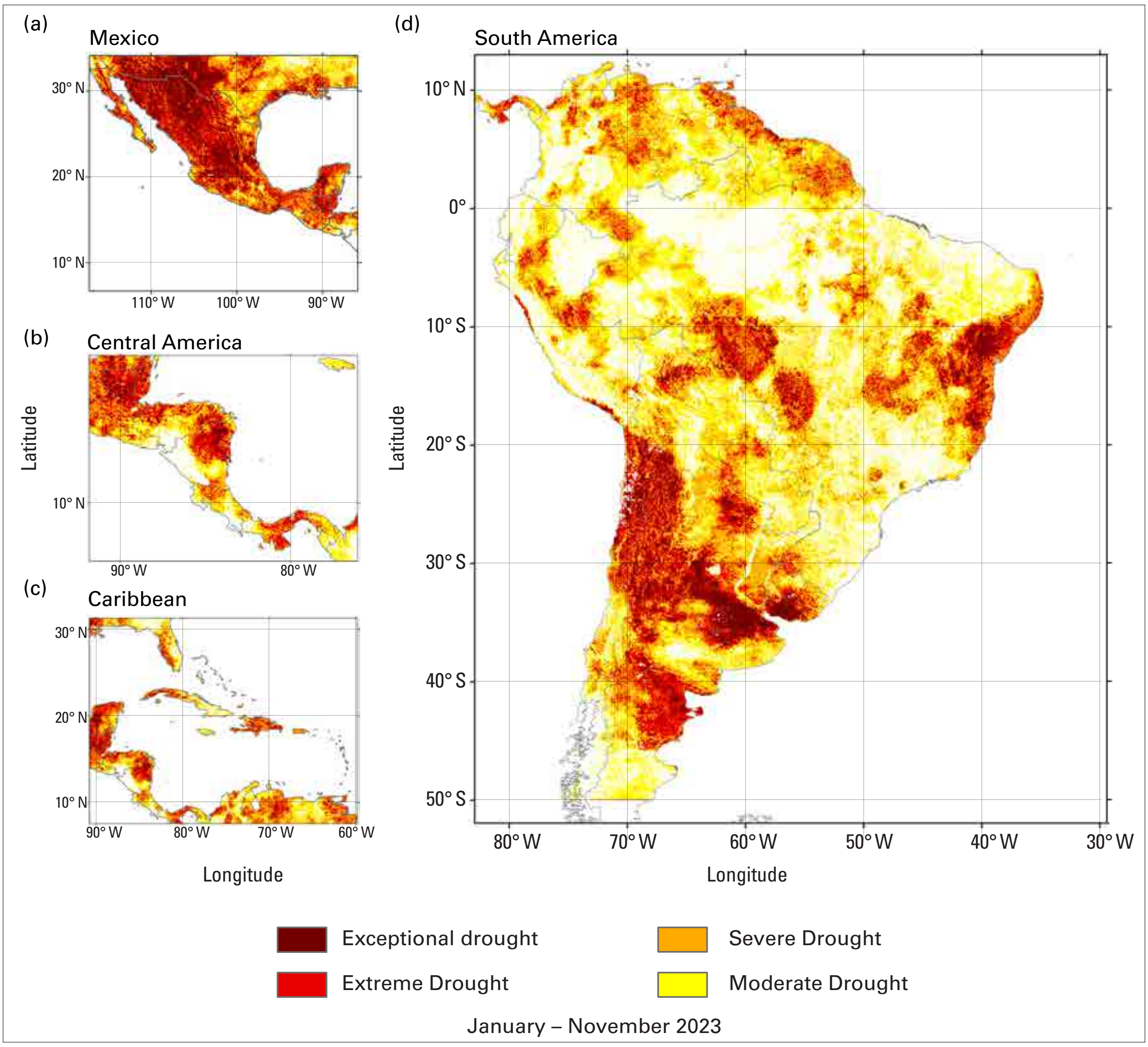

Figure 11. IDI for January–November 2023 in Mexico, Central America, the Caribbean and South America

Source: Standardized Precipitation Index (SPI), calculated from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) and Vegetation Health Index data from the Center for Satellite Applications and Research (STAR/NOAA). The calculation was based on Cunha, A. P. M. A.; Zeri, M.; Deusdará Leal, K. et al. Extreme Drought Events over Brazil from 2011 to 2019. *Atmosphere* **2019**, *10* (11), 642. https://doi.org/10.3390/atmos10110642.

meteorological-based drought index and a remote sensing-based index, was used to provide an integrated assessment of drought conditions in LAC. Figure 11 shows the intensity of the drought by the end of November according to the IDI. Areas affected by severe drought include most of Mexico, central Chile, the Altiplano, western and eastern Amazon, the central and southern Andes, Panama, Nicaragua, Guatemala, El Salvador, central Bolivarian Republic of Venezuela, and the Guianas; areas affected by moderate drought include Cuba, Dominican Republic and Haiti. In Costa Rica, severe drought conditions were detected in the country as reported by the national weather service.

In Mexico, by the end of September, almost 60% of the territory, mostly in central and north-west Mexico, was affected by severe and extreme drought.[27] In some states, such as Durango, San Luis Potosí, Queretaro and Hidalgo, exceptional drought (the highest of the five drought intensity categories) was detected during the second half of the year. In Mexico, 2023 was the driest year on record (records began in 1941).[28] By the end of December, drought conditions affected 76% of the country, including extreme drought across much of central and north Mexico. Rainfall in 2023 was below average through most of Central America. Low water levels restricted traffic in the Panama Canal from August onwards.

