State of the Climate in Latin America and the Caribbean

2020

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

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Key Messages

The year 2020 was one of the three warmest years on record for Mexico/Central America and the Caribbean, and the second warmest year for South America. Temperatures were 1.0 °C, 0.8 °C and 0.6 °C above the 1981–2010 average, respectively.

In the Chilean and Argentine Andes, glaciers have been retreating during the last decades. Ice mass loss has accelerated since 2010, in line with an increase in seasonal and annual temperatures and a significant reduction in annual precipitation in the region.

The intense drought in southern Amazonia and the Pantanal was the worst in the past 60 years, and 2020 surpassed 2019 to become the most active fire year in the southern Amazon.

Widespread drought across the Latin America and the Caribbean region has had significant impact on inland shipping routes, crop yields and food production, leading to worsening food insecurity in many areas. Precipitation deficits are particularly adverse in the Caribbean region, which presents high vulnerability to drought and has several of its territories on the global list of the most water-stressed countries, with less than 1 000 m^3 freshwater resources per capita.

Hurricanes *Eta* and *Iota* reached category 4 intensity and made landfall in the same region in quick succession; they followed identical paths across Nicaragua and Honduras, affecting the same areas and exacerbating related impacts.

Marine life, coastal ecosystems and the human communities that depend on them, particularly in Small Island Developing States, are facing increasing threats from ocean acidification, sea-level rise, warming oceans, and more intense and frequent tropical storms.

Adaptation measures, particularly multi-hazard early warning systems, are underdeveloped in the Latin America and the Caribbean region. Support from governments and the science and technology community is critical to strengthening their development, as well as to improving data collection and storage and firmly integrating disaster risk information into development planning. Strong financial support is fundamental to achieving this outcome.

Foreword

The State of the Climate (SoC) in Latin America and the Caribbean (LAC) report for 2020 is the first report of its kind to be released, under the auspices of the WMO Regional Association of South America and the Regional Association of North America Central America and the Caribbean. It focuses on a set of up-to-date key climate indicators, climate trends, and extreme weather and climate events which were recorded in 2020. The report aims at providing science-based knowledge that can contribute to informing decision making in climate change mitigation and adaptation.

Increasing temperatures, glaciers retreat, sea level rise, ocean acidification, coral reefs bleaching, land and marine heatwaves, intense tropical cyclones, floods, droughts, and wildfires have been highlighted in this report, which primarily affected the region in 2020, with impacts to most vulnerable communities, among which are the Small Islands Development Countries.

Based on the existing research and studies provided by various institutions in the region, the report made also an emphasis on enhancing climate resilience through identified pathways, such as ecosystem-based responses and enhancing climate services and multi-hazard early warning among other areas of improvement.

I take this opportunity to congratulate all individuals and institutions who contributed to this report and thank sister United Nations agencies for joining efforts and delivering this highly informative report.

(P. Taalas)
Secretary-General

Overview

State of the Climate in Latin America and the Caribbean 2020 represents the first multi-agency effort involving National Meteorological and Hydrological Services (NMHSs), WMO Regional Climate Centres (RCCs), research institutions, and international and regional organizations. A multidisciplinary group of 40 experts developed and reviewed this report through an interactive process coordinated by the WMO Offices for Regional Association III and Regional Association IV.

This report provides a snapshot of climate trends, variability, observed high-impact weather and climate events, and associated risks and impacts in key sensitive sectors for the period January–December 2020. It is the result of a collaboration among countries, presenting information from various independent sources to assess weather, hydrology and climate conditions in the region. It includes transboundary analyses, including of the drought in the South American Pantanal and of the intense hurricane season in Central America and the Caribbean and associated impacts. In addition, the report identifies areas for improvement in the management of hydrometeorological risks and data, and knowledge gaps.

The findings presented in this report are based on a standard methodology for assessing the physical aspects of the climate system, drawing on data from 1700 meteorological stations in Mexico, Central America and the Caribbean, and from gridded data for South America. The data were compiled through a joint effort by WMO RCCs. Anomalies and percentages were derived for air temperature and rainfall data relative to the 1981–2010 reference period. National and international institutions provided additional information and data. In some cases, auxiliary information was obtained from local and national news from newspapers, websites and social networks.

High-impact events affecting the region in 2020 were associated with loss of or damage to vital infrastructures of communities and populations. Notable impacts included water and energy-related shortages, displacement, and compromised population safety, health and livelihoods. Towards the end of 2020, intense rainfall events brought landslides, floods and flash floods to rural and urban areas in Central and South America. A weak North American monsoon and colder-than-normal sea-surface temperatures along the eastern Pacific associated with La Niña resulted in drought in Mexico. The devastation that resulted from Hurricanes *Eta* and *Iota* in Guatemala, Honduras, Nicaragua and Costa Rica, and the intense drought and unusual fire season in the Pantanal region of Brazil, the Plurinational State of Bolivia, Paraguay and Argentina, demonstrate the critical need for operational and scientific collaboration, and for continuous data exchange, in order to better characterize those phenomena and their impacts. These impacts were exacerbated by the COVID-19 outbreak. From the various analyses provided in this report, it is evident that urgent efforts should be pursued to enhance resilience through appropriate prevention and risk-management measures. These include strengthening multi-hazard early warning systems (MHEWSs), through enhanced synergy among various stakeholders at the national and international levels, to save lives and protect property.

Global Climate Context in 2020

TEMPERATURE

The global mean temperature in 2020 was one of the three warmest since the observation period. The past six years, including 2020, have been the six warmest years on record (Figure 1). Rising temperatures contribute to ocean thermal expansion, the increased melting of ice sheets in Greenland and Antarctica, mountain glacier melt and changes in ocean circulation, which in turn contribute to rising global mean sea level. Such changes in these and other climate indicators are largely driven by accumulating greenhouse gases in the atmosphere.

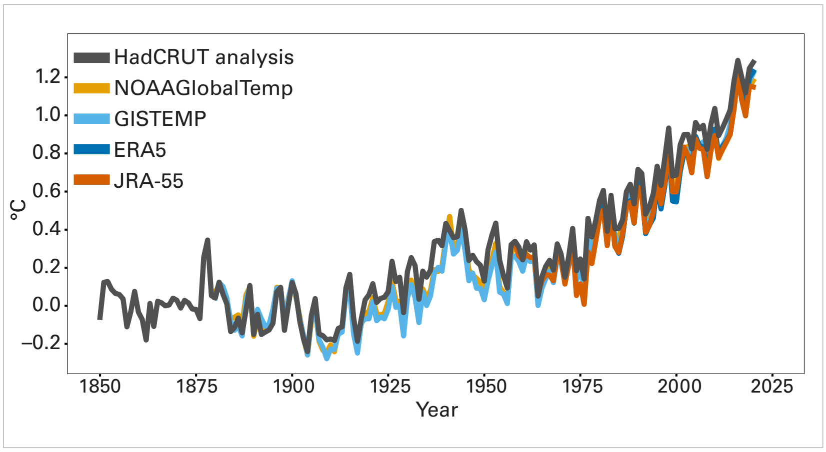


Figure 1. Global annual mean temperature difference from pre-industrial conditions (1850–1900) for five global temperature data sets. For further explanation and details of the data sets, see WMO, *State of the Global Climate 2020* (WMO-No. 1264). *Source:* Met Office, United Kingdom

GREENHOUSE GAS CONCENTRATIONS

Globally, atmospheric concentrations of greenhouse gases reflect a balance between emissions (from both human activities and natural sources) and sinks in the biosphere and ocean. Despite a temporary reduction in emissions in 2020 related to measures taken in response to COVID-19[1,2,3,4], the resulting likely slight decrease in the annual growth rate of carbon dioxide (CO_2) concentration in the atmosphere will be practically indistinguishable from the natural interannual variability driven largely by the terrestrial biosphere. Real-time data from specific locations, including Mauna Loa (Hawaii) and Cape Grim (Tasmania), indicate that levels of CO_2, methane (CH_4) and nitrous oxide (N_2O) continued to increase in 2020 (Figure 2).

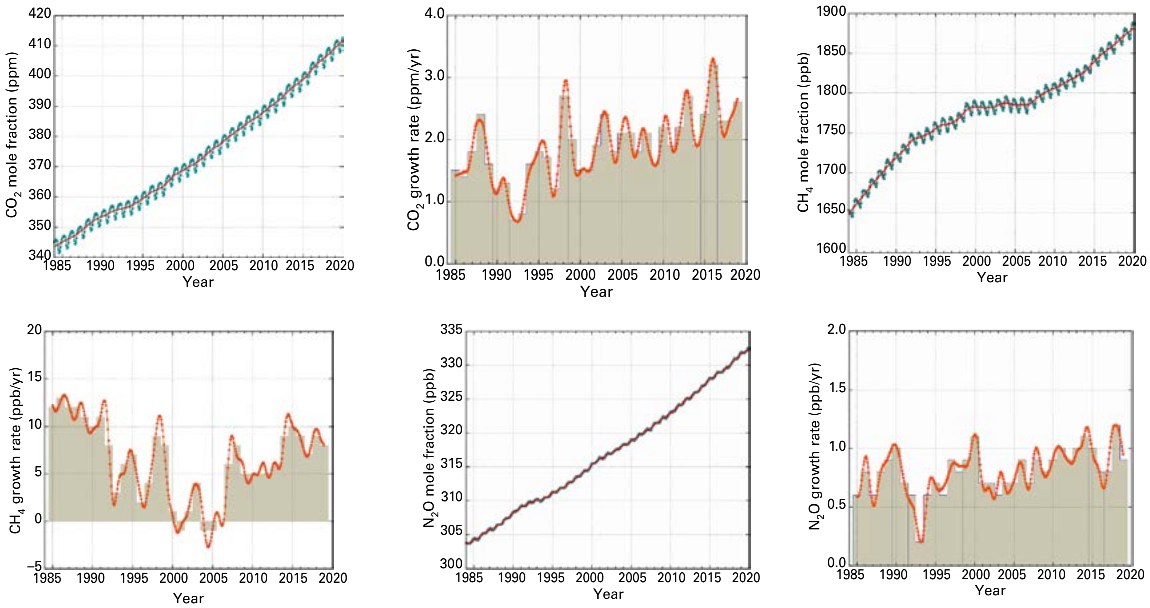


Figure 2. Top row: Globally averaged mole fraction (measure of concentration), from 1984 to 2019, of CO_2 in parts per million (left), CH_4 in parts per billion (centre) and N_2O in parts per billion (right). The red line is the monthly mean mole fraction with the seasonal variations removed; the blue dots and line show the monthly averages. Bottom row: The growth rates representing increases in successive annual means of mole fractions are shown as grey columns for CO_2 in parts per million per year (left), CH_4 in parts per billion per year (centre) and N_2O in parts per billion per year (right).
Source: WMO Global Atmosphere Watch

1 Liu, Z. et al., 2020: Near-real-time monitoring of global CO_2 emissions reveals the effects of the COVID-19 pandemic. *Nature Communications*, 11(1): 5172, https://doi.org/10.1038/s41467-020-18922-7.

2 Le Quéré, C. et al., 2020: Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement. *Nature Climate Change*, 10: 647–653, https://www.nature.com/articles/s41558-020-0797-x.

3 Friedlingstein, P. et al., 2020: Global Carbon Budget 2020. *Earth System Science Data*, 12(4): 3269–3340, https://doi.org/10.5194/essd-12-3269-2020.

4 Global Carbon Project, 2020: An annual update of the global carbon budget and trends, https://www.globalcarbonproject.org/carbonbudget.

Latin America and the Caribbean

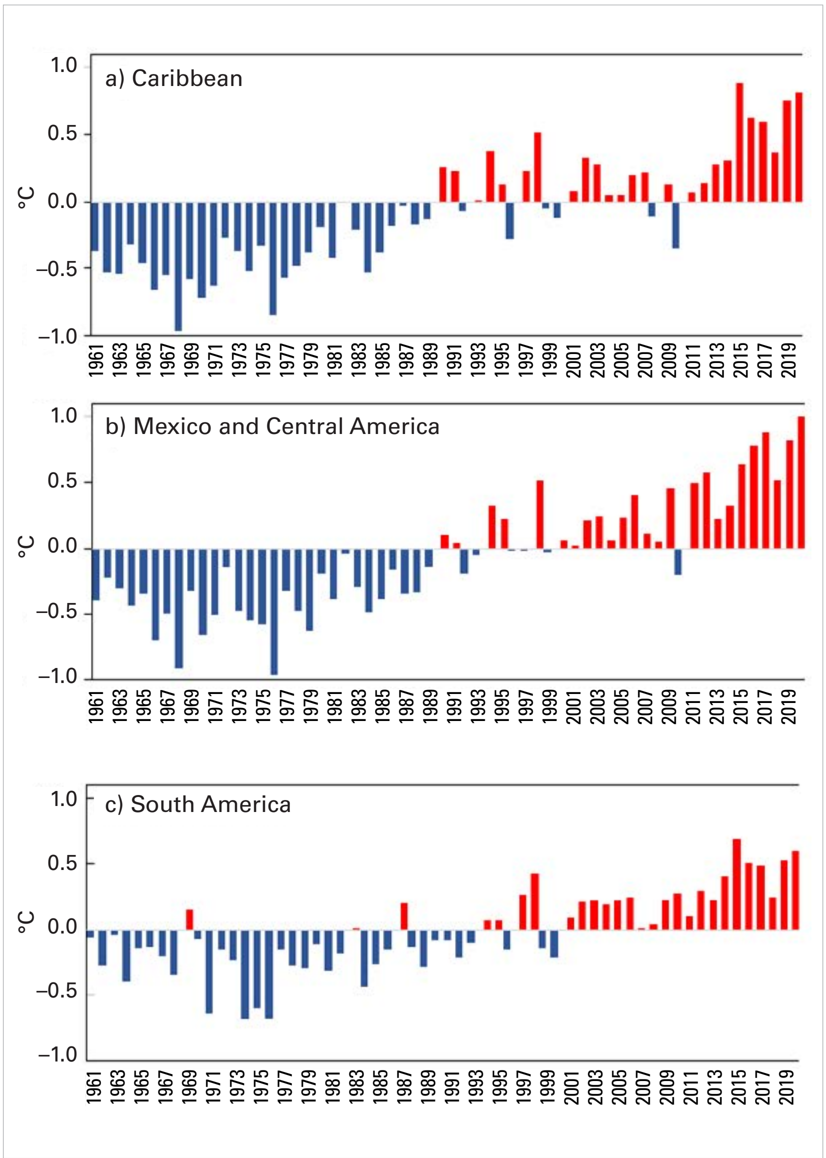
TEMPERATURE

The year 2020 was one of the three warmest years on record for the Caribbean and Mexico/Central America, with a mean temperature anomaly of +0.8 °C and +1.0 °C, respectively, compared with the average temperature for the 1981–2010 period. For South America, 2020 was the second warmest year on record after 2016, with +0.6 °C compared with 1981–2010 (Figure 3).

In nearly all the Caribbean islands, temperatures were warmer than average, especially the Bahamas, Belize, the Cayman Islands, Cuba, French Guiana, Jamaica, Puerto Rico, the United States Virgin Islands and the southern half of the Lesser Antilles (Caribbean Climate Outlook Forum). Throughout 2020, monthly mean temperatures were also higher than normal in nearly all of the Caribbean region. In addition, most of Mexico and Central America had above-normal mean temperatures for the year.

Below-normal temperatures were recorded in parts of Central America, in southern Belize, eastern Costa Rica, southern El Salvador and north-eastern Nicaragua, as well as in Mexico, mainly in the west.

Figure 3. Time series of annual mean regional air temperature anomalies from 1961 to 2020. Anomalies are relative to the 1981–2010 average. *Source:* HadCRUT version 4.



