

