Drought became increasingly widespread in the northern half of South America as the year progressed. June–September rainfall was well below average in much of the Amazon Basin, and rivers fell to well below-average levels. Eight Brazilian states recorded their lowest July to September rainfall in over 40 years, with precipitation totals of around 100 to 300 mm/month below normal.[29] According to the Port of Manaus authorities, the level of the Negro River fell to 12.70 m at Manaus (Brazil) on 26 October (Figure 12), the lowest on record (observations started in 1902).[30]

Together with the lack of rainfall in the region, a warmer austral winter and spring were observed in the south-western region of the Amazon, due to a dome of hot and dry air. Six heatwaves affected the region between August and December. In an area neighbouring Manaus, thousands of fish were found floating dead on the surface of Piranha Lake by the end of September. In Tefé Lake, 500 km west of Manaus, more than 150 *botos cor-de-rosa* (an Amazon River dolphin) were found dead in late September, with the potential cause related to the excessive heat, as the water temperature reached a record high 39.1 °C on 28 September. Other main rivers in the Amazon, including the Solimões, Purus, Acre and Branco, suffered extreme drops in their levels in some regions, and dried up completely in others. The level of the Madeira River in Porto Velho (Brazil) was the lowest observed in 56 years of measurements (15 m on

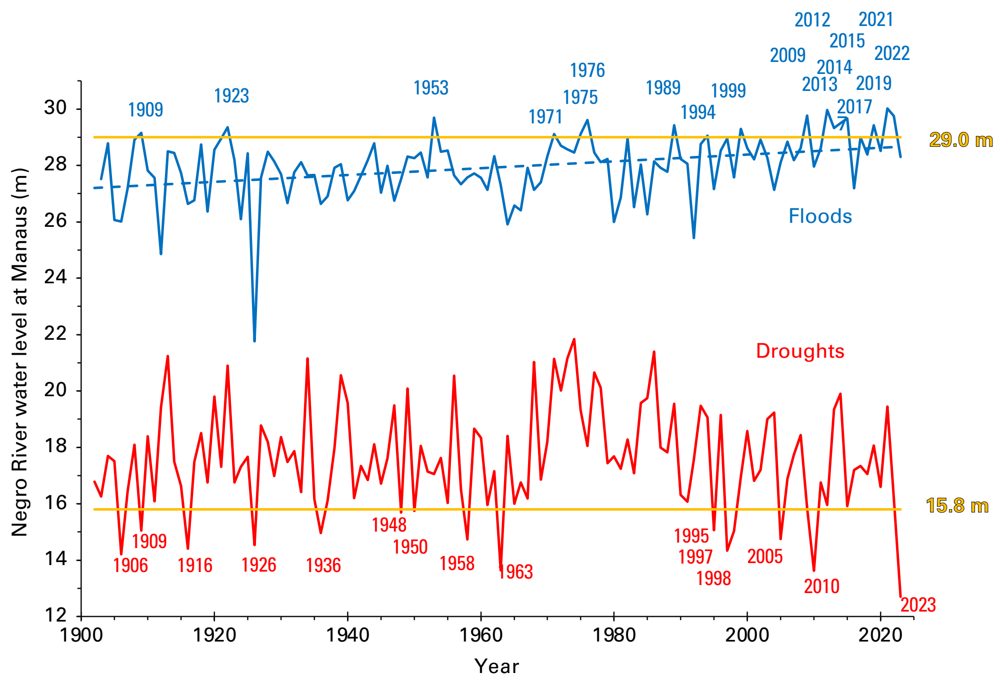

Figure 12. Maximum (blue lines) and minimum (red lines) levels of the Negro River at the Port of Manaus, 1902 to November 2023. Blue and red numbers indicate record floods and droughts, respectively. Orange lines represent the higher (29.0 m) and lower (15.8 m) thresholds to define floods and droughts, respectively. Values are in metres.

Source: J. Schongart, *National Institute for Amazonian Research* (INPA), Brazil

15 October).[31] In the Peruvian Amazon, the flows and levels recorded on the Amazon, Marañón, Huallaga and Ucayalí Rivers were average to much lower than average. The discharge of the Huallaga River at Tingo María (Peru) was 45% below normal in October.[32] In the Plurinational State of Bolivia, the Mamoré, Guaporé and Madeira Rivers remained very low due to deficient rainfall from July 2022 to June 2023.[33]

In the northern and central Bolivian Altiplano, the extreme drought that started in August–September 2022 peaked in January 2023, reducing the yield of potatoes by more than 50% and of some other Andean crops, thus causing very heavy economic losses for many thousands of farmers. According to the meteorological service of the Plurinational State of Bolivia, the lack of water in the country has affected more than 487 000 families. La Paz, Cochabamba, Santa Cruz, Oruro, Chuquisaca, Potosí and Tarija were the most affected departments. By September, the drought in the Altiplano and Valles regions had accelerated the melting of several Andean glaciers, triggering a water crisis in the country.[34]

In Peru, drought prevailed over the Andean region's northern and southern sections. The level of Lake Titicaca was very low in January–April (132 cm below average), lower than in the historical dry period of 1982–1983. This exceptionally low level persisted until October, in both Peru and the Plurinational State of Bolivia, and slightly recovered thereafter. Due to the influence of El Niño, the Puno region has experienced the driest conditions of the last 60 years. The drought affected the population, crops, harvest and regional economy. The lack of water began in 2022, but further intensified with El Niño. It is estimated that the water deficit has generated agricultural losses in Puno of 80% in potato and sweet potato production, and 90% in Andean grains production.[35]

Long-term drought continued in subtropical South America. During the first half of the year, the effects of La Niña were still visible; the cascading impacts from lack of water in the La Plata Basin hit Uruguay, northern Argentina and southern Brazil the hardest. Rainfall from January to August was 20% to 50% below average over much of northern and central Argentina, with some regions experiencing their fourth successive year of significantly below-average rainfall. There were major crop losses in Argentina, with wheat production in 2022–2023 more than 30% below the five-year average. In Uruguay, the summer of 2023 was the driest of the last 42 years on record. Water storage reached critically low levels affecting the quality of potable water for over 60% of the population, including in major centres such as Montevideo. Earlier in June, Uruguay's government declared a water emergency, exempting taxes on bottled water and ordering the construction of a new reservoir.[36] These conditions threatened the economy and ecosystems in South America.[37] Through mid-October in major food-producing areas in eastern Argentina and southern Brazil, the occurrence of rainfall improved conditions but did not completely bring an end to the drought in the area.[38]

In Chile, prolonged dry conditions were partially interrupted by two episodes of intense precipitation in June and August 2023. Some frontal systems reached the southern part of Chile. However, the central region received lower-than-average rainfall. Central Chile had been experiencing warm and dry conditions for at least a decade, but events in 2023 are a good reminder of climate variability, and heavy rains can occur even during a prolonged drought and not be sufficient to end it.[39]

Normal to below-normal conditions were seen throughout the eastern Caribbean over the twelve-month period (according to the Standardized Precipitation Index, January–December 2023). Dominica and Saint Croix were predominantly moderately dry; Guadeloupe, Antigua and Saint Kitts were severely to extremely dry. The southern part of Puerto Rico was severely dry. In Cuba, extremely dry conditions for the 12-month period were observed in west-central areas.[40]

HEATWAVES AND WILDFIRES

Extreme heat was recorded in South America on numerous occasions during the year, leading to health impacts, including excess mortality, and exacerbating drought conditions and wildfires.