REGIONAL TEMPERATURE ANOMALIES

Caribbean

For Aruba, Dominica and locations in four other island countries, 2020 was the warmest year on record. Moreover, a high number of hot days (i.e. days with a maximum temperature exceeding the 90th percentile across the 1985–2014 period) were recorded in three island countries/territories. In 2020, mean temperatures in Grenada, Saint Kitts and Nevis, and locations in Guyana, Jamaica, Martinique, Puerto Rico and Saint Lucia were their highest on record.

In 2020, several monthly heat records were broken in the Caribbean. Dominica, Grenada and Puerto Rico broke their national/territorial all-time high temperature records in September. The historical highest monthly mean maximum temperature was also observed in September, in Aruba, Saint Lucia and at least one location in Martinique.

On 9 April 2020, Guáimaro, Cuba, registered 39.2 °C (the previous record was 38.0 °C on 17 April 1999). In Belize, the highest daily maximum temperature was recorded at the Punta Gorda station, with a value of 35.6 °C on 4 January 2020, and the Tower Hill station recorded the highest monthly mean maximum temperature of 30.7 °C.

Mexico and Central America

The warmest daily mean temperatures on record were exceeded in most of Belize, Guatemala and Cuba, as well as in some places in Mexico.

Several locations in Honduras and Mexico surpassed the previous record for daily maximum temperatures. In Santa Rosa de Copán, Honduras, a new record of 39.6 °C (compared with the previous 36.2 °C) was set. In Oaxaca, Mexico, a new record of 44 °C (compared with the previous 40 °C) was established.

In Mexico, the previous record for the coldest daily mean temperature was broken on 19 January, with –16 °C in the town of La Rosilla (municipality of Guanaceví, state of Durango), the lowest that has ever been recorded by the National Water Commission (CONAGUA). New records for daily minimum temperatures were registered only in locations across Mexico, such as in Tamaulipas, Sinaloa and Chihuahua. Many other locations in Mexico broke previous cold temperature records, including in Sonora where a temperature of –9.5 °C broke the previous record of –6 °C.

South America

A major heatwave stretched across the region in late September and early October, and in November, covering much of central South America, the Peruvian Amazon, the Pantanal and the regions of west-central and south-eastern Brazil. Cuiabá, Curitiba and Belo Horizonte (Brazil); Asunción (Paraguay); and Iñapari (Peru) were among the locations which had their hottest day on record. Higher temperatures and heatwaves in west-central, southern and south-eastern Brazil contributed to the development of wildfires. Moreover, a number of cold waves were detected in south-eastern South America, with cooling reaching western Amazonia in August 2020 (see Extreme events).

In Peru, the 2020 annual mean temperature anomaly was 0.61 °C above the 1981–2010 mean, the third warmest annual value since 2000, after +0.79 °C in 2016 and +0.74 °C in 2015 (Servicio Nacional de Meteorología e Hidrología (SENAMHI-Peru)). In Argentina, the average annual temperature for 2020 was 0.63 °C warmer than the 1981–2010 reference period, making 2020 the second warmest year on record since 1961 (National Meteorological Service (SMN)). In Paraguay, temperatures were well above normal, between 0.5 °C and 1.0 °C warmer than the 1981–2010 average, particularly in the northern region (Dirección de Meteorología e Hidrología (DMH)) (see Figure 4c).

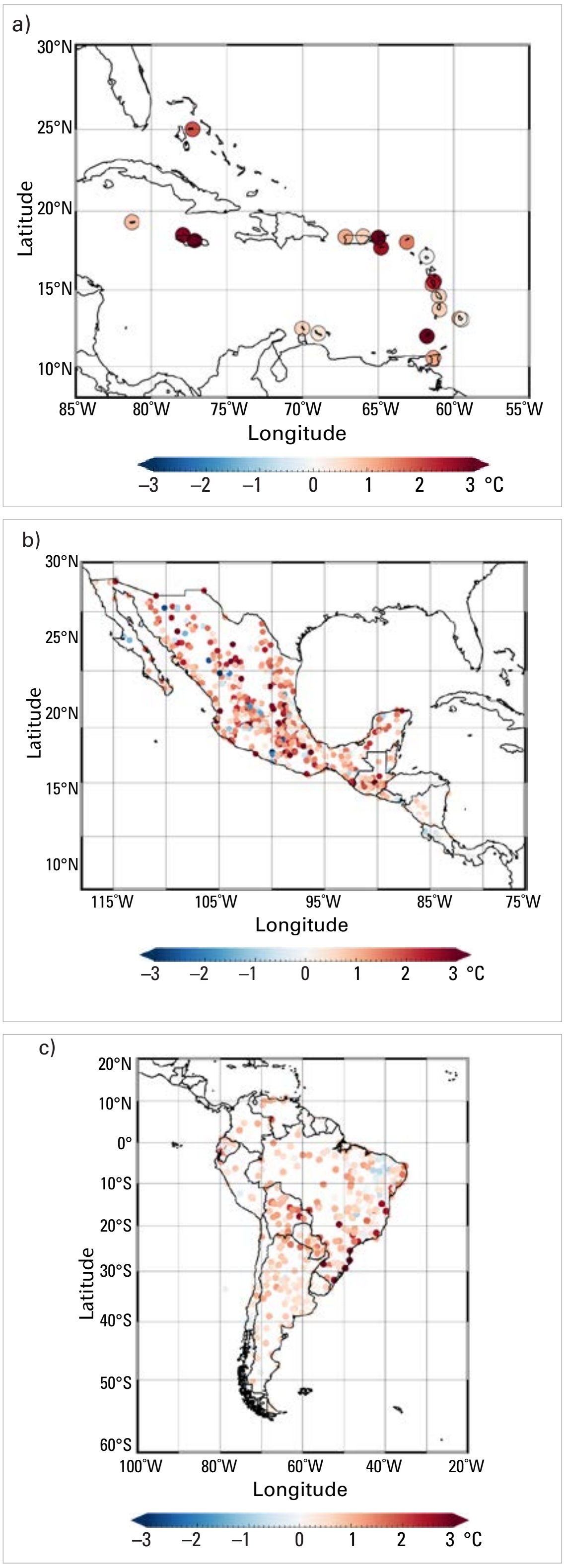


Figure 4. Air temperature (2 m) anomalies for 2020 (relative to 1981–2010) for (a) the Caribbean; (b) Mexico/Central America; and (c) South America, in °C. The colour scale is shown below the maps. *Source:* Data obtained from NMHSs of the Caribbean and the Central and South American countries and plotted by Dr. Teddy Allen (CIMH).

PRECIPITATION

Cumulative precipitation in 2020 was variable across Mexico and Central America in relation to the 1981–2010 average. Below-normal rainfall was recorded in Mexico, mainly in the north-western region, and in parts of the Caribbean coast. Precipitation above the long-term average was observed in the Pacific coast of Central American countries, as well as in the Yucatán Peninsula and in Jalisco, Mexico (Figure 5b).

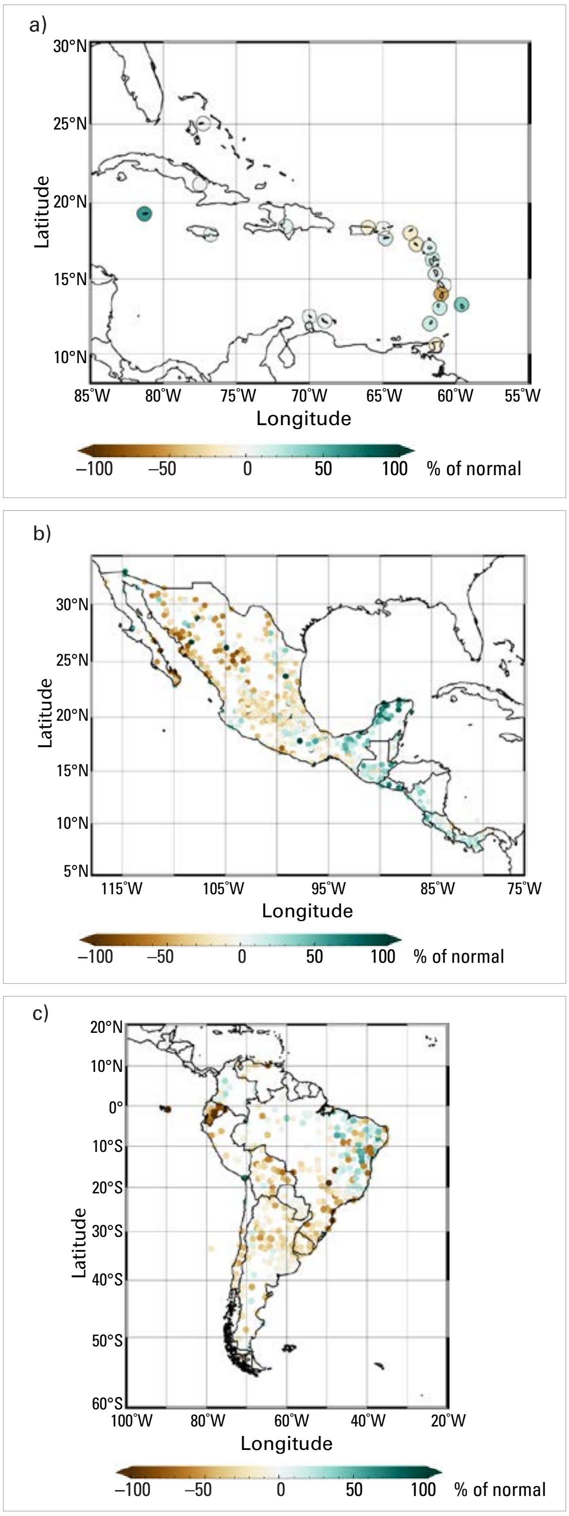


Figure 5. Rainfall anomalies for 2020 (% with respect to the 1981–2010 reference period) in (a) the Caribbean, (b) Mexico/Central America and (c) South America. The colour scale is shown below the maps. *Source:* Data obtained from NMHSs of the Caribbean and the Central and South American countries and plotted by Dr. Teddy Allen (CIMH).

Annual precipitation totals in 2020 were also below the long-term mean in most of tropical South America, including the central Andes, southern Chile, northern South America, the Amazon and the Pantanal, and south-eastern South America. The exception was the semi-arid region of north-eastern Brazil, where rainfall was above normal (Figure 5c). In Ecuador, rainfall deficits were detected in the coastal region from July to December, due to La Niña. The austral summer (December to February) was characterized by weak rainy seasons in the southern Amazon and Pantanal regions and southern Brazil. Rainfall above normal over the semi-arid region of north-eastern Brazil, from March to May, ended a six-year drought. However, in the second half of July, no significant rains were recorded in much of Brazil, causing precipitation deficits to increase again.

In central South America, precipitation totals were close to about 40% of normal values. The seasonal precipitation period from September 2019 to May 2020 was marked by a precipitation deficit that was most accentuated between January and March. In the central Andes, several extreme rainfall events occurred in February, while in northern Peru, a drought was reported during the austral summer (December to February). In Argentina, 2020 was a dry year, with an estimated national anomaly of –16.7% in relation to the 1981–2010 average, placing 2020 as one of the driest years on record since 1961 and as the driest since 1995. For the north-eastern region of Argentina, 2020 was the fifth driest year since 1961. The below-normal precipitation totals in Argentina were an extension of the same drought that affected the Pantanal region.

REGIONAL PRECIPITATION ANALYSES

Caribbean

For most of the Caribbean region, below-normal rainfall during the first months of 2020 resulted in widespread drought conditions. In general, the start of the rain season (June–November) was delayed by extremely dry late spring rainfall anomalies (Figure 5a). However, an active latter part of the rain season, associated with an abundance of tropical waves, brought a cessation to the region-wide drought conditions by October. An active hurricane season in the Central America–Caribbean region led to intense rainfall events.

Mexico and Central America

The 12-month Standardized Precipitation Index (SPI)[5,6], values generated by NMHSs in Mexico and Central America indicate the persistence of below-normal rainfall conditions in many places during 2020. Meteorological stations in Central America that recorded below-normal rainfall were located on the Caribbean coast of Costa Rica and throughout Panama, Honduras, Guatemala and Belize. In Costa Rica, rainfall deficit was reported in July and August 2020.

Above-normal precipitation was recorded in 2020 around the Pacific coasts of Costa Rica, Panama and Guatemala, as well as throughout El Salvador, Colón (Panama) and north-western Belize. Mexico, El Salvador, Costa Rica and Panama registered very rainy and extremely rainy conditions, as shown by their 6-month SPI values >1.5. In Central America, these maximum values were observed in El Salvador (Ilopango, San Salvador), Costa Rica (Nicoya, Guanacaste) and Guatemala (Asunción Mita, Jutiapa). Honduras experienced rainfall and flooding during March, accounting for well over half the people affected by floods in the region during March 2020.

In Mexico, persistently below-normal precipitation was recorded in the north-west and in some other regions: some areas of Sonora and Chihuahua experienced annual precipitation totals between 25% and 50% below normal values. However, above-normal precipitation values were reported in the south-east and in Baja California (except in the north-east). The highest 6-month SPI values were recorded in Muná (Yucatán) and Jacatepec (Oaxaca), both being the highest in their corresponding historical records.

South America

In most of South America, rainfall during the first half of 2020 was below the 1981–2010 average, especially in the Caribbean and the Andean regions of Colombia. The channels of the Magdalena River experienced reduced flows and levels, affecting navigation between January and March 2020, and 11 municipalities declared a state of public calamity. In Chile, intense rainfall on 27–28 January in the Atacama region produced landslides and floods.

In the first quarter of 2020, during the rainy season, the coastal region of Ecuador experienced an extraordinary current of dry air from the Pacific Ocean, which led to a dry spell of at least 20 consecutive days. This altered the sowing and harvesting periods of crops in the Costa and the Sierra. In February, the current weakened and allowed the return of moisture from the Amazon.

In Peru, during the rainy season from September 2019 to May 2020, a rainfall deficit accumulated between January and March, but several extreme rainfall events occurred in the central Andes in February. During January and March 2020, the southern coast of Peru reported very wet conditions on 22–24 January: 32.4 mm/day in Camaná (Arequipa), 16.4 mm/day in Jorge Basadre (Tacna), 17.3 mm/day in Copara (Ica) and 13.2 mm/day in Calana (Tacna).

Finally, above-normal rainfall over the semi-arid region of north-eastern Brazil in February and March ended a six-year drought. However, the southern region of Brazil experienced drought during most of the year, interrupted by intense short-term rainfall events. During the austral summer of 2020 (December to February), various episodes of intense rainfall were associated with extensive damage and fatalities in south-eastern Brazil, in the cities of Belo Horizonte, São Paulo, Espírito Santo and Rio de Janeiro.

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5 The SPI is a drought index proposed in 1993 by McKee et al. For more information about the index, see *Standardized Precipitation Index: User Guide* (WMO-No. 1090).

6 McKee, T.B. et al., 1993: The relationship of drought frequency and duration to time scales. *Proceedings of the Eighth Conference on Applied Climatology*, American Meteorological Society, 179–184.

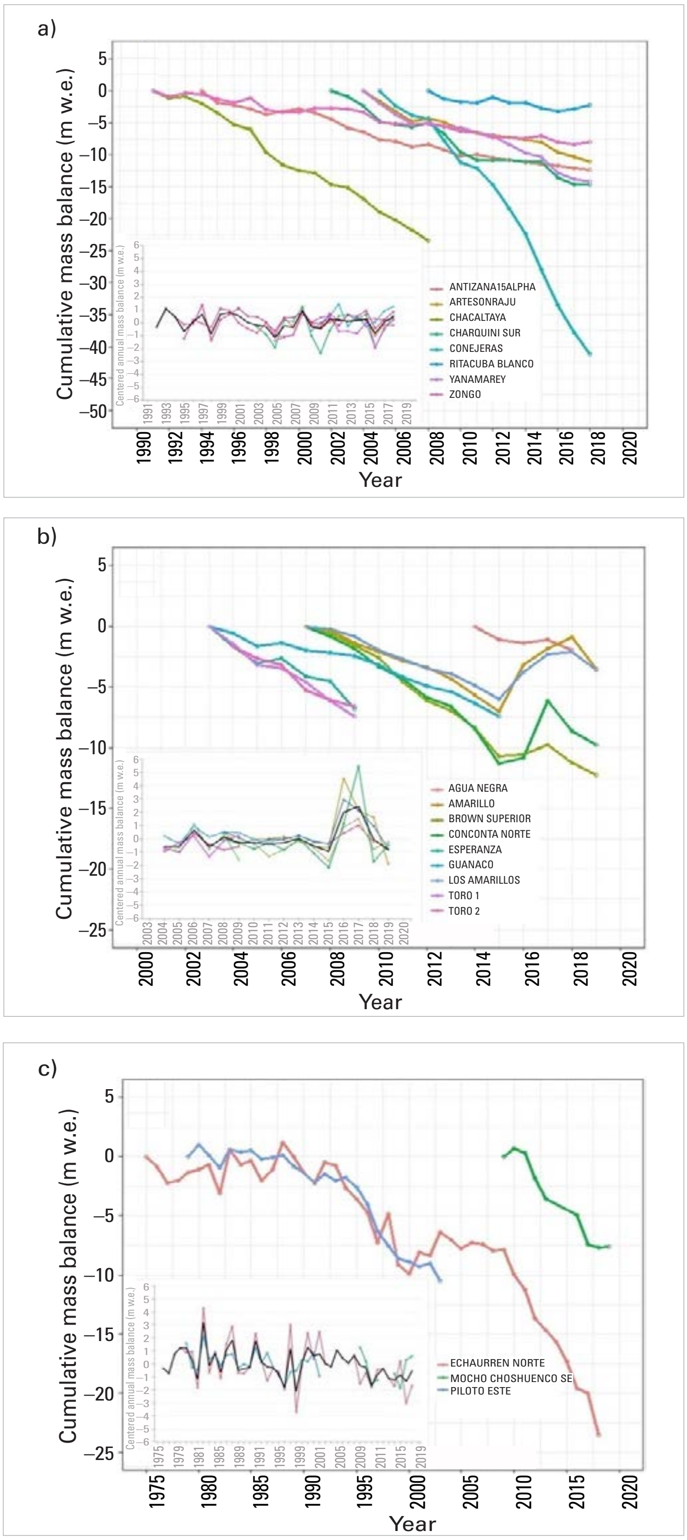


Figure 6. The cumulative mass balance of 20 monitored glaciers shows the evolution of the Andean ice masses in the three zones: (a) tropics (1992–2019), (b) dry Andes (2004–2019) and (c) central Andes (1976–2019). The inset figures show the centred mass balance of the data series. The average centred balance is shown by the black line.
Source: World Glacier Monitoring Service, 2020: Fluctuations of glaciers database http://dx.doi.org/10.5904/wgms-fog-2020-08, plotted by Dr. Rubén Basantes(IKIAM).

GLACIERS

Rising temperatures have significant impacts on glaciers. Mountain glaciers represent a measurable indicator of the spatial and temporal patterns of global climate variability. In the Andes, glaciers constitute important sources of fresh water for water consumption, power generation, agriculture and ecosystem conservation. In this region, glacier monitoring programmes were established in the 1990s, and few glaciers have continuous long-term series.[7,8,9,10] Only the Echaurren Norte glacier, in the central Andes of Chile, has had continuous observations for more than 40 years.[11] The data series show generalized glacier mass loss across the region over the past decades, but there are some differences from one glacier to another which can be explained by the feedback between the regional climate and local glacier morphology (Figure 6).

To achieve a better understanding of Andean glacier evolution, the Cordillera is divided into three zones:[12] the tropics, the dry Andes and the central Andes. In the tropics, glacier mass balance has a negative trend of −0.71 metre water equivalent (m.w.e.) per year during the monitoring period (Figure 6a). Previous studies have shown that tropical glaciers had moved into a period of significant ice mass

[7] Dussaillant, I. et al., 2020: Author correction: two decades of glacier mass loss along the Andes. *Nature Geoscience*, 13: 711, https://doi.org/10.1038/s41561-020-0639-5.

[8] Ferri L. et al., 2020: Ice mass loss in the central Andes of Argentina between 2000 and 2018 derived from a new glacier inventory and satellite stereo-imagery. *Frontiers in Earth Science*, 8: 530997, https://www.frontiersin.org/articles/10.3389/feart.2020.530997/full.

[9] Falaschi D. et al., 2019: Six decades (1958–2018) of geodetic glacier mass balance in Monte San Lorenzo, Patagonian Andes. *Frontiers in Earth Science*, 7: 326, https://doi.org/10.3389/feart.2019.00326.

[10] Hugonnet, R. et al., 2021: Accelerated global glacier mass loss in the early twenty-first century. *Nature*, 592: 726–731, https://doi.org/10.1038/s41586-021-03436-z.

[11] Gärtner-Roer, I. et al., 2019: Worldwide assessment of national glacier monitoring and future perspectives. *Mountain Research and Development*, 39(2): A1–A11, https://doi.org/10.1659/MRD-JOURNAL-D-19-00021.1.

[12] Masiokas, M.H. et al., 2020: A review of the current state and recent changes of the Andean cryosphere. *Frontiers in Earth Science*, 8: 99, https://doi.org/10.3389/FEART.2020.00099.

loss since the late 1970s.[13] This could be associated, at least partly, with a decreasing trend in snow accumulation at high elevations.[14]

Further south, in the Andes of Chile and Argentina, glaciers have been retreating for several decades, with a differential rate of –0.72 m.w.e. a-1 for the 2004–2019 period in the dry Andes (Figure 6b) and –0.58 m.w.e. a-1 from 1976 to 2019 in the central Andes (Figure 6c). This loss of ice mass has been increasing since 2010, in line with an increase in temperatures and a significant reduction in precipitation in the region.[15]

To ensure that the signals from glaciers within each region are comparable, mass balances were calculated centred on the available period. Thus, despite the different behaviour of the glaciers, a common response to climate variability in the region can be distinguished.

OCEAN

SEA LEVEL

As concentrations of greenhouse gases rise, excess energy accumulates in the Earth system, of which approximately 90% is absorbed by the ocean.

As its temperature rises and water warms, the ocean expands. This thermal expansion, combined with increased ice loss from glaciers and ice sheets, contributes to sea-level rise. Accurate sea-level projections over the next decades are important for both decision-making and the development of successful adaptation strategies in coastal and low-lying regions, including the Caribbean Sea.[16]

On average, since early 1993, the altimetry-based global mean rate of sea-level rise has amounted to 3.3 ± 0.3 mm/yr, as a result of ocean warming and land ice melt. The data also show that the rate of rise is not geographically uniform, mostly as a result of non-uniform ocean thermal expansion and regional salinity variations.

South America

The regional sea-level trends around South America are shown in Figure 7. The rates of sea-level change on the Atlantic side are higher than on the Pacific side. Time series reveal sea-level trends and variability from January 1993 to June 2020 in the Pacific, equatorial Atlantic and south Atlantic, based

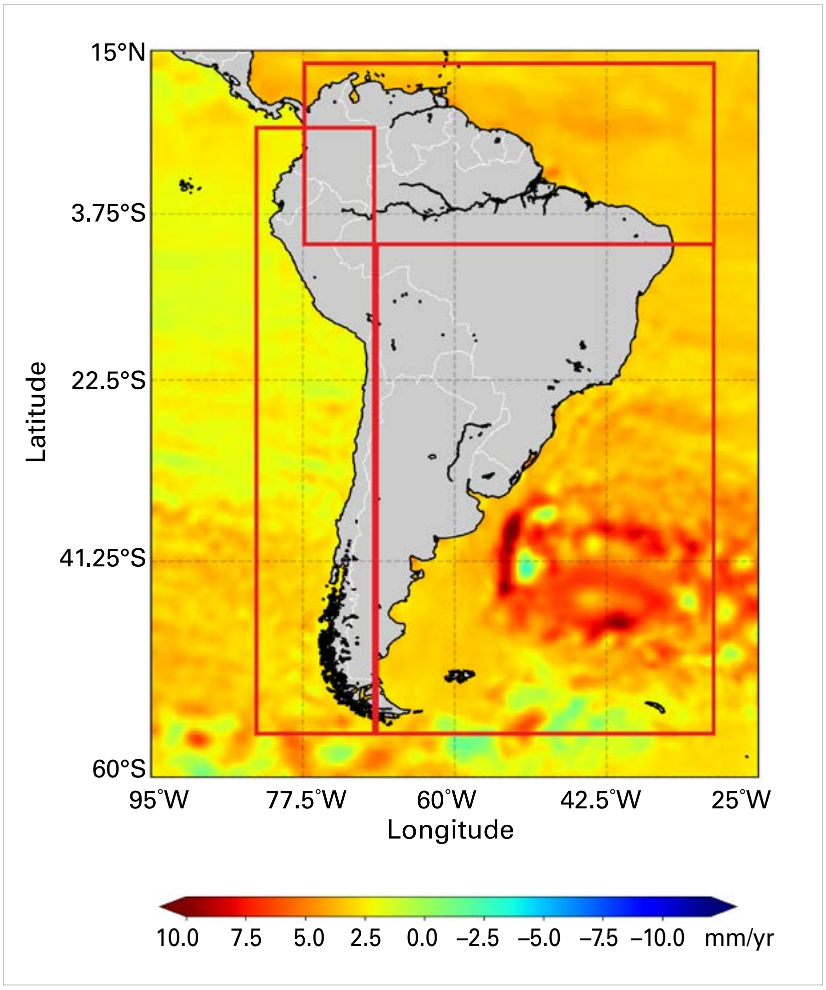


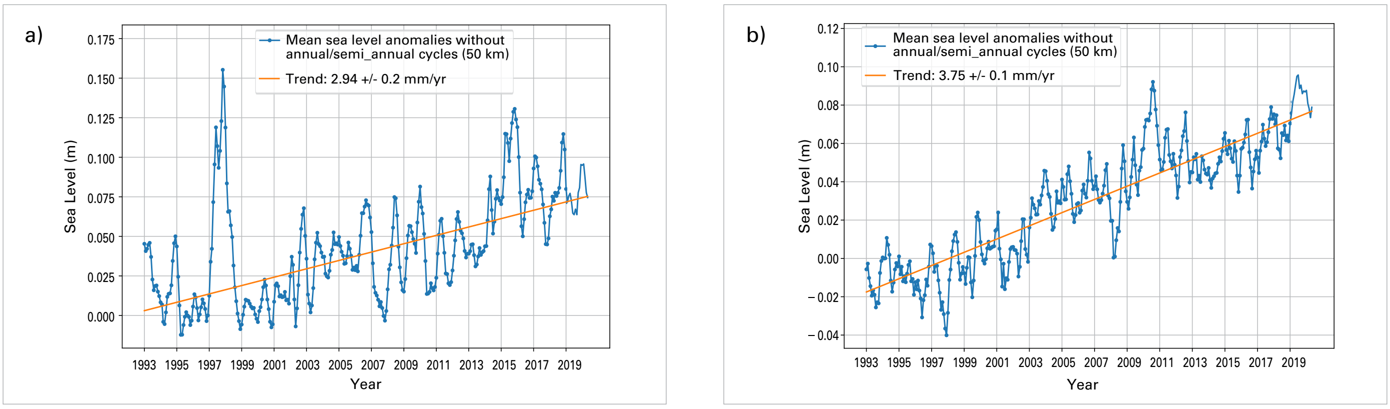
Figure 7. Regional sea-level trends around South America from January 1993 to June 2020 (based on satellite altimetry). The red boxes indicate the areas where the coastal sea-level time series in Figure 8 are computed. *Source:* Copernicus Climate Change Service (C3S), https://climate.copernicus.eu/sea-level

[13] Rabatel, A. et al., 2013: Current state of glaciers in the tropical Andes: a multi-century perspective on glacier evolution and climate change. *The Cryosphere*, 7: 81–102, https://doi.org/10.5194/tc-7-81-2013.

[14] Masiokas et al., 2020: A review of the current state and recent changes of the Andean cryosphere.

[15] Garreaud, R. et al., 2017: The 2010–2015 mega drought in central Chile: impacts on regional hydroclimate and vegetation. *Hydrology and Earth System Sciences - Discussions*, https://doi.org/10.5194/hess-2017-191.

[16] van Westen, R.M. et al., 2020: Ocean model resolution dependence of Caribbean sea-level projections. *Scientific Reports*, 10: 14599, https://doi.org/10.1038/s41598-020-71563-0.



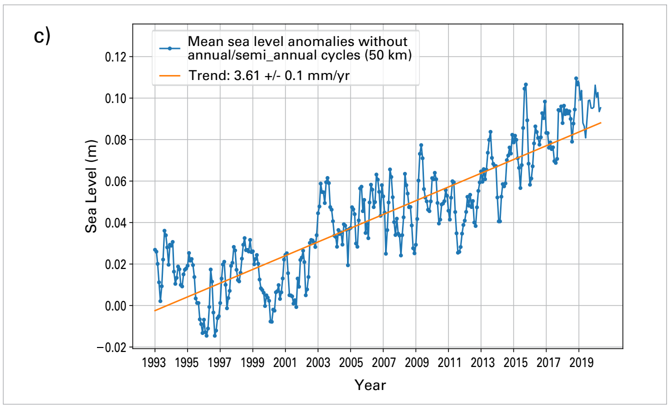


Figure 8. Altimetry-based coastal sea-level time series (m) from January 1993 to June 2020 for (a) the Pacific side of South America; (b) the equatorial Atlantic side; and (c) the south Atlantic side. Seasonal cycle was removed; glacial isostatic adjustment correction was applied. The orange line represents the linear trend.
Source: C3S

on gridded altimetry data averaged from 50 km offshore to the coast (Figure 8). The coastal sea level on the Pacific side (Figure 8a) displays important interannual variability driven by El Niño–Southern Oscillation (ENSO). The curve shows temporary high sea level (>10–15 cm) during the 1997–1998 and 2015–2016 El Niño events. Along the Atlantic coast of South America, the rate of sea-level rise is slightly higher than the global mean (~3.6 mm/yr), while it is lower along the Pacific coast (2.94 mm/yr).

Central America

The regional sea-level trends around Central America are shown in Figure 9. The map shows high rates of sea-level change in the Caribbean Sea and the Gulf of Mexico compared with the Pacific side.

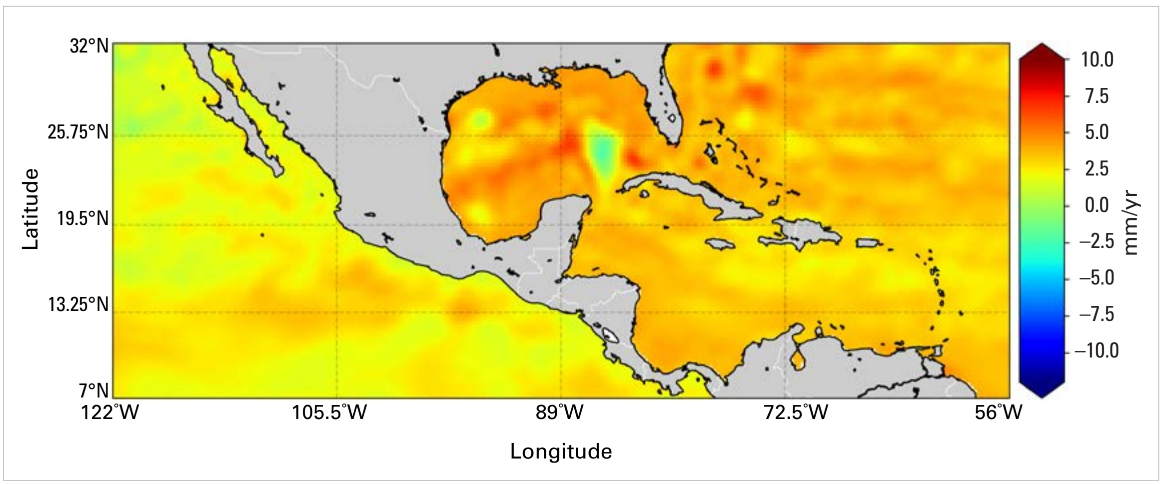


Figure 9. Regional sea-level trends around Central America from January 1993 to June 2020 (based on satellite altimetry).
Source: C3S

Figure 10 shows coastal sea-level time series from January 1993 to June 2020 for the Pacific and the Caribbean Sea/Gulf of

Mexico. A clear ENSO signal can be seenin Figure 10b, with temporary high sea levels (>20 cm) during the 1997–1998 and 2015–2016 El Niño events, which might influence the overall trend for this series. The coastal sea-level rise is higher than the global mean on the Caribbean Sea/Gulf of Mexico side (3.7 mm/yr) and lower than the global mean on the Pacific side (2.6 mm/yr).