The heatwave in Argentina from 28 February to 20 March was an extraordinarily late extreme heat phenomenon, which mainly affected the central zone of the country, but also affected northern and coastal zones. The heatwave was the most extensive experienced in Argentina since the 2013 heatwave, affecting the provinces of Buenos Aires, Santa Fe, Cordoba, and all the northern provinces, with record temperatures in multiple locations. The high temperatures were exceptional for March, when there is usually a drop in temperature corresponding to the beginning of the austral autumn. In Chile, wildfires in the Biobío, Ñuble and La Araucanía regions were described as among the worst in years. The government issued emergency declarations for affected areas to help speed up relief efforts.[41]

Many intense heatwaves affected central South America at the end of the austral winter and in the spring, from August to December. During the second half of August, temperatures in parts of Brazil exceeded 41 °C as South America was hit by scorching weather in the middle of the winter and near-all-time high temperatures were recorded. In Cuiabá, in central-western Brazil, the temperature reached 41.8 °C on 20 August. The heatwave also hit Rio de Janeiro and São Paulo, Brazil's two most populous cities. In Rio de Janeiro, the temperature reached 38.7 °C on 22 August.[42] Many locations in Argentina also saw highs of 30 °C to 35 °C. The temperature in Buenos Aires set a daily record for the start of August, with 30.1 °C, which was more than 9 °C above the previous daily record.[43]

Countries including Brazil, Peru, the Plurinational State of Bolivia, Paraguay and Argentina all recorded their highest September temperatures. This was due to a heat dome, which occurs when high pressure stays over an area and remains there, trapping hot and dry air for a prolonged period. Record high temperatures were set in French Guiana, with 38.8 °C in Saint-Laurent, and in Brazil, with 38.6°C in Belo Horizonte, on 25 September. The heatwave

Amazon forest fire

Credit: SPmemory, iStock

covered most of the Brazil central region, including the western Amazon, where the combination of higher temperature and dry conditions has contributed to one of the worst springtime droughts and some of the lowest river levels this century (see section on Droughts). In Peru, the temperature in Tingo de Ponaza reached 41.4 °C on 27 September. This heatwave was also felt in Bolivia which recorded its all-time highest September temperature of 40.3 °C in Magdalena on 25 September. In Argentina, on 16 October, temperatures reached 45.0 °C in Las Lomitas, 43.8 °C in Resistencia, 43.2 °C in Corrientes and 44.1 °C in Formosa, more than 10 °C above the 1991–2020 monthly normal of 29.0 °C.

In western Paraguay, in the period from 7 to 13 November, the temperature reached 44.5 °C in Mariscal Estigarribia and 42.0 °C in Puerto Casado (the average monthly maximum is 35.1 °C and 33.4 °C, respectively).[44] This same heatwave affected almost all of Brazil, except the southern region, with record temperatures across the country. About 120 stations recorded their highest maximum temperatures on 12 November. The highest maximum was recorded in Rio de Janeiro, which registered 40.4 °C, followed by Cuiabá with 39.6 °C and Teresina with 38.9 °C. São Paulo had the highest maximum in the last nine years, with 37.1 °C on 12 November. According to the Brazilian meteorological service (INMET), Porto Murtinho recorded a maximum of 42.3 °C on 11 November, and the recorded 44.8 °C in Araçuaí (in the state of Minas Gerais) on 19 November was the highest temperature ever recorded in Brazil.

Large wildfires burned across the heat-affected regions in Paraguay, Brazil and the Plurinational State of Bolivia.[45] In the Amazon, 22 061 fire outbreaks were recorded in October, the worst record for the month since 2008,[46] resulting in heavy smoke impacting the entire population of Manaus (over 2 million people).[47]

The boreal summer of 2023 was exceptional for extreme heat over Mexico. Temperatures surpassing 45 °C were recorded in many stations and the highest temperature, 51.4 °C, occurred on 29 August, in Mexicali, in the state of Baja California.[48] According to the Ministry of Health, the number of cases of health impacts related to extreme heat in 2023 doubled those of 2022. From 19 March to 7 October there were 4 306 cases of heatstroke, dehydration and burns associated with extreme heat, and 421 deaths.[49] The most affected states were Nuevo Leon, Tamaulipas, Veracruz, Sonora and 12 others.

COLD WAVES AND SNOW

In Argentina, a mass of cold air of polar origin affected the country causing intense cold from the middle of July. On the morning of 17 July, the temperature reached –22.5 °C in Perito Moreno, in southern Patagonia, Argentina. From 19 to 22 August, heavy snowfall across the central Andes produced between 3 m and 5 m of snow accumulation in the south of Mendoza Province. The nearest city, Malargüe, recorded 60 cm of snowfall, breaking its historical record.

On 18 June, a wave of snow, ice and heavy rain hit the department of Santa Cruz, the Plurinational State of Bolivia's most significant agricultural zone, causing widespread damage to crops and leading to the death of cattle. The cold front extended beyond Santa Cruz, with record-breaking temperatures of –9 °C in the north of the country. Notably, temperatures also took a steep dive in the southern wine-producing department of Tarija, a critical area for the country's winegrowing industry.[50]

Climate-related impacts and risks

Climate-related impacts in the LAC region are associated not only with hazardous events, but also with a complex scenario of increased exposure and vulnerability.[51] The presence of El Niño in the second half of 2023 contributed to the climate-driven impacts (see also Extreme events section). As in previous years, added to this complex scenario are the high and rising food prices, increasing poverty in the context of the post COVID-19 period, high levels of income inequality, and increasing levels of hunger, food insecurity and obesity.[52,53]

AFFECTED POPULATION AND DAMAGES

The present section complements the Extreme events section. Based on information from the Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT),[54] in 2023, 67 meteorological, hydrological and climate-related hazards were reported in the Latin America and the Caribbean region. Of these 67 hazards, 77% were storm- and flood-related events and accounted for 69% of the 909 fatalities documented in this database (Figure 13). The estimated USD 21 billion of economic damage reported to EMDAT was mainly due to storms (66%) (including the USD 12 billion of damages associated with Hurricane *Otis*), floods (16%) and droughts (14%). The actual amount of damage related to the impacts of extreme events is likely to be worse because of under-reporting and because data on impacts are not available for some countries.