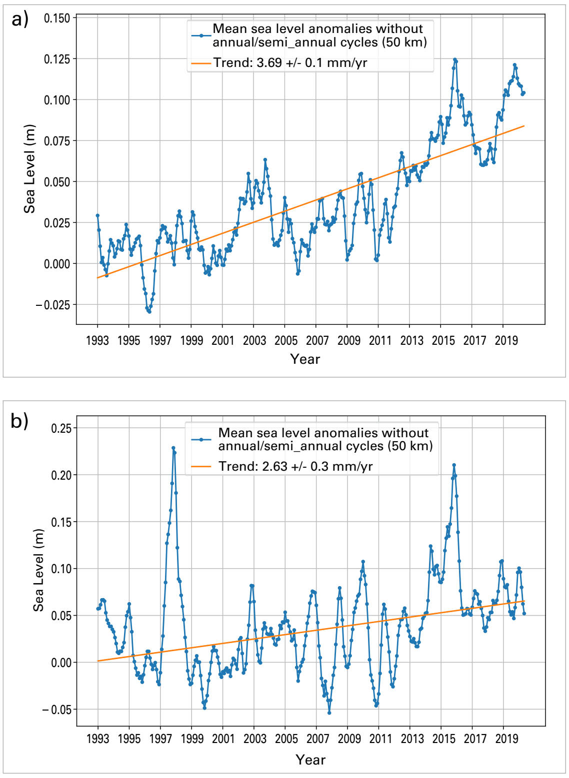


Figure 10. Altimetry-based coastal sea-level time series from January 1993 to June 2020 for (a) the Atlantic side of Central America (Caribbean Sea/Gulf of Mexico); and (b) the Pacific side of Central America. Seasonal cycle was removed; glacial isostatic adjustment correction was applied. The orange line represents the linear trend.
Source: C3S

Caribbean

The regional sea-level trends around the Caribbean are shown in Figure 11 and Figure 12. Although sea-level rise in the Caribbean is not uniform (Figure 11), the linear trend is rising at a slightly higher rate (3.56 ± 0.1 mm/yr) than the global average. Sea level in the Caribbean is highly correlated with ENSO, with larger increases in sea level occurring during stronger El Niño events.[17] Interannual variability in sea level is particularly relevant in the Caribbean, as it is correlated with hurricane activity. Both hurricane intensity and sea-level interannual variability have increased since 2000 (see Extreme events).

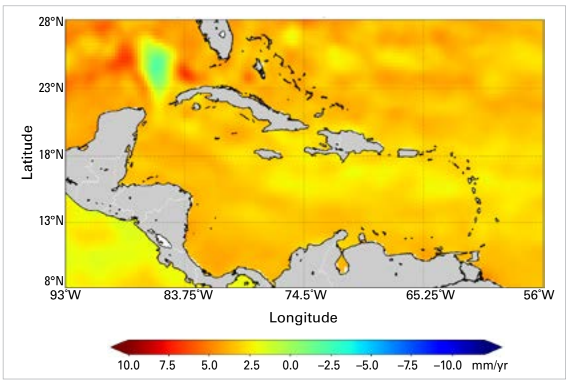


Figure 11. Regional sea-level trends around the Caribbean region from January 1993 to June 2020 (based on satellite altimetry).
Source: C3S

OCEAN ACIDIFICATION

The ocean absorbs about 23% of annual anthropogenic emissions of CO_2 in the atmosphere,[18] thereby helping to alleviate the impacts of rising emissions on Earth's climate.

However, CO_2 reacts with seawater and lowers its pH. This process, known as ocean acidification, affects many organisms and ecosystem services, threatening food security by endangering fisheries and aquaculture.

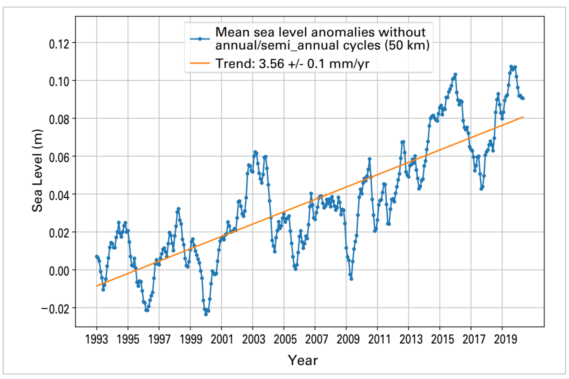
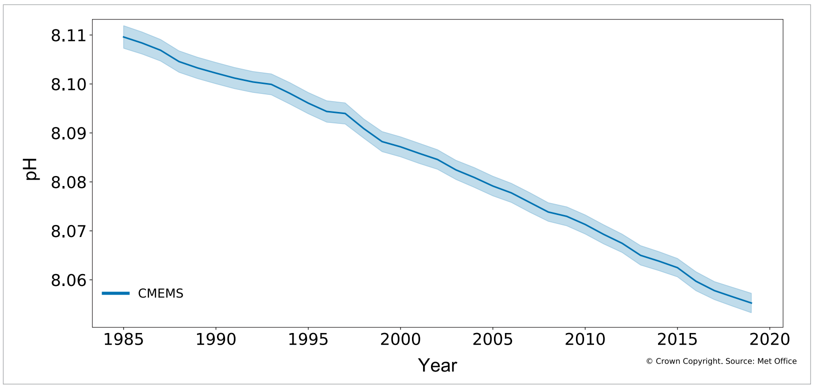


Figure 12. Altimetry-based coastal sea-level time series from January 1993 to June 2020 for the Caribbean Sea and Gulf of Mexico (based on gridded altimetry data averaged from 50 km offshore to the coast). Seasonal cycle was removed; glacial isostatic adjustment correction was applied. The orange line represents the linear trend.
Source: C3S

[17] Climate Studies Group Mona (eds.), 2020: *The State of the Caribbean Climate*. Produced for the Caribbean Development Bank.

[18] World Meteorological Organization, 2019: *WMO Greenhouse Gas Bulletin: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2018*, No. 15, https://library.wmo.int/index.php?lvl=notice_display&id=21620.

Figure 13. Global mean ocean pH.
Source: Met Office, United Kingdom



Global ocean pH levels have been steadily declining, reaching a new low in 2020 (Figure 13). Along the Pacific coast of South America, the Humboldt Current, one of the world's four major upwelling systems, is being affected by ocean acidification and oxygen loss, with negative impacts on key ecosystems.[19]

KEY CLIMATE DRIVERS

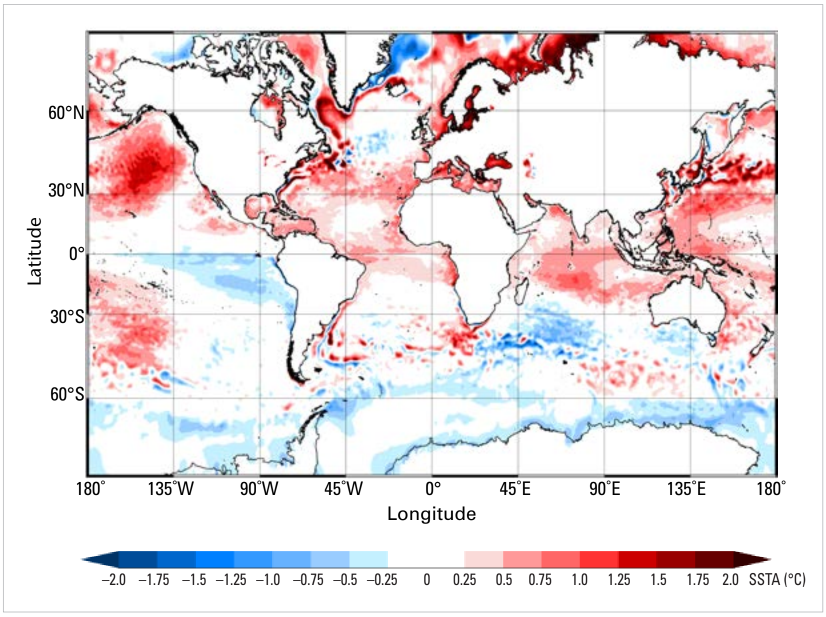
As Latin America and the Caribbean is surrounded by the Pacific and the Atlantic oceans, climate conditions in the region are largely modulated by the prevailing sea-surface temperatures of the oceans and associated large-scale atmosphere-ocean coupling phenomena, such as ENSO.

The year 2020 started with higher than long-term average sea-surface temperature observed in the tropical western Pacific, with the Oceanic Niño Index reaching 0.6 °C in January–March 2020. Despite being slightly above the 0.5 °C threshold usually considered for warm events in the equatorial Pacific, the atmospheric counterpart, the Southern Oscillation Index, was near zero in the early months of 2020. Therefore a fully coupled El Niño event never developed

A significant sea-surface temperature cooling was in progress from May in the easternmost part of the equatorial Pacific Ocean, which reached La Niña levels in the last quarter of the year. During La Niña, more hurricanes can form in the deep tropics from African easterly waves, posing an increased threat to the Caribbean.[20]

The Atlantic Warm Pool in the Caribbean and adjacent ocean areas likely also contributed to the record-breaking Atlantic tropical cyclone activity in 2020 (see Extreme events and Figure 14). The sea-surface temperature anomaly in the Caribbean Sea in 2020 was 0.87 °C above the 1981–2010 average, surpassing the previous highest value of +0.78 °C in 2010.[21]

Figure 14. Sea-surface temperature anomalies in 2020 (reference period 1981–2010). *Source:* National Oceanic and Atmospheric Administration (NOAA), Optimum Interpolation Sea Surface Temperature (OISST) v2 data set, plotted by the Caribbean Institute for Meteorology and Hydrology (CIMH).



[19] Intergovernmental Panel on Climate Change (IPCC), 2019b: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (H.-O. Pörtner et al., eds.), https://www.ipcc.ch/srocc/.

[20] Climate Studies Group Mona (eds.), 2020: *The State of the Caribbean Climate.*

[21] Australian Antarctic Data Centre, 2003: Reynolds-Smith V2 global monthly average sea surface temperatures (revised in 2019), https://data.aad.gov.au/metadata/records/REYNOLDS_MONTHLY_SST.

Extreme events

TROPICAL CYCLONES

In 2020, the Atlantic basin cyclone season registered a total of 30 storms, beating the previous record of 28 storms in 2005. Eight had direct or indirect impacts in the region: Tropical storm *Amanda*/*Cristobal*, and Hurricanes *Gamma*, *Marco*, *Nana*, *Delta*, *Zeta*, *Eta* and *Iota*. Furthermore, *Eta* and *Iota* reached category 4 intensity (according to post-storm intensity analyses)[22], made landfall in the same region in quick succession (two weeks) and followed identical paths across Nicaragua and Honduras, severely affecting many of the same areas in these countries.

Tropical storm *Amanda* emerged in the Pacific Ocean and moved to the Caribbean Sea. Its remnants evolved into Tropical storm *Cristobal*. Both systems produced rainfall and contributed to floods and landslides over Guatemala, Honduras, El Salvador and Costa Rica (which was affected only by *Amanda*). *Nana* resulted in flooding and landslides in Guatemala and Honduras. Costa Rica suffered overflow of rivers and floods on the North Pacific side following *Marco*.

Hurricanes *Eta* and *Iota* brought a large amount of rainfall to eastern Mexico and the Yucatán Peninsula, Belize, Guatemala, Honduras, Costa Rica and Panama. Estimated rainfall accumulations over parts of Nicaragua and Honduras were in excess of 305 mm after the passage of *Eta* on 6 November. Parts of eastern Nicaragua, Honduras, Belize and Costa Rica picked up more than 150–300 mm of rain from *Iota* by 15–16 November.

The Caribbean is particularly exposed to hurricanes, with more than 110 storms affecting the region between 1980 and 2016. Tropical cyclones account for more than 70% of meteorological-related disasters, representing nearly 95% of damage from meteorological disasters in the Caribbean countries since 1960.

In 2020, Hurricane Isaias produced devastating flooding and wind damage in Puerto Rico and the Dominican Republic, leading to the death of three people. A state of emergency was declared in Puerto Rico resulting from the effects of Tropical storm *Laura*. *Laura* also contributed to the death of 31 people in Haiti and 4 in the Dominican Republic. An estimated 80% of total land area in Puerto Rico was classified as abnormally dry by late June, triggering water rationing during the hot summer months. In contrast, by 31 July intense rainfall due to Hurricane Isaias triggered numerous landslides in the steep terrain along the Cordillera Central and over the Sierra de Luquillo, affecting local roadways.

DROUGHT

Caribbean

The Caribbean faces significant, and often overlooked, challenges due to drought. During the past decades, the Caribbean has experienced several drought events, including in 1957, 1968, 1976–1977, 1986–1987, 1991, 1994, 1997–1998, 2009–2010 and 2013–2016.[23] In 2020, based on an analysis using the Integrated Drought Index (IDI)[24], the Caribbean region recorded severe to extreme drought in the Dominican Republic, Haiti, northern

[22] National Hurricane Center, NOAA, 2021: Hurricane Iota. Tropical cyclone report (AL312020), https://www.nhc.noaa.gov/data/tcr/AL312020_Iota.pdf.

[23] Climate Studies Group Mona (eds.), 2020: *The State of the Caribbean Climate*

[24] Cunha, A.P.M.A. et al., 2019: Extreme drought events over Brazil from 2011 to 2019. *Atmosphere*, 10: 642, https://doi.org/10.3390/atmos10110642.