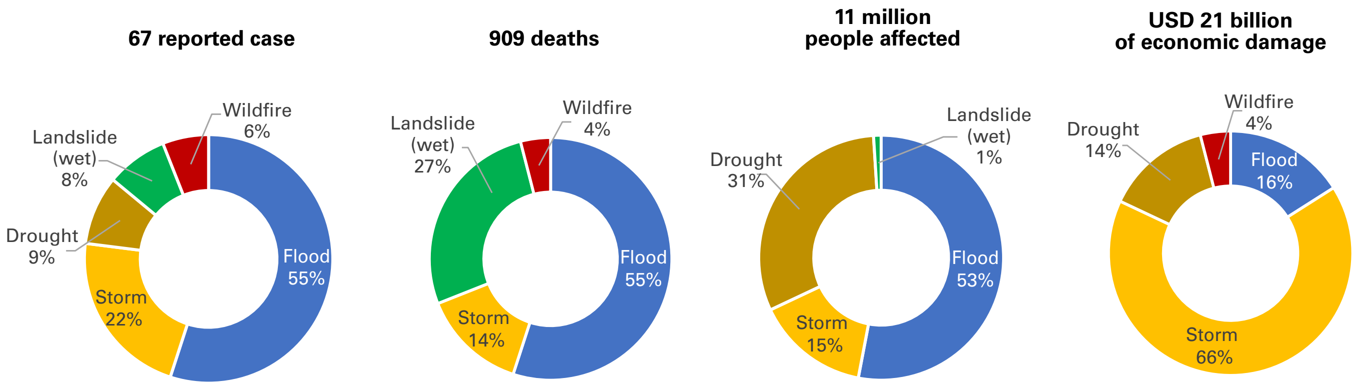

Figure 13. Weather-, climate- and water-related disasters in Latin America and the Caribbean in 2023.
Note: Impact numbers for some disaster occurrences may be lacking due to data unavailability.

Source: CRED EM-DAT, accessed 21 February 2024

AGRICULTURE AND FOOD SECURITY

Disasters and climate change, along with socioeconomic shocks, are the main drivers of acute food insecurity in the region,[55] such that in 2023, 13.8 million people were reported to be in a situation of acute food crisis (Integrated Food Security Phase Classification (IPC) phase 3 or above), especially in Central America and the Caribbean.[56] Extreme weather and climate events linked to climate change impact all pillars of food security (availability, access, utilization and stability).[57] Impacts on agricultural production reduce the availability of food and income, thereby restricting access to food and also leading to a loss of dietary diversity. Today in Latin America and the Caribbean, disasters represent a greater caloric loss than in other regions.[58] Finally, in the face of these shocks, consumers may resort to overstocking, thereby destabilizing food markets. For this reason, the impacts on agriculture continue to have impacts on food and nutritional security, as explicitly reported in the Bolivarian Republic of Venezuela and Colombia in 2023. In other countries in the region, such as in Haiti, violence and governance problems, together with impacts of extreme weather and climate events, are cumulative factors that generate and exacerbate food crises.

Climate change intensifies weather-related impacts such as floods, storms, droughts and extreme temperatures, significantly impacting agriculture[59] and affecting to a greater extent small and medium-sized farms, women and indigenous communities.[60] El Niño conditions during the second half of 2023 contributed to the prolonged droughts in the Central American Dry Corridor and northern South America, and to intense rainfall and flooding along the coasts of Ecuador and Peru, leading to negative impacts on agriculture. Such impacts exacerbated food insecurity, especially in communities reliant on agriculture for their livelihoods, and will likely be felt in 2024 and beyond.[61]

According to the Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) Crop Monitor, crop conditions over the main growing areas are assessed based on a combination of inputs, including remotely sensed data, ground observations, field reports, and national and regional experts. Regions that were in conditions other than favourable are labelled on Figure 14 with a symbol representing the crop(s) affected. At the end of October, conditions for wheat, maize, rice and soybeans remained mixed. Maize prospects improved in parts of the northern hemisphere as the harvesting of crops wrapped up, while the expanding dryness in Argentina was impacting planting.[62]

The latest available data indicates that in 2023, record maize production in Brazil compensated for below-average harvests due to prolonged dry spells elsewhere in South America, especially in Argentina where drought conditions were expected to result in a 15% decrease in cereal production compared with the five-year average.

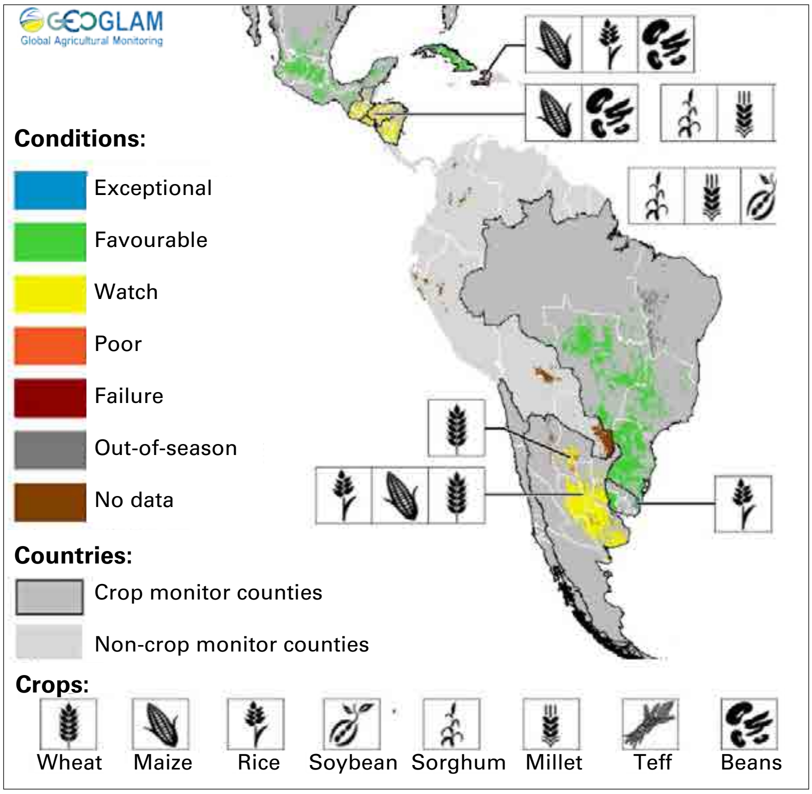

Figure 14. Synthesis map from the Crop Monitor for Agricultural Market Information System (AMIS) report showing crop conditions as of 28 October 2023

Source: https://static1.squarespace.com/static/636c12f7f9c2561de642a866/t/65677cc181d9f979640493cb/1701280965248/AMIS_CropMonitor_202311.pdf

In Brazil, both excess rain and drought, linked to El Niño, set back the soybean planting. The increase in rainfall in southern Brazil should help the 2023/2024 soybean productivity levels to recover and, therefore, avoid greater losses in second-crop corn as well. Wheat production in the state of Paraná fell by 889 000 metric tonnes in relation to potential, and a 30% loss is expected in its wheat harvest, while authorities in the state of Rio Grande do Sul reported a delay in soybean planting. Between 14 and 20 November, the excess moisture in the soil hampered operations to complete soybean planting in south-western Paraná. The climate-related impacts favoured by the La Niña event in the 2022/2023 harvest and by El Niño in the following cycle, generated losses of USD 550 million for agriculture in the state of Paraná. The state of Santa Catarina already estimates a loss of USD 500 million in agriculture. The end of the austral winter crop cycle – wheat, barley and oats – saw a significant reduction in production quantity and quality.[63] As a result of the hail, rain and strong winds that hit Rio Grande do Sul, there were losses related to infrastructure, primary production, livestock and pastures, with 198 municipalities affected and an emergency declared in 115 of them. The main grain crops affected were wheat, soybean, corn, corn silage and rice. Losses in production areas reached 120 600 hectares, with an estimated loss of more than 186 000 metric tonnes.

Ecuador experienced an increase in precipitation linked to El Niño Costero (coastal), affecting the main agricultural cycles.[64] Farmers in the states of Guárico and Apure, in the Bolivarian Republic of Venezuela, face the prospect of a food crisis until May 2024, attributed to the intensification of dry periods linked to El Niño and a lack of water.[65] Uruguay suffered a serious drought until mid-2023, affecting crops, harvests and dairy production.[66] In Argentina, severe floods affected 5 million heads of livestock.[67]

El Niño conditions (increase of sea temperature) also impacted fisheries,[68] reducing tuna catches in Ecuador by 30%,[69] and significantly affecting anchoveta fishing in Peru, both key fishing resources in terms of volume.[70] In Colombia, it is estimated that 8 million people are susceptible to reduced food and nutritional security (FNS) due to El Niño.[71]

In Mexico, a late onset of the rainy season in addition to progressively increasing extreme drought in the vast majority of the territory, impacted rain-fed agriculture. The boreal summer–spring agricultural cycle reported an agricultural performance of nearly 60% for basic grains.[72] Hurricane *Otis* further aggravated some of the impacts.[73]

Overall, harvesting of the main cereal production season (*primera*) was mostly finalized in September under poor conditions in Central America and the Caribbean. In Central America, the rainfall deficit and high temperatures linked to El Niño delayed rainstorms and affected basic grain crops.[74] In Guatemala, this shock affected the agricultural seasons.[75] In El Salvador, Honduras and Nicaragua the delay in the harvest at the end of the year was expected to reduce the income of subsistence homes and commercial production by at least 25%.[76] In December 2023, accumulated losses reportedly continued to hamper the production of the *frijol* bean throughout Nicaragua and Guatemala.[77]

In the Caribbean, in Haiti, 78% of agricultural producers reported that lack of water and/or precipitation was the main difficulty in producing, and 44% reported a decrease in harvesting. The United States Department of Agriculture (USDA) anticipates that the irregular rains and high temperatures of 2023 will reduce corn and rice production by 4%–5%, affecting the seed reserves of small farmers, thus reducing the crop for the boreal spring season of 2024.[78] In August, Hurricane *Idalia* damaged plantations of plane trees, yuca and sweet potato (camote) in Cuba. At the end of November, rains and floods in the Dominican Republic affected more than 7 000 agricultural producers, with damage estimated at more than USD 460 million.[79]

HEALTH

The LAC region faces increased health risks due to population exposure to heatwaves, wildfire smoke, sand dust and aeroallergens leading to cardiovascular and respiratory problems, as well as rising food insecurity and malnutrition. These health risks are projected to increase the disability-adjusted life years (DALYs) by 10% by 2050.[80] In the 2013–2022 period, in Latin America, people older than 65 years experienced an average of 271% more days of heatwave per year than in 1986–2005. This was associated with an increase in heat-related mortality of 140% from 2000–2009 to 2013–2022.[81] In Latin America and the Caribbean, an estimated 36 695 (20 064– 59 526) annual heat-related excess deaths occurred between 2000 and 2019.[82] Furthermore, there are indirect impacts, as heatwaves affect key infrastructure such as water and energy systems, further affecting livelihoods, particularly in marginalized areas.