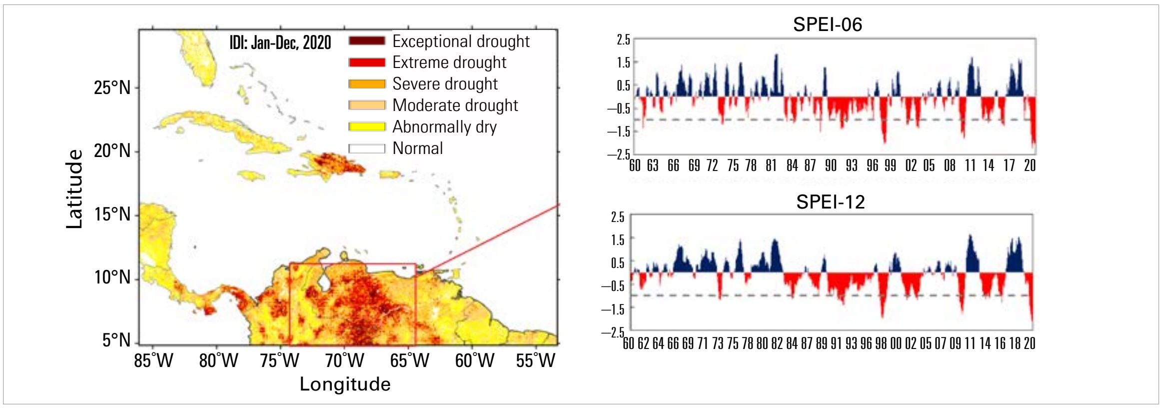


Figure 15. IDI map (left) and SPEI (6-month and 12-month) time series (right) in some regions with severe to exceptional drought in the Caribbean region. *Source:* National Center for Monitoring and Early Warning of Natural Disasters, Brazil (CEMADEN)

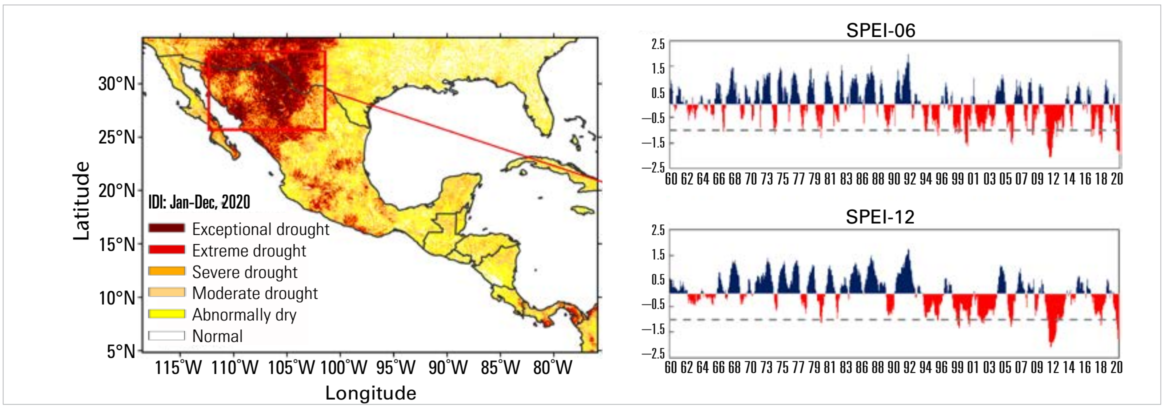


Figure 16. IDI map (left) and SPEI (6-month and 12-month) time series (right) in some regions with severe to exceptional drought in Mexico/Central America. *Source:* CEMADEN

Colombia, Panama and north-western Bolivarian Republic of Venezuela (Figure 15).

The IDI map corresponds to the 12-month period (2020), based on 12-month SPI. The graphs correspond to the 6-month and 12-month Standardized Precipitation Evapotranspiration Index (SPEI).[25]. Northern Colombia and north-western Bolivarian Republic of Venezuela show large negative values (generally less than –1.5) for 6-month SPEI and 12-month SPEI[26] in 2020 (Figure 15), which was a year without El Niño but with a warmer-than-normal tropical North Atlantic, as well as in 2015–2016 and 1997 (both El Niño years).

In Puerto Rico, in the middle of the COVID-19 outbreak, the government declared a state of emergency in June 2020 owing to drought. About 60% of Puerto Rico was experiencing drought conditions, which improved after Hurricane Isaias and Topical Storm Laura during July and August, respectively.

By October 2020, severe drought had developed in Saint Vincent and the Grenadines, western French Guiana, eastern Guadeloupe, northernmost Guyana, Martinique, Saint Lucia and eastern Suriname. In December the severe drought conditions changed to moderate.

Mexico and Central America

In 2020, severe to moderate drought conditions were reported in Belize, northern Guatemala, eastern Costa Rica, Honduras and Nicaragua and northern South America. Extreme to exceptional drought conditions prevailed during 2020 in north-western Mexico, associated with a weak North American monsoon, as reflected in the negative 6-month SPEI and 12-month SPEI, comparable only to the drought of 2012 (Figure 16).

Mexico, Belize, Honduras, Costa Rica and Panama reported regions with severe and extreme meteorological droughts, with

[25] The SPEI was designed to consider both precipitation and potential evapotranspiration in determining drought. It was first proposed in Vicente-Serrano S.M. et al., 2010: A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index. *Journal of Climate*, 23(7): 1696–1718, https://doi.org/10.1175/2009JCLI2909.1.

[26] The reference period used for the 6-month SPEI and 12-month SPEI is 1981–2010.

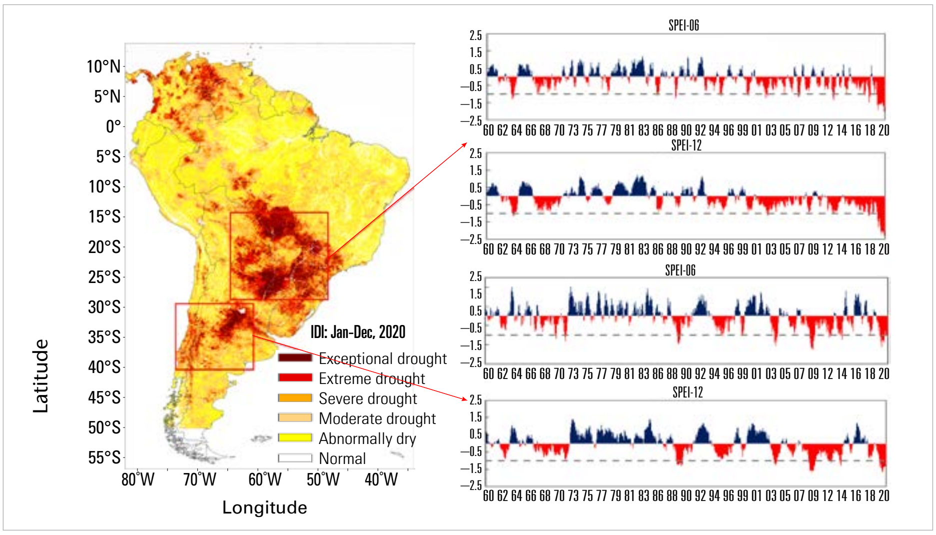


Figure 17. IDI map (left) and SPEI (6-month and 12-month) time series (right) in some regions with severe to exceptional drought in South America. *Source:* CEMADEN

6-month SPI <–1.5. In Central America, the areas with drought were located mainly on the Caribbean coast, with the lowest values (–1.7) in Panama (Piedra Candela, Chiriquí) and Honduras (Catacamas, Olancho).

In Mexico, the drought mostly affected regions concentrated in the centre and north-west of the country, where the lowest 6-month SPI was –3.4 (Cerritos, San Luis Potosí). At the end of 2020, extreme to exceptional drought conditions covered almost 30% of Mexico.

South America

Large parts of South America were in the grip of a serious drought in 2020. The IDI map (Figure 17) shows the regions with severe to extreme drought in north-western Bolivarian Republic of Venezuela, Colombia, central Chile, central and northern Argentina, southern Brazil and in the Paraguay River basin, including the Pantanal region. In west-central Brazil, in the Pantanal region, previous drought conditions with 6-month SPEI and 12-month SPEI <–1.5 were detected in 2018–2020, where the summertime rainy season was well below normal. In southern Chile, eastern Argentina and the Andes, the lowest 6-month SPEI and 12-month SPEI were detected in 2007–2008 and 2018–2020, where severe to exceptional drought was detected in 2020 (Figure 17).

In Chile, the drought observed in 2020 is a continuation of the mega drought in central Chile that started in 2010 as the result of an uninterrupted sequence of dry years, with mean rainfall deficits of 20%–40%. It has had adverse effects on water availability, vegetation and forest fires, which have scaled into social and economic impacts.[27,28]

The Bolivian Chaco and Pantanal regions suffered the most severe droughts in the past 60 years. As a consequence, forest fires propagated and affected more than 1.4 million hectares. In Paraguay, apart from January and August, 2020 was drier than normal, with moderate to dry conditions on the western side of the country.

In the Brazilian Pantanal, there was a decrease in austral summer (December to February) rainfall by about 50% in 2019 and 2020. In 2020, the drought situation over west-central Brazil in austral summer and autumn extended into the Paraguayan Pantanal, with almost 200 mm rainfall below the 1981–2010 average. Drought caused the Paraguay River to shrink to its lowest levels in half a century. The river levels at the Ladário gauging site represent the hydrological regime of the Upper Paraguay River basin, enabling the characterization of a given period of drought or flood in the Pantanal. The annual mean level at Ladário is 273 cm (1900–2020), and by

[27] Garreaud et al., 2017: The 2010–2015 mega drought in central Chile: impacts on regional hydroclimate and vegetation.

[28] Garreaud R.D. et al., 2019: The central Chile mega drought (2010–2018): a climate dynamics perspective. International *Journal of Climatology*, 40(1): 421–439, https://doi.org/10.1002/joc.6219.

September 2020 the lowest minimum value was 1 cm, the lowest level in 47 years. In the Paraguay River, the anomalously low river levels hampered shipping. Several ships ran aground, and many vessels had to reduce their cargo in order to navigate to and from inland river ports.[29]

Argentina recorded a dry year with an estimated national rainfall anomaly of –16.7% compared with the 1981–2010 average, placing 2020 as the driest year since 1995. The National Fire Management Service (SNMF), Argentina, reported that the drought was fuelling the wildfires, as many of the fires were burning in dry areas that would normally be flooded during this time of year, and that the drought had dried up the streams and river channels that normally serve as firewalls and sources of moisture.

HEATWAVES AND WILDFIRES

A series of heatwaves and extreme temperatures affected several places in South America during the year and induced favourable weather conditions for wildfires, especially in the Amazonian forest. A heatwave occurred in the Cuyo Region in Argentina on 18–28 January, with temperatures of 36–43 °C across the region. In Mariscal Estigarribia, Paraguay, temperature reached 42.5 °C on 8 March.

On 20 and 21 February, temperatures above the 90th percentile were recorded in the department of San Martín, in the northern Amazonia of Peru. The Saposoa station recorded a 39.5 °C daily maximum temperature on 21 February (compared with the long-term mean of 32.4 °C). During 17–22 April, a heatwave affected Valparaíso in Chile, with temperatures of 28.8 °C and a corresponding anomaly greater than 9 °C compared with the long-term mean of 19.3 °C. In May, record temperatures were observed in Chile during the three episodes of heatwaves between Arica and Santiago, with temperatures of 35.5 °C in Rodelillo, 30.6 °C in Santo Domingo and 28.8 °C in Calama on 25–28 April, the highest since the late 1960s.

Between 29 September and 15 October, a major heatwave affected central South America. Some locations experienced warming of about 10 °C above normal, and some even had temperatures above 40 °C several days in a row (Figure 18). Maximum temperatures at some stations showed record-breaking values, with temperatures up to 10 °C above normal. October maximum temperature in Asunción (Paraguay) reached 42.3 °C, a new historical record. In the city of São Paulo (Brazil), the maximum temperature reached 37.5 °C on 2 October (compared with the long-term mean of 28.8 °C), and on three occasions temperatures surpassed 37.4 °C (Figure 18). In the Plurinational State of Bolivia,

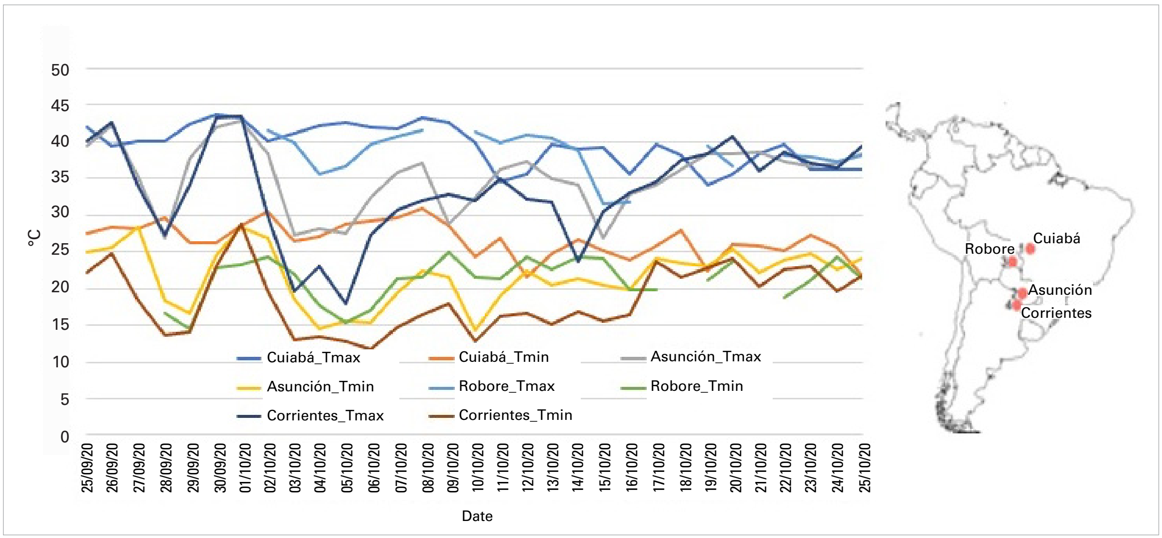


Figure 18. Time series of maximum and minimum temperatures in some locations in Brazil, Paraguay, the Plurinational State of Bolivia and Argentina, from 25 September to 25 October 2020. *Source:* CEMADEN and INMET

[29] Marengo, J.A. et al., 2021: Extreme drought in the Brazilian Pantanal in 2019–2020: characterization, causes, and impacts. *Frontiers in Water*, 3: 639204, https://doi.org/10.3389/frwa.2021.639204.

the heatwave produced record-breaking temperatures in October in four cities, and the highest temperature ever recorded in San José de Chiquitos of 43.4 °C.

November was very hot in many places in South America. Between 22 and 24 November, the Plurinational State of Bolivia reported new record maximum temperatures in the regions of Santa Cruz and Beni, and maximum temperatures reached 41.3 °C in Rurrenabaque (compared with the long-term mean of 30.0 °C) and 40.2 °C in San Joaquín (compared with the long-term mean of 32.0 °C). In Requena, in the northern Amazon region, maximum temperatures reached 40.7 °C on 22 November (compared with the long-term mean of 31.7 °C). Brazil reported a record maximum temperature on 5 November of 44.8 °C in Nova Maringá (state of Mato Grosso) (compared with the long-term mean of 30.0 °C). This is the highest maximum temperature recorded in Brazil in 111 years (i.e. since 1909 when the National Meteorological Institute of Brazil (INMET) was created).

The year 2020 saw the most catastrophic fire season over the Pantanal, with burned area exceeding 26% of the region (Figure 19), according to the ALARMES warning system from the Laboratory for Environmental Satellite Applications (LASA-UFRJ).[30] This was four times larger than the long-term average observed between 2001 and 2019.[31,32]

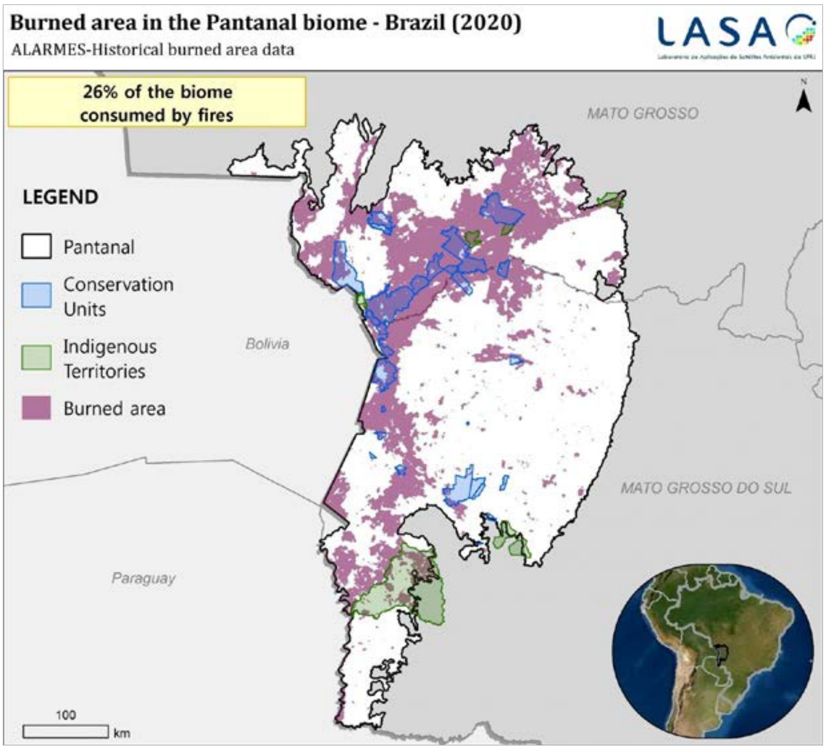


Figure 19. Burned area in the Pantanal biome, Brazil, in 2020. *Source:* LASA-UFRJ

The number of heat sources (which are indicators of wildfires) registered by the National Institute for Space Research (INPE), Brazil, in the Pantanal was 241% higher in 2020 compared with 2019.[33,34,35] Moreover, 2020 surpassed 2019 to become the most active fire year in the southern Amazon since 2012,[36] with 574 000 active fires in 2020, compared with 509 000 for the same period last year.