Air pollution, often worsened by climate change, is a serious health threat, with over 150 million people in the LAC region living in areas exceeding World Health Organization (WHO) air quality guidelines. In 2020, a rise in premature deaths linked to ambient $PM_{2.5}$, exacerbated by increasing wildfires and ozone levels, was reported in South America.[83]

In addition to the direct health impacts, changing rainfall patterns and warming temperatures due to climate change are altering the geographic distribution of diseases transmitted by water, air and soil. In some cases, the geographic range has expanded into areas of higher elevation in the tropical Andes and into southern temperate latitudes, in the southern cone of South America. For example, in 2023 the first cases of chikungunya were reported in Uruguay, and Chile issued alerts due to the expanded presence of the *Aedes aegypti* mosquito vector that transmits arboviruses.[84,85] In 2019, over 3 million cases of dengue were reported in the Americas, the highest number on record. However, this number was already exceeded in the first 7 months of 2023, setting a new record for the Americas.[86]

Alter do Chao beach along the dry Tapajos River, impacted by the 2023 drought in the Amazon

Credit: Tarcisio Schnaider (Brazil)

Enhancing climate resilience and adaptation policies for health

STRENGTHENING CLIMATE–HEALTH COOPERATION

The integration of climate and health sciences and services is vital in order to address growing health risks from climate extremes, climate variability and change, ecosystem change and the deepening social inequalities that increase vulnerability.[87] Effective climate-informed early warning systems (EWSs) go beyond infrastructure; they demand a multifaceted health sector response. To optimize climate services for public health, enhancements in data infrastructure and cooperation between health, climate services and other key sectors are essential, as is training across the climate and health sectors. An EWS should activate a range of health sector responses, including healthcare worker training, capacity enhancement of health systems to mobilize first responders, and strengthening of epidemiological and entomological teams if needed. It should also increase lab analysis capacity, enhance risk communication and ensure adequate infrastructure to support these actions. This holistic approach not only bolsters public health resilience but also lays the groundwork for health and climate change observatories.

An example of a relevant joint initiative by the World Health Organization (WHO) and WMO is the ClimaHealth platform,[88] whose goal is to facilitate access to actionable knowledge in order to protect populations from the health risks of climate change and other environmental hazards, and to serve as a technical reference point for users of interdisciplinary health, environmental and climate science.

At the United Nations 2023 Climate Change Conference, COP28, 124 countries, including 17 from the LAC region, endorsed a Declaration on Climate and Health, advocating for health benefits through substantial greenhouse gas reductions. This includes promoting just transitions, cleaner air, active lifestyles and sustainable diets.[89] These actions include shared goals of strengthening climate–health information services, surveillance, early warning and response

San Juan River in Matanzas, Cuba
Credit: Anabel del rio Viamonte (Cuba)

systems, and cultivating a climate-ready health workforce. Emphasizing intersectoral cooperation and governance, the commitments in the Declaration on Climate and Health extend across various levels to deliver comprehensive solutions. Additionally, there is a dedicated effort towards climate-resilient health systems, ensuring their adaptability to evolving challenges.

In the Americas, strides are being made to increase health sector resilience to climate change. Twelve of thirty-five countries are developing Health National Adaptation Plans (HNAPs), while nine have completed and six are developing Vulnerability and Adaptation Assessments (V&As). While South American countries acknowledge the health impacts of climate change in their plans, enhancing public health protection requires maximizing climate policy benefits and including health-related issues across all relevant sectors.[90] The collaborative efforts in developing HNAPs and V&As are promising signs of tackling climate challenges. However, there is still a significant gap in effective adaptation responses, particularly for vulnerable populations, and very limited climate financing focused on health sector adaptation.[91]

The Nationally Determined Contributions (NDCs) submitted by LAC countries have placed significant emphasis on adaptation. The submitted NDCs have identified water, agriculture and health as priority areas of focus with regard to adaptation. In terms of health, 9 (30%) of the 30 reviewed NDCs have identified vector-borne diseases as one of the climate health risk areas of concern in the region. This is followed by injury and mortality from extreme weather events and heat-related illnesses (Figure 15). Despite some NDCs now including health aspects, overall progress is slow and the health sector is still lagging in climate change adaptation.[92]

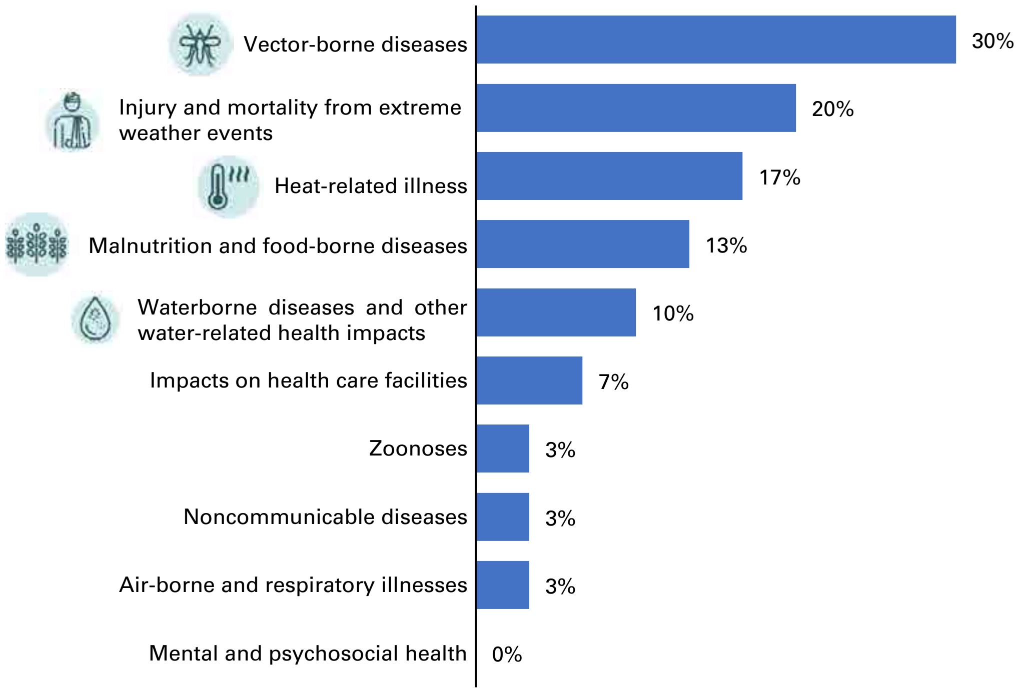

Figure 15. Percentage of WMO Members from the LAC region that refer to climate-sensitive health risks or outcomes. Note: Percentages in the chart are based on the 30 Members whose NDCs were reviewed.

Source: Readapted by WMO, based on data in: World Health Organization (WHO). *2023 WHO Review of Health in Nationally Determined Contributions and Long-term Strategies: Health at the Heart of the Paris Agreement*; WHO: Geneva, 2023. https://iris.who.int/handle/10665/372276.

WEATHER AND CLIMATE SERVICES CAPACITIES

Climate services are the provision and use of climate data, information and knowledge to assist decision-making. Climate services require appropriate engagement between the recipient of the service and its provider, along with an effective access mechanism to enable timely action.[93] Based on the available data from 32 WMO Members from the LAC region, 16 (50%) Members are currently providing climate services at essential/full capacities, as illustrated in Figure 16. This finding underscores the commitment and capabilities within the region to provide climate services.

Specifically, some climate services for health may be developed in a form of partnership, defined as the iterative process of collaboration between relevant transdisciplinary partners to identify, generate and build capacity to develop, deliver and use relevant and reliable climate knowledge to enhance decision-making and action in the health sector. Examples of climate products and services may include monitoring and warning systems for population exposure to wildfire smoke or early warning systems for extreme temperatures.[94] The ClimaHealth platform also includes the countries' climate services profile pages and reference to WMO Health Focal Points.

The provision of data services for the health sector is provided by 63% of WMO Members from the LAC region, however only less than half of the Members are providing climate projections

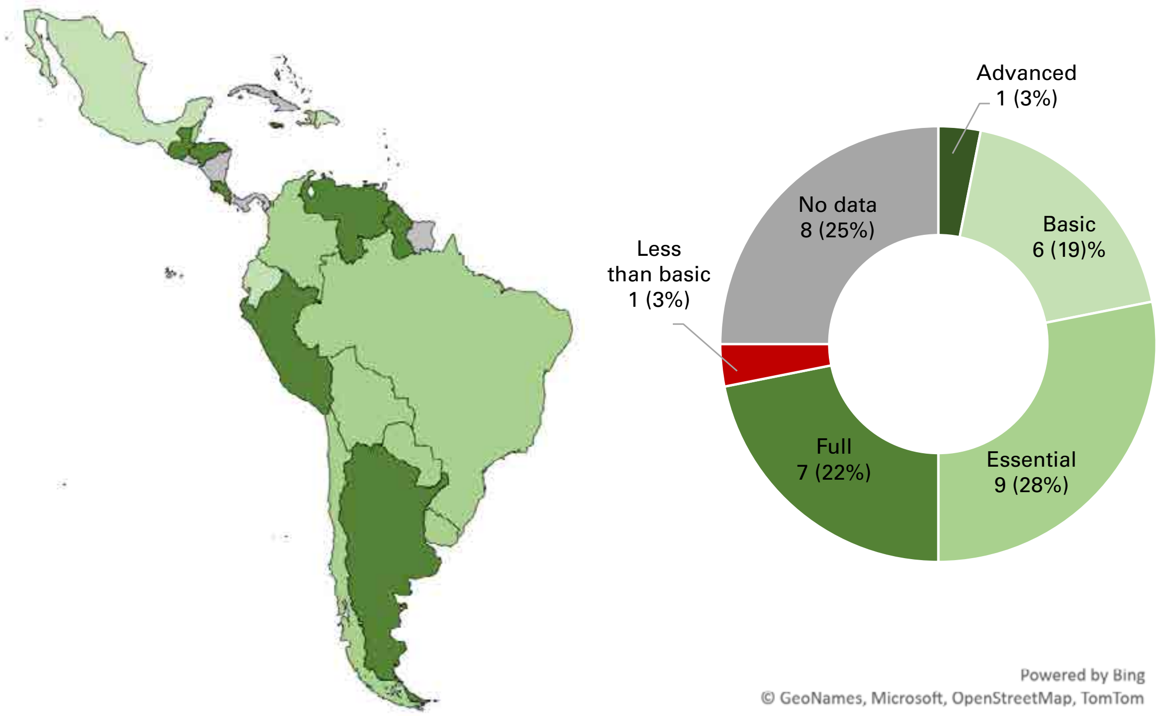

Figure 16. Overview of generalized climate services capacities (not sector specific). The information in the figure represents 32 WMO Members whose data have been validated by internationally certified auditors.

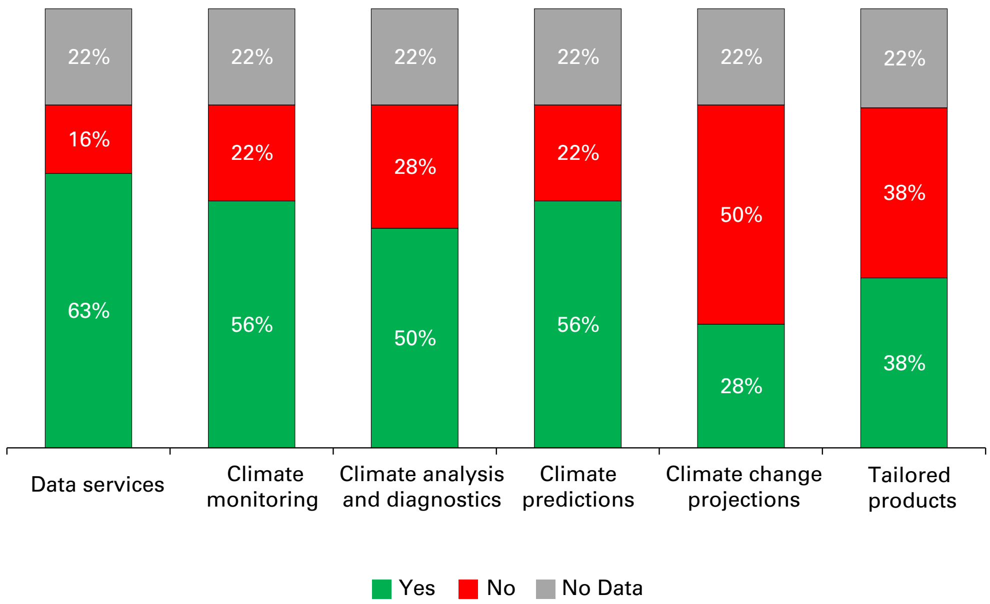

Figure 17. Breakdown of the diverse range of climate services provided by NMHSs to the health sector in the LAC region

Note: Percentages are based on the 32 WMO Members from the LAC region.

and tailored products. It is pertinent to note that most of the services provided are still not sector tailored, as only 38% of Members in the region indicated providing tailored products for the health sector (Figure 17). The National Meteorological and Hydrological Services (NMHSs)' self-reported level of service provision to the health sector was evaluated on a scale of 1–6, with 1 corresponding to "initial engagement" and 6 to "full engagement". This scale was used to assess the level of socioeconomic benefits achieved and documented. The average score was reported to be 3.1 out of 6 for the region, which suggests that most of the engagement is at the initial stage (1–3), where definition of needs is prioritized, rather than at the stage of providing tailored products and services (4–6).