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[30] https://lasa.ufrj.br/alarmes

[31] Libonati, R. et al., 2020: Rescue Brazil's burning Pantanal wetlands. *Nature*, 588: 217–219, https://doi.org/10.1038/d41586-020-03464-1.

[32] Garcia et al., 2021: Record-breaking wildfires in the world's largest continuous tropical wetland: Integrative fire management is urgently needed for both biodiversity and humans, *Journal of Environmental Management*, 293: 112870, https://doi.org/10.1016/j.jenvman.2021.112870.

[33] Marengo et al., 2021: Extreme drought in the Brazilian Pantanal in 2019–2020: characterization, causes, and impacts.

[34] Libonati et al., 2020: Rescue Brazil's burning Pantanal wetlands.

[35] Leal Filho, W. et al., 2021: Fire in paradise: why the Pantanal is burning. *Environmental Science and Policy*, 123: 31–34, https://doi.org/10.1016/j.envsci.2021.05.005.

[36] Global Fire Emissions Database, 2020: Amazon fire activity in 2020 surpasses 2019, https://globalfiredata.org/pages/2020/09/22/amazon-fire-activity-in-2020-surpasses-2019.

COLD WAVES

During 21–23 August, a cold wave affected most of Brazil due to the entrance of a polar air mass with a cold front that reached as far as western Amazonia. In the state of Acre, western Amazonia, the city of Rio Branco recorded minimum temperatures of 12 °C on 22 August (compared with the long-term mean of 17.4 °C). Temperatures were below 10 °C in Curitiba, in the state of Paraná, and the city experienced freezing rain. In the city of São Paulo, temperatures reached 1 °C early morning on 21 August (compared with the long-term mean of 12.8 °C). In the lower Chaco region of Paraguay, new record minimum temperatures were observed on 21 August, with −0.8 °C in the city of Pilar (compared with the long-term mean of 2.8 °C), the lowest since 2011. The cold wave reached Peruvian Amazonia, with temperatures reaching 12.8 °C on 21 August in Iquitos (compared with the long-term mean of 22.2 °C). In Caballococha, minimum temperatures reached 12.8 °C on 22 August (compared with the long-term mean of 21.3 °C), closer to the historical lowest values recorded on 21 July 1975.

From mid-June to early July, a high pressure blocking pattern over southern Patagonia led to extremely low temperatures that persisted up to eight days in the city of Rio Grande and in most parts of central Argentina, southern Patagonia (Santa Cruz and Tierra del Fuego), where temperatures ranged from –20 °C to –9 °C. Cold temperatures and several snowfalls affected the whole region during austral winter (June to August), producing significant accumulation of snow depth (1–2 m), particularly in the high mountain areas. According to estimates from satellite measurements, the snow-cover extent for central and southern Patagonia was the highest since 2000.

HEAVY PRECIPITATION AND ASSOCIATED FLOODING

Heavy rains and related floods, flash floods and landslides affected Brazil in January and February. On 10 February, the weather station Mirante de Santana, in the state of São Paulo, recorded 114 mm (February was the wettest month in 77 years with 483.6 mm, almost double the normal average of 249.7 mm). Dozens of lives were lost and thousands of people lost their homes from the flash floods and landslides. Floods were also recorded in March, which affected the Plurinational State of Bolivia, Brazil, Colombia, Ecuador and Peru. In Uruguay, heavy rain from 22 to 24 June led to flash floods, cutting roads and prompting evacuations. According to the Instituto Uruguayo de Meteorología (INUMET), the town of José Batlle y Ordóñez, in the department of Lavalleja, recorded 105 mm of rain in 24 hours.

During 30 June–1 July, an intense extratropical cyclone (called ciclone bomba by local meteorologists) affected southern Brazil, with tornadoes, hails and wind gusts exceeding 130 km/h. Some 18 people were killed from the falling trees and structures in Rio Grande and Santa Catarina. A total of 229 municipalities were affected, 2 600 people lost their homes and 1.5 million people were left without electricity in Santa Catarina.

Further north, between 9 and 15 September, several states in the Bolivarian Republic of Venezuela were severely affected by floods of the Limón River. The states of Aragua, Portuguesa and Bolívar were the most affected. On 9 September, the Rancho Grande location in Ecuador recorded 90.5 mm in 4 hours, triggering landslides that affected 1 409 people.

Climate-related Impacts and Risks

IMPACTS ON SECTORS

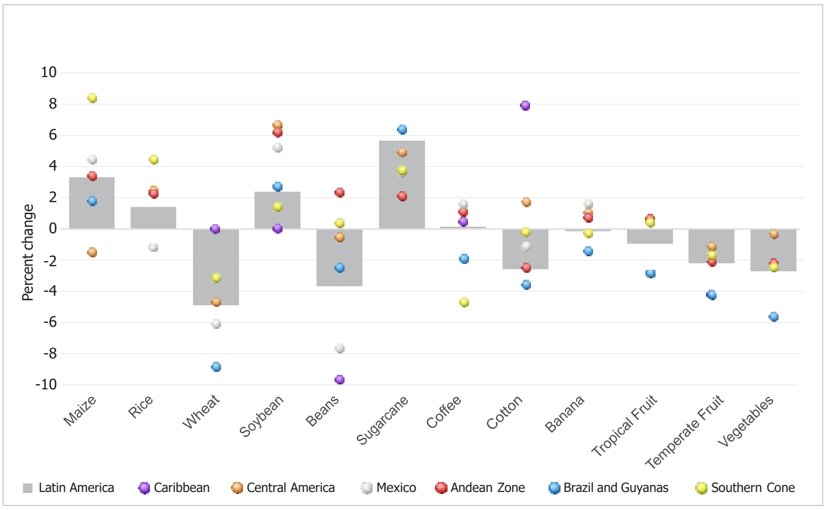
The importance of action to tackle climate change and to limit global warming to 1.5 °C above pre-industrial levels is strongly emphasized in the IPCC special report on global warming of 1.5 °C.[37] As mentioned in the *State of the Global Climate 2020* (WMO-No. 1264), the risk of climate-related impacts depends on complex interactions between climate-related hazards and the vulnerability, exposure and adaptive capacity of human and natural systems. According to the IPCC Sixth Assessment cycle special reports,[38,39] Latin America and the Caribbean is one of the world regions where climate change effects and impacts – such as heatwaves, decrease in crop yield, wildfires, coral reef depletion and extreme sea-level events – are projected to be more intense. Thus, limiting global warming to well below 2 °C, as prescribed in the Paris Agreement, is important for reducing climate-related risks in a region already facing economic and social asymmetries to its sustainable development.

The IPCC special report on global warming of 1.5 °C highlights that, compared with current conditions, even 1.5 °C of global warming would pose heightened risks to eradicating poverty, reducing inequalities and ensuring human and ecosystem well-being.[40] The associated impacts would disproportionately affect disadvantaged and vulnerable populations through food insecurity, higher food prices, income losses, lost livelihood opportunities, adverse health impacts and population displacements. Small Island Developing States (SIDS) are among the regions and ecosystems where the worst climate change impacts are expected.

IMPACTS ON AGRICULTURE AND WATER RESOURCES

Climate change is considered one of the major disruptors of agriculture and food systems in Latin America and the Caribbean, owing to the projected reductions in most yields (Figure 20).[41] This impact was also addressed in the IPCC special report on climate change and land, which refers to reductions of 6% in the Latin America and the Caribbean region by 2046–2055 for a group of 11 major global crops.[42] Some of the worst impacts on sustainable development are expected to be felt among those whose livelihood depends on agriculture and the coasts. On many small islands, such as SIDS, freshwater stress is expected to occur as a result of projected aridity change. Constraining warming to 1.5 °C, however, could prevent a substantial fraction of water stress, compared with 2°C, especially across the Caribbean region.[43]

Figure 20. Projected changes in yields due to climate change in the Latin America and the Caribbean subregions, 2010 vs. 2030. *Source:* Morris et al., 2020



[37] IPCC, 2018: *Global Warming of 1.5°C: an IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (V. Masson-Delmotte et al., eds.), https://www.ipcc.ch/sr15/.

[38] IPCC, 2019a: *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems* (P.R. Shukla et al., eds.), https://www.ipcc.ch/srccl/.

[39] IPCC, 2019b: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.*

[40] IPCC, 2018: *Global Warming of 1.5°C.*

[41] Morris, M. et al., 2020: *Future Foodscapes: Re-imagining Agriculture in Latin America and the Caribbean.* Washington, DC, International Bank for Reconstruction and Development/The World Bank.

[42] IPCC, 2019a: *Climate Change and Land.*

[43] IPCC, 2018: *Global Warming of 1.5°C.*

In 2020, drought conditions significantly affected crop yields across Latin America and the Caribbean. In the state of Zacatecas, northwest of Mexico City, drought significantly reduced the bean harvest, with production at its lowest level in 20 years. In nearby San Luis Potosí, the hard-hit municipality of Cerritos was affected by drought and suffered a 50% drop in cultivated crops, including sorghum, sunflower and maize. Sorghum production alone in Cerritos is expected to drop from 8 000 tons to 200 tons. After an irregular rainy season and an unpromising harvest, almost 80% of maize grown in Guatemala's highland region was lost.[44]

In South America, the worst-affected areas by the drought were northern Argentina, Uruguay, Paraguay and the western border areas of Brazil. Decreases in maize and soybean yields were reported across Argentina and Brazil, mostly affecting early-planted maize exposed to drier-than-usual conditions at early growing stages. In the Pantanal region, drought limited Paraguay's access to potable water and affected cargo traffic on the river, leading to increased transportation costs for fuel, agricultural supplies, food and other imports. Winter maize crops have suffered low yields, and the late arrival of spring rain delayed new plantings of soy.[45] In Argentina, intense drought triggered fires which destroyed pasture lands in the Gran Chaco area and affected livestock feed production and productivity.[46] The drought affected people's quality of life due to low food production, impacts on livestock and, consequently, a significant decrease in people's daily food consumption.

According to the Global Report on Food Crises, in 2020 acute food insecurity increased significantly in Central America and Haiti, with approximately 11.8 million people suffering from "Crisis" or worse (Integrated Food Security Phase Classification (IPC), Phase 3 or above).[47] Extreme weather events affected over 8 million people across Central America, exacerbating food insecurity in countries already crippled by economic shocks, COVID-19 impacts and conflict. Haiti stood among the top 10 countries experiencing the worst food crises, driven by ongoing drought, currency depreciation, high inflation and a deteriorating security environment. In 2020, 4.1 million people in Haiti were facing "Crisis" or worse (IPC Phase 3 or above), including 1.2 million facing "Emergency" or worse (IPC Phase 4 or above).

IMPACTS ON FOREST AND ECOSYSTEM SERVICES

Latin America and the Caribbean is the world's largest provider of ecosystem services, for agriculture and human and animal well-being at both regional and global levels.[48] With almost half of its area covered by forests, the region represents about 57% of the world's remaining primary forests, storing approximately 104 gigatons of carbon (the Amazon biome alone stores 10% of global carbon). It is also the source of between 40% and 50% of the world's biodiversity and one third of all plant species.

The importance of the region's natural areas is recognized, and the percentage of territory dedicated to nature conservation and ecosystem services is about 20%, which is 1.5 times higher than the developing world average of 13%.[49]

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[44] Paredes, L., 2019: Oxfam reporta más del 70 por ciento de pérdida de maíz y frijol en cuatro departamentos. *El Periódico*, 02 August, https://elperiodico.com.gt/nacionales/uncategorized/2019/08/02/oxfam-reporta-mas-del-70-por-ciento-de-perdida-de-maiz-y-frijol-en-cuatro-departamentos2/.

[45] National Aeronautics and Space Administration (NASA), Earth Observatory, 2020: Severe drought in South America, https://earthobservatory.nasa.gov/images/147480/severe-drought-in-south-america.

[46] United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2020: *Argentina: Sequía 2020. Análisis preliminar de situación*, https://reliefweb.int/sites/reliefweb.int/files/resources/An%C3%A1lisis%20de%20situaci%C3%B3n_Argentina-sequia_2020-OCHA%20%281%29.pdf.

[47] Food Security Information Network and Global Network Against Food Crises, 2021: *Global Report on Food Crises. Joint Analysis for Better Decisions*, https://docs.wfp.org/api/documents/WFP-0000127343/download/?_ga=2.243928333.908853298.1624875097-1494.

[48] Morris et al., 2020: *Future Foodscapes: Re-imagining Agriculture in Latin America and the Caribbean.*

[49] Ibid.

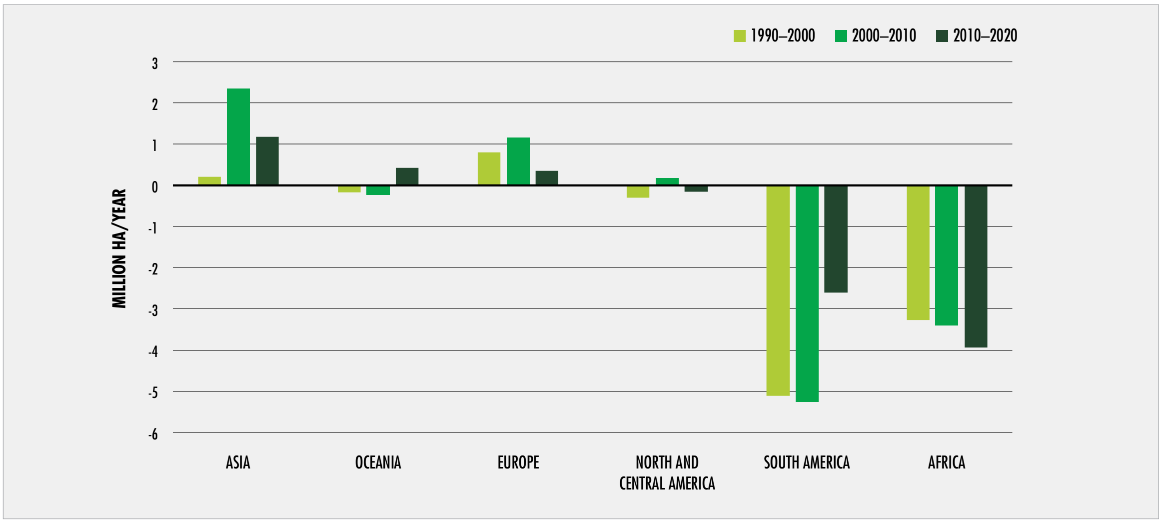

Figure 21. Net forest area change by region in million hectares per year, 1990–2020. *Source:* FAO and UNEP, 2020

In the Latin America and the Caribbean region, forest loss is identified as a major problem and an important contributor to climate change due to CO_2 release. Between 2000 and 2016, nearly 55 million hectares of forests were lost, about 5.5% of the region's total and constituting more than 91% of forest losses worldwide (Figure 21).[50] Nonetheless, it is worth mentioning that the rate of net loss has decreased significantly in the last decade, to about a half relative to previous decades.[51]

The natural regeneration of second-growth forests enhances carbon sinks in the global carbon budget. In Latin America, second-growth forests (up to 60 years old) covered 240 million hectares of land in 2008 and in the last decade remained the main contributor to forest restoration in the region. Over 40 years, these lands can potentially accumulate 8.5 gigatons of carbon in above-ground biomass via low-cost natural regeneration or assisted regeneration, corresponding to a total CO_2 sequestration of 31.1 gigatons of carbon.[52,53]

For much of 2020, warm ocean temperatures in the tropical Atlantic shifted rainfall away from South America, producing warm and dry conditions in the dry forests and savannas of the south-eastern Amazon. Overall, wildfires in South America have occurred more frequently in 2020, compared with 2019, which was already a critical year in terms of fire activity. Many of the largest fires occurred in the Pantanal, a floodplain along the border of Brazil, Paraguay and the Plurinational State of Bolivia, where fires consumed over 43 000 km^2.[54] The increased rate of wildfires in 2020 caused irreversible damage to ecosystems, including adverse impacts on vital ecosystem services and the livelihoods that depended on them.

IMPACTS ON SOCIOECONOMIC DEVELOPMENT, INFRASTRUCTURE AND DISPLACEMENT

In May/June 2020, Tropical storm *Amanda* hit El Salvador, and 50% of households who had grown maize and beans saw their production reduced by half. According to a survey conducted by the World Food Programme, due to the combined effects of hurricanes and the COVID-19 pandemic, 162 000 households

[50] Ibid.

[51] Food and Agriculture Organization of the United Nations (FAO) and United Nations Environment Programme (UNEP), 2020: *The State of the World's Forests 2020. Forests, Biodiversity and People*. Rome, FAO, https://doi.org/10.4060/ca8642en.

[52] IPCC, 2019a: *Climate Change and Land.*

[53] FAO and UNEP, 2020: *The State of the World's Forests 2020*.

[54] NASA, Earth Observatory, 2021: Fires raged in the Amazon again in 2020, https://earthobservatory.nasa.gov/images/147946/fires-raged-in-the-amazon-again-in-2020.

in El Salvador became food insecure.[55] In August, Topical Storm *Laura* struck the island of Hispaniola, home to Haiti and the Dominican Republic, producing extensive flood damage. In addition to the prolonged droughts affecting Haiti, *Laura* and associated heavy rains and floods led to notable losses in crop production and livestock. The impacts on agriculture were estimated to be significant, particularly in the department of Sud-Est, where losses ranged from 50% to 80% for certain crops.[56]

Hurricanes *Eta* and *Iota* were among the most destructive events of 2020 for Latin America and the Caribbean. *Eta* and *Iota*, two category 4 hurricanes, affected over 8 million people in Central America. Guatemala, Honduras and Nicaragua were the worst-affected countries, with damage to 1 million hectares of crops and disruptions to the agricultural livelihoods of people living in the indigenous territories. In the livestock sector, more than 190 000 head of cattle, pigs and poultry were lost, as well as critical assets such as infrastructure and agricultural equipment.[57]

In Honduras, 4.7 million people were affected, and 569 220 hectares of crops were damaged due to the concurrent impacts of Hurricanes *Eta* and *Iota*.[58] Some 745 communities in 155 municipalities reported varying degrees of damage, and communications were cut off for more than 95 000 people in 68 communities.

In Guatemala, *Eta* and *Iota* afflicted 1.8 million people, damaged 164 448 hectares of cultivated land and caused the death of 126 812 livestock.[59] Guatemala had to deal with the effects of *Eta* in 18 of its 22 departments, particularly the extensive damage to agriculture, livestock and rural livelihoods, which contributed to worsening the existing food insecurity.

The total costs of the events in both countries fell mainly on the private sector, while the social sector, specifically housing, was most affected by damage. As regards losses, in both countries, the productive sector was the most affected, specifically the agriculture, commerce and industry subsectors. The sources of income of families and the places where they lived were affected. In Honduras, for 2020, the impact on growth was 0.8 points of gross domestic product (GDP), while in Guatemala it was 0.1 points of GDP.

In Nicaragua, 1.8 million people were affected, and 220 000 hectares of cultivated land and 43 667 livestock were lost. The fisheries sector was also severely affected, resulting in the loss of fishing equipment for 4 000 small-scale fishers.[60]

Nicaragua, which bore the brunt of *Eta* for the first time while it was still a category 4 storm, issued a preliminary report indicating that 8 000 homes, 16 health centres and various roads and bridges were damaged, with more than 47 000 people seeking shelter in 325 centres. Authorities estimate that material damages amount to US$ 172 million and immediate restoration costs amount to US$ 36.4 million.

The broad reach and range of rains attributed to *Eta* contributed to significant impacts in Panama, Costa Rica, Belize and south-eastern Mexico, which also saw the combined effects of a passing cold front. The government of Panama allocated US$ 100 million to meet needs related to *Eta* and reported 3 330 affected people. Costa Rica reported 325 000 people affected directly or indirectly. Belize reported major flood conditions in the districts of Cayo, Stann Creek and Toledo, which initially limited full damage

55 https://reliefweb.int/report/el-salvador/el-salvador-covid-19-informe-de-situaci-n-no17-al-25-de-agosto-2020

56 OCHA, 2020: Haiti: Tropical Storm Laura. Situation report No. 4, https://reliefweb.int/report/haiti/haiti-tropical-storm-laura-situation-report-no-4-28-august-2020-1600.

57 FAO, 2021: Subregional Central America: Hurricanes Eta and Iota – Urgent call for assistance, http://www.fao.org/3/cb3810en/cb3810en.pdf.

58 FAO, 2020: The Republic of Honduras: Hurricanes Eta and Iota – Urgent call for assistance, http://www.fao.org/3/cb2604en/cb2604en.pdf.

59 FAO, 2020: The Republic of Guatemala: Hurricanes Eta and Iota – Urgent call for assistance, http://www.fao.org/3/cb2587en/cb2587en.pdf.

60 FAO, 2021: The Republic of Nicaragua: Hurricanes Eta and Iota – Urgent call for assistance, http://www.fao.org/3/cb2821en/cb2821en.pdf.

assessments; preliminary estimates cited between 50 000 and 60 000 people affected among riverside communities. The Mexican authorities reported that the interaction of *Eta* with the cold front in southern Mexico affected the states of Chiapas, Tabasco and Veracruz, and estimated that more than 177 600 people required assistance throughout those states and 58 800 homes were damaged.

IMPACTS ON LOW-LYING ZONES AND SMALL ISLANDS

Sea-level rise poses a major risk to low-lying coastal zones in the Latin America and the Caribbean region, and the people living in those areas (SIDS) are particularly at risk. Such risk may increase owing to potential doubling in frequency of even small water-level rises (0.1–0.2 m).[61] This threat, enhanced by the increasing occurrence of extreme events, is especially pronounced for the Caribbean SIDS, as recently outlined by the Economic Commission for Latin America and the Caribbean (ECLAC).[62] In Latin America and the Caribbean, more than 27% of the region's population lives in coastal areas.[63] It is estimated that 6%–8% of the population lives in areas that are at high or very high risk of being affected by coastal hazards, and the number of people living below the hundred-year extreme sea-level events in Latin America and the Caribbean will increase from 7.5 million in 2011 to 9 million by the end of the century (assuming no population growth).[64]

According to the IPCC, ocean changes already affect low-lying islands and coasts, with cascading and compounding risks. The high risks are expected to increase over the twenty-first century. Vulnerable human communities, such as those in coral reef environments, may exceed adaptation limits well before the end of the century, even in a low greenhouse gas emission pathway. Effective and successful mitigation and adaptation measures to combat climate change are critical for these high-exposed and vulnerable low-lying regions, as most of them may face adaptation limits beyond 2100 owing to the long-term commitment of sea-level rise.[65]

OCEAN ACIDIFICATION AND IMPACTS ON CORAL REEFS

The impacts of ocean acidification are already present in the Latin America and the Caribbean region, particularly on coral reefs. The lowest surface pH values in the world are found in the eastern tropical Pacific, which covers the Pacific Ocean side of Mexico and Central America up to the coastal areas of Ecuador. The Mesoamerican Barrier Reef is the second largest coral reef in the world, and its net eroding due to acidification is 37%, with only 26% accreting, with low net calcification rates. In the Pacific Central American Coastal region, the reefs are already at the environmental limits for development and in the north-east tropical Pacific, large marine ecosystems are projected to be rapidly reaching aragonite limitation for coral reef development. The impacts of ocean acidification on coral reefs and the potential detrimental consequences for marine life and dependent human communities in the Latin America and the Caribbean region are particularly acute for the Caribbean SIDS.[66]

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61 IPCC, 2018: *Global Warming of 1.5°C*.

62 Tambutti T. and J.J. Gómez (eds.), 2020: *The Outlook for Oceans, Seas and Marine Resources in Latin America and the Caribbean: Conservation, Sustainable Development and Climate Change Mitigation, Project Documents*. Santiago, ECLAC.

63 Ibid.

64 IPCC, 2019b: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*.

65 Ibid.

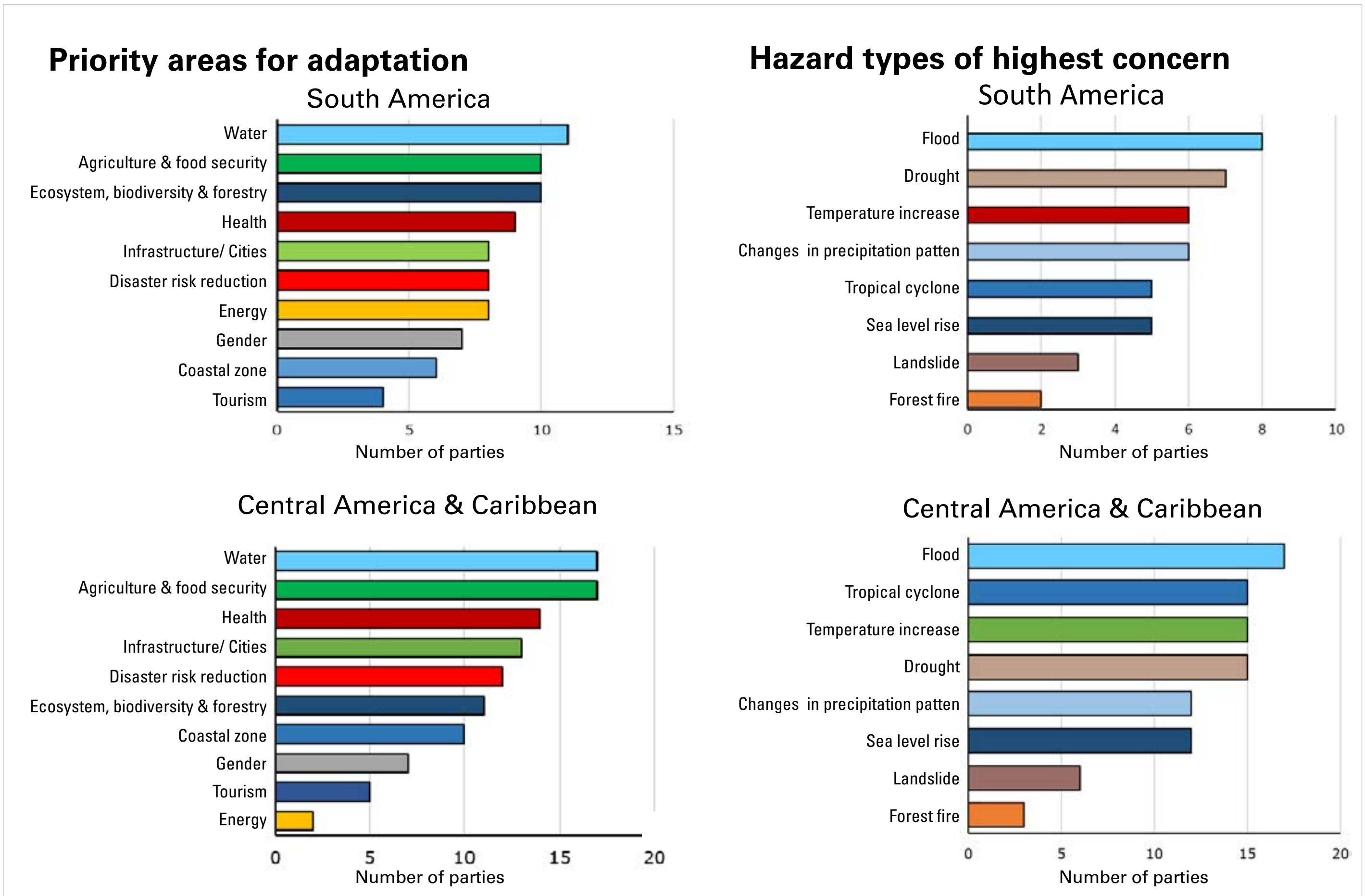
66 Tambutti and Gómez (eds.), 2020: *The Outlook for Oceans, Seas and Marine Resources in Latin America and the Caribbean*.

RISKS ASSOCIATED WITH EXTREME EVENTS

Latin America and the Caribbean is one of the world regions most challenged by climate-related disasters. Hydrometeorological events, such as floods, storms, droughts and heatwaves, account for 93% of all disasters that took place over the last 20 years. The most frequent disaster types recorded globally from 2000 to 2019 were floods (44%) and storms (28%).[67] Furthermore, in addition to larger-scale disasters, the region suffers thousands of smaller events every year, which attract less attention but result in huge cumulative costs and immeasurable suffering. Such events include localized flooding in rural or urban areas, landslides, damage related to intense rains or winds, crops affected by frosts, heatwaves and droughts.[68]

The nationally determined contributions (NDCs) of Latin America and the Caribbean countries submitted to the United Nations Framework Convention on Climate Change reflect this combination of hazards (Figure 22). NDCs focus on water-related extreme events, such as floods and droughts, but tropical cyclones, changes in precipitation pattern and temperature increases are also of high concern. Top sectoral priorities for adaptation include water; agriculture and food

Figure 22. Hazard types of highest concern and priority areas for adaptation in the NDCs of Latin America and the Caribbean countries
Source: NDCs



[67] Centre for Research on the Epidemiology of Disasters (CRED) and United Nations Office for Disaster Risk Reduction (UNDRR), 2020: *The Human Cost of Disasters. An Overview of the Last 20 Years (2000–2019).*

[68] UNDRR (2021), Regional Assessment Report on Disaster Risk in Latin America and the Caribbean, United Nations Office for Disaster Risk Reduction (UNDRR).

security; health; ecosystems, biodiversity and forestry; infrastructure and cities; and disaster risk reduction.