The 2021 Pan American Health Organization (PAHO) survey shows advancements in Latin America, with 17 countries integrating meteorological data into health surveillance, focusing on diseases and extreme weather impacts.[95] This reflects a move towards stronger public health strategies amid climate issues.

Moreover, there has been progress in setting up a National Framework for Climate Services[96] (NFCS) in various Member countries in the region, as a mechanism to promote coordination, governance and collaboration to improve the development, delivery and use of climate services at the country level, to support decision-making. Recent data indicate that 16 Member countries in the region are in the process of establishing their respective NFCS.

Weather services are instrumental to safeguarding public health by providing timely and accurate information, thereby empowering both communities and individuals to effectively prepare for and respond to weather-related risks within a short timescale of less than 30 days. The crucial role of weather services lies in their ability to offer insights into upcoming weather conditions, which is vital for planning and mitigating the potential impacts on health and safety. However, despite their significance, the available data reveal a notable gap in the level of services provided by NMHSs. Only 6% of the WMO Members from the LAC region provide "full or advanced" weather services, indicating a comprehensive range of information and

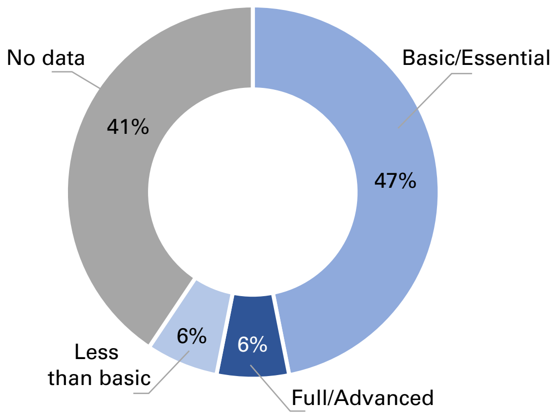

Figure 18. Overview of generalized weather services capacities (not sector specific).

Note: Percentages are based on the 32 WMO Members from the LAC region.

advanced capabilities. In contrast, 47% provide only "basic or essential" weather services, suggesting limitations in the scope and depth of the information available to the public and relevant authorities (Figure 18).

The results highlight the need for substantial improvements and investments in weather services infrastructure. However, it is important to note that a significant percentage of responses fall into the category of "No data", making these findings highly dependent on the countries/territories that responded to the survey. Achieving a higher percentage of NMHSs offering "full or advanced" services is essential to enhance the overall preparedness and resilience of communities and individuals in the face of weather-related risks. Such advancements would ensure that a broader array of information, including more sophisticated forecasts, is accessible to the public, enabling better decision-making and response strategies to protect public health and safety. As extreme weather events become more intense and impactful due to climate change, the importance of strengthening and expanding advanced weather services cannot be overstated.

Datasets and methods

TEMPERATURE

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

1. Read the gridded dataset;

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 get 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 the anomalies relative to that base period.

The following six datasets 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.

GISTEMP v4 – GISTEMP Team. *GISS Surface Temperature Analysis (GISTEMP), version 4*. NASA Goddard Institute for Space Studies, 2022. 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. The data are available here.

HadCRUT.5.0.2.0 – 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*. https://doi.org/10.1029/2019JD032361. HadCRUT.5.0.2.0 data were obtained from http://www.metoffice.gov.uk/hadobs/hadcrut5 on 17 January 2024 and are © British Crown Copyright, Met Office 2024, provided under an Open Government Licence, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/.

JRA55 – Kobayashi, S.; Ota, Y.; Harada, Y. et al. The JRA55 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 v5.1 – NOAA Interim: Vose, R. S.; Huang, B.; Yin, X. et al. Implementing Full Spatial Coverage in NOAA's Global Temperature Analysis. *Geophysical Research Letters* **2021**, *48*. https://doi.org/10.1029/2020GL090873. The data are available here.

Temperature in situ data from National Meteorological and Hydrological Services were also used.

PRECIPITATION

Precipitation in situ data from National Meteorological and Hydrological Services were used.

GLACIERS

Glacier mass balance data for 22 monitored glaciers in the Andes were obtained from the World Glacier Monitoring Service (WGMS), https://www.wgms.ch.

SEA-SURFACE TEMPERATURE

Sea-surface temperature anomalies were processed by CIIFEN using data from the NOAA/NCEP Global Ocean Data Assimilation System (GODAS).

SEA LEVEL

Regional sea-level trends are based on gridded C3S altimetry data averaged from 50 km offshore to the coast by the Laboratory of Space Geophysical and Oceanographic Studies (LEGOS).

FLOODS

Data from National Meteorological and Hydrological Services and from United Nations organizations were used, as well as data from https://floodlist.com/.

DROUGHT

The Integrated Drought Index (IDI) uses Standardized Precipitation Index (SPI) data calculated using Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) and the Vegetation Health Index from the Center for Satellite Applications and Research (STAR/NOAA).

Drought data were also provided by the United States Drought Monitor (USDM) https://droughtmonitor.unl.edu/.

WILDFIRES

Active fire data for South America come from NASA satellite images (MODIS-AQUA) processed by the Brazilian National Institute for Space Research (INPE).

COLD WAVES

In situ data from National Meteorological and Hydrological Services were used.

CLIMATE SERVICES

2023 State of Climate Services: Health (WMO-No. 1335).
2020 State of Climate Services: Risk Information and Early Warning Systems (WMO-No. 1252).
WMO analysis of the NDCs of the parties to the Paris Agreement, complemented by the United Nations Framework Convention on Climate Change (UNFCCC) synthesis report: *Nationally Determined Contributions Under the Paris Agreement: Synthesis Report by the Secretariat*. Readapted from WMO based on data from World Health Organization (WHO). *2023 WHO Review of Health in Nationally Determined Contributions and Long-term Strategies: Health at the Heart of the Paris Agreement*; WHO: Geneva, 2023. https://iris.who.int/handle/10665/372276.
Checklist for Climate Services Implementation (Climate Services Dashboard)

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Endnotes

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