Climate change may result in longer warm seasons, lack of rain, as well as an increase in the intensity and frequency of tropical storms. Sea-level rise will increasingly affect coastal communities, particularly in the small Caribbean islands. In the Caribbean, a region in constant disaster recovery, climate change-related risk factors may include temperature increases, greater vulnerability to drought, projected decrease in rainfall, coastal erosion, coral bleaching and threats to marine resources. According to the State of the Caribbean Climate report, towards the end of the century an increase in frequency of temperature extremes, including very hot days and nights, a decrease in very cold days and nights, an increase in consecutive hot days (or warm spells) and drying conditions are projected for this region (Figure 23).[69]

Although there is little consensus that there may be an increase in Atlantic storms and hurricanes, projections of increased frequency of the most intense storms at 1.5 °C and higher warming levels are significant cause for concern, making adaptation a matter of survival. Extreme weather, linked to tropical storms and hurricanes, represents one of the largest immediate risks faced by the Caribbean island nations specifically.[70]

The Caribbean should contemplate a future in which tropical storm/hurricane genesis, frequency and tracks would be similar to those experienced in the last two decades, but with higher intensities (rainfall rates and

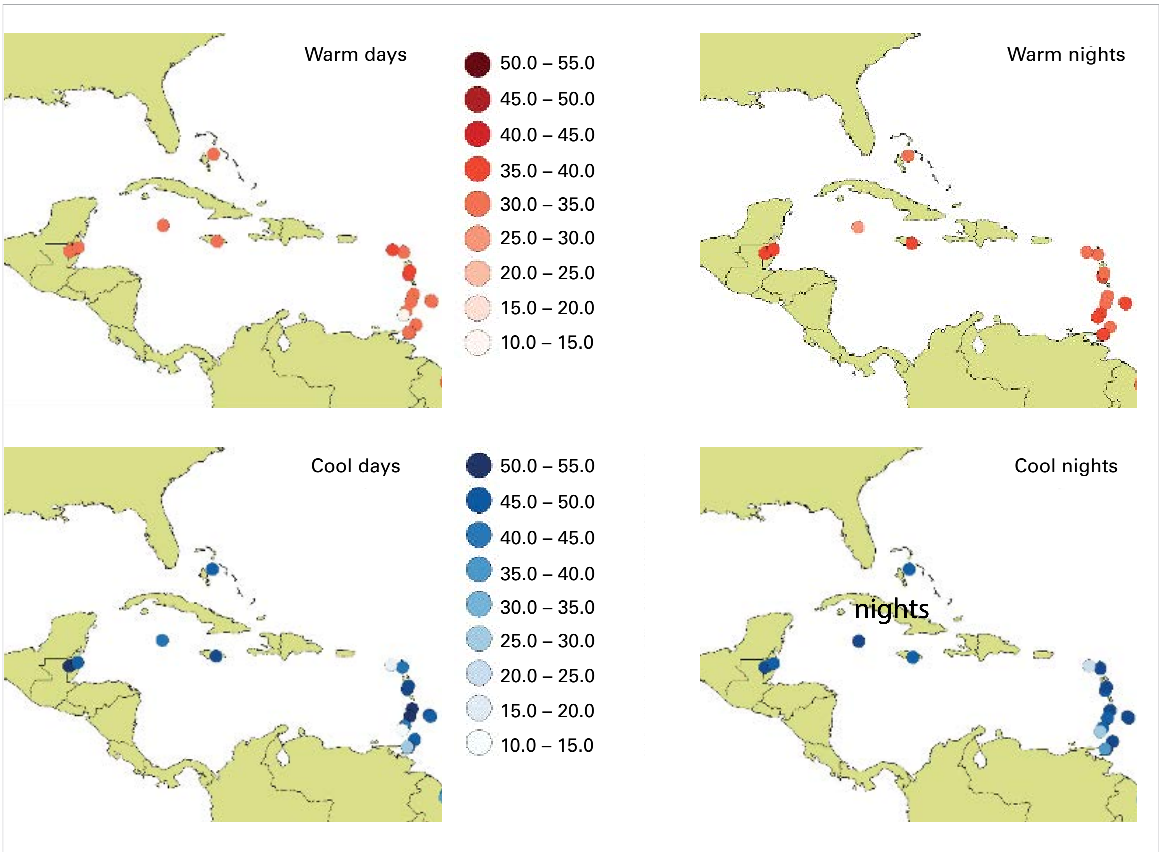
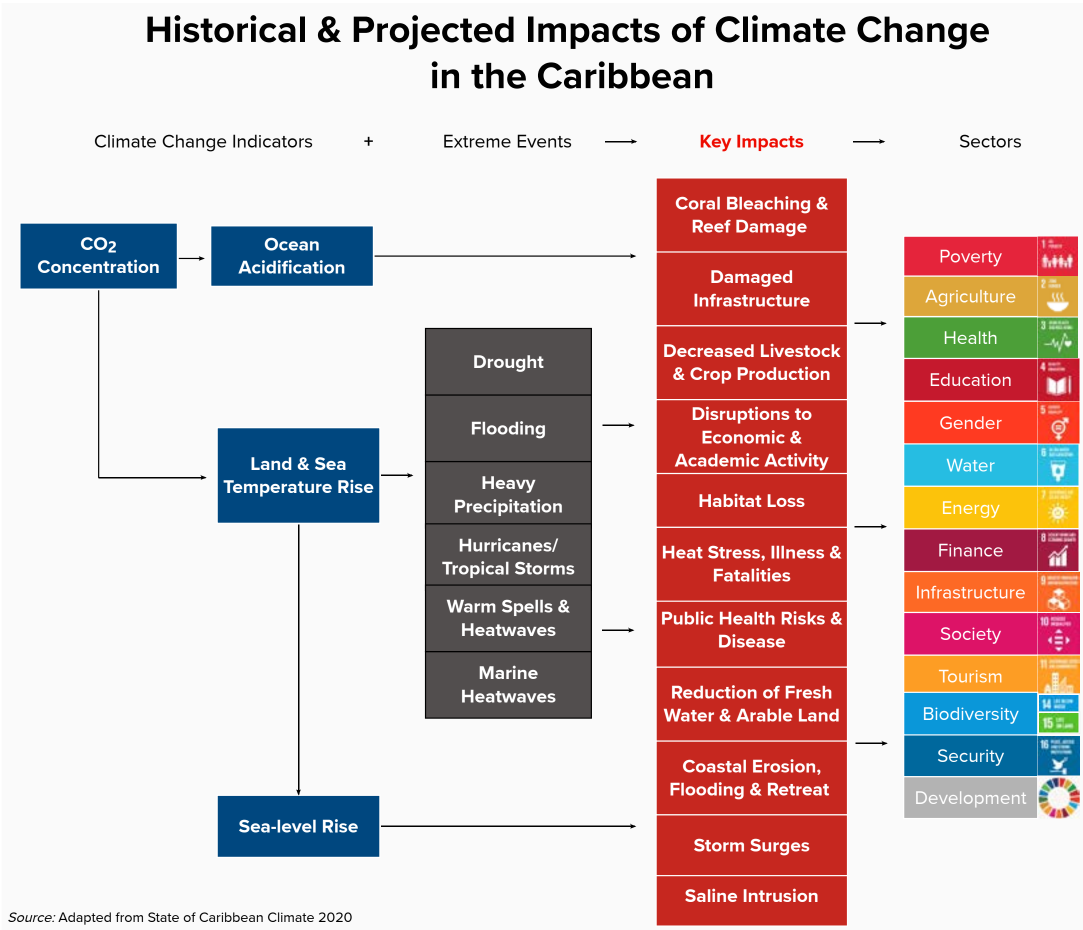


Figure 23. Projections of warm days and nights (90th percentile), cool days and nights (10th percentile), for the period 2090–2100 relative to 2006–2016 for Representative Concentration Pathway (RCP) 8.5. Units are in days.
Source: Climate Studies Group Mona (eds.), 2020

[69] Climate Studies Group Mona (eds.), 2020: *The State of the Caribbean Climate*.

[70] IPCC, 2018: *Global Warming of 1.5°C*.

Figure 24. Historical and projected impacts of climate change in the Caribbean region. *Source:* WMO, adapted from Climate Studies Group Mona (eds.), 2020



wind speeds).[71] A projected warmer ocean will likely lead to the generation of more intense hurricanes and have increasingly negative impacts on coral health and general marine ecology. The complex relationship between climate change and sustainable development in the Caribbean region is demonstrated by a cascading effect exerted by key climate indicators (such as CO_2 concentration, ocean acidification, sea-level rise and extreme events) on various sectors through key impacts (Figure 24).

Climate and climate change-related risk factors by themselves are insufficient to explain the level of devastation, the cost of disasters in the region and their future evolution.

Risk factors related to exposure and vulnerability, created by humanintervention in our physical environment (e.g. uncontrolled or unregulated urbanization, destruction of ecosystems), and other underlying factors of risk, such as poverty, inequality and corruption, are also key contributors.[72]

[71] Climate Studies Group Mona (eds.), 2020: *The State of the Caribbean Climate.*

[72] UNDRR (2021), Regional Assessment Report on Disaster Risk in Latin America and the Caribbean, United Nations Office for Disaster Risk Reduction (UNDRR).

Enhancing climate resilience and adaptation policies

ECOSYSTEM-BASED ADAPTATION

A variety of adaptation responses to coastal impacts and risks have been implemented around the world, but mostly in reaction to current coastal risk or experienced disasters.[73] The Latin America and the Caribbean region's great vulnerability to climate change in its coastal areas and the need to prioritize an adaptation agenda have been continuously emphasized by ECLAC. However, although most countries have adaptation strategies, plans and programmes that include actions related to coastal zones, not much attention has been given to the opportunities for climate change mitigation.

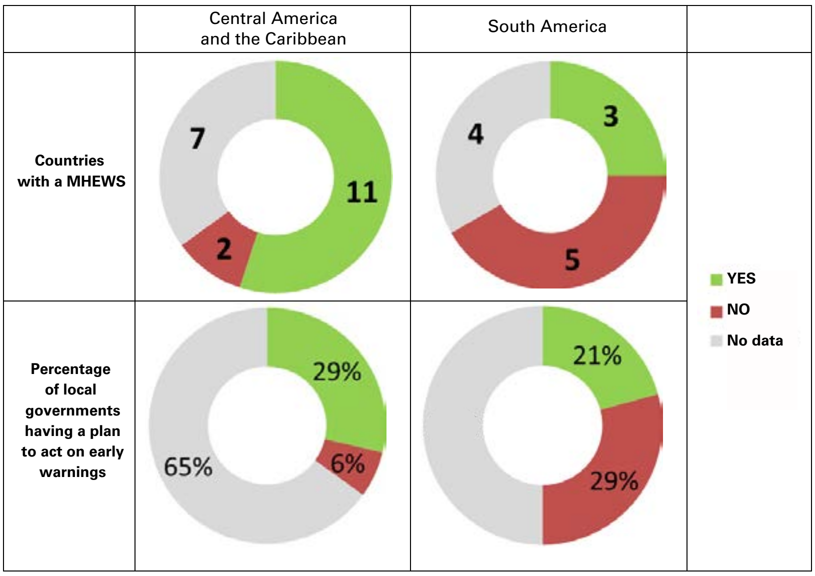
The NDCs of Central American and the Caribbean countries incorporate ocean-related adaptation proposals, such as mangrove and wetland restoration, to reduce the impacts of sea-level rise and extreme sea level. Ecosystem-based adaptation measures include the conservation and restoration of existing blue carbon ecosystems, such as mangroves, seagrass beds and salt marshes, and are an important opportunity for mitigating global warming. Particularly in Latin America and the Caribbean, mangroves are an exceptional resource for this purpose. This ecosystem presents the capacity to store three to four times more carbon than most of the forests on the planet, and it provides other services such as shore stabilization, biodiversity conservation, disaster mitigation and many others. However, contrary to the adaptation preferences of several coastal nations, in particular the SIDS, opportunities to implement ecosystem-based adaptation measures as a means to address coastal hazards and sea-level rise are increasingly limited. Recent data suggest that mangrove areas in Latin America and the Caribbean have declined 20.22 % for the 2001–2018 period.[74]

IMPROVING MULTI-HAZARD RISK-INFORMATION SYSTEMS AND CLIMATE SERVICES

Adaptation measures, such as MHEWSs, are underdeveloped in the Latin America and the Caribbean region. In particular, South America, together with Africa, faces the largest capacity gaps in early warning systems (Figure 25). The capacities related to preparedness for response, monitoring and evaluation of socioeconomic benefits of such systems are particularly weak.

The Caribbean region presents high vulnerability to drought. Seven of its territories are on the global list of the most water-stressed countries, with less than 1 000 m^3 freshwater resources per capita.[75,76] Further stress is expected with the expansion of the tourism industry, population growth, urbanization, increasing societal affluence, ineffective water management practices and strategies, and declining water quality due to anthropogenic activities and climatic factors.[77] Consequently, drought early warning in the Caribbean should at least focus on the seasonal-to-interannual

Figure 25. MHEWS implementation as reported by regional WMO Members (20 from Central America and the Caribbean, and 12 from South America). *Source:* WMO, *2020 State of Climate Services* (WMO-No. 1252)



[73] IPCC, 2019b: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*.

[74] Tambutti and Gómez (eds.), 2020: *The Outlook for Oceans, Seas and Marine Resources in Latin America and the Caribbean*.

[75] FAO defines countries as water-scarce if they have less than 1 000 m3 freshwater resources per capita. See FAO, 2021: The Caribbean must prepare for increased drought due to climate change, http://www.fao.org/americas/noticias/ver/en/c/419202/. See also FAO, 2016: *Drought Characteristics and Management in the Caribbean*. Rome, FAO.

[76] Climate Studies Group Mona (eds.), 2020: *The State of the Caribbean Climate*.

[77] Ibid.

timescale. The Caribbean Climate Outlook Forum outlooks, prepared by the Caribbean Institute for Meteorology and Hydrology (CIMH), with input from a wider group of regional meteorologists and climatologists, examine the relative climate risk on sub-seasonal to seasonal timescales. Those seasonal forecasts are an important source of information for anticipating potential impacts, such as those related to drought.

Strong climate hazard monitoring linked to early warning systems can inform anticipatory action and contingency plans for reducing disaster risk and disaster impacts on lives, livelihoods and food security. Hazard-specific monitoring systems, such as the Agriculture Stress Index System from FAO, in combination with other existing monitoring tools (food insecurity indices and weather forecasts), are examples of useful tools that allow governments to issue early warning alerts for specific sectors, such as agriculture. The Global Framework for Climate Services (GFCS) provides detailed guidance on co-developing and delivering the climate services needed to support decision-making in climate-sensitive sectors, including those highlighted as priorities in the NDCs of Latin America and the Caribbean countries. In addition to climate services for agriculture and food security and for disaster risk reduction, the GFCS provides guidance for climate services in support of improved climate-related outcomes in the areas of water resource management, human health and energy. The GFCS further provides guidance for the establishment of national frameworks for climate services (NFCSs).[78] NFCSs are multi-stakeholder user interface platforms that enable the development and delivery of climate services at the country level. This key GFCS mechanism focuses on improving co-production, tailoring, delivery and the use of science-based climate predictions and services to address country priorities. NFCSs can help parties to the Paris Agreement to prepare, maintain and communicate their NDCs. Moreover, NFCSs can complement national adaptation plans by providing climate services that help to assess climate vulnerabilities, identify adaptation options, improve understanding of the climate and its impacts, and enhance the adaptation planning and implementation capacity of climate-sensitive sectors.

Governance structures must be agile and adaptive, as well as cognizant of the interactions and reverberation of systems, if they are to deal adequately with such complexity and facilitate the development of the necessary tools for climate and risk-informed decision-making, thus allowing human societies to respond to uncertainty. This requires, among other efforts, enhanced multisectoral collaboration and coordination that adhere to scientific evidence. The role of the science and technology community is of particular relevance to supporting other key actors to collect the required evidence, strengthen data-collection mechanisms, improve loss and damage databases, strengthen MHEWSs and climate services, and firmly integrate disaster risk information into development planning.[79,80] Partnerships across levels of intervention, between the public sector, science and technology community, the private sector, academia, as well as civil society and community-based organizations, will be key to meeting the evolving needs of our common agenda for consolidated and coherent risk-informed development based on innovative solutions. Multi-hazard approaches acknowledge the links between climate and other hazards and are imperative to design risk-management strategies that are capable of reducing cascading impacts. Intersectoral risk analysis grounded on existing coordination mechanisms for development actors will help to build this capacity. Multidimensional and disaggregated vulnerability assessments will expose the relationship between risk, poverty, food insecurity, gender, age, ethnicity and other key factors that compound risk, leading to increasingly integrated policy solutions.

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[78] https://gfcs.wmo.int/national-frameworks-for-climate-services

[79] United Nations Conference on Trade and Development, *The Role of Science, Technology and Innovation in Building Resilient Communities, Including Through the Contribution of Citizen Science*. Geneva, United Nations, https://unctad.org/system/files/official-document/dtlstict2019d11_en.pdf.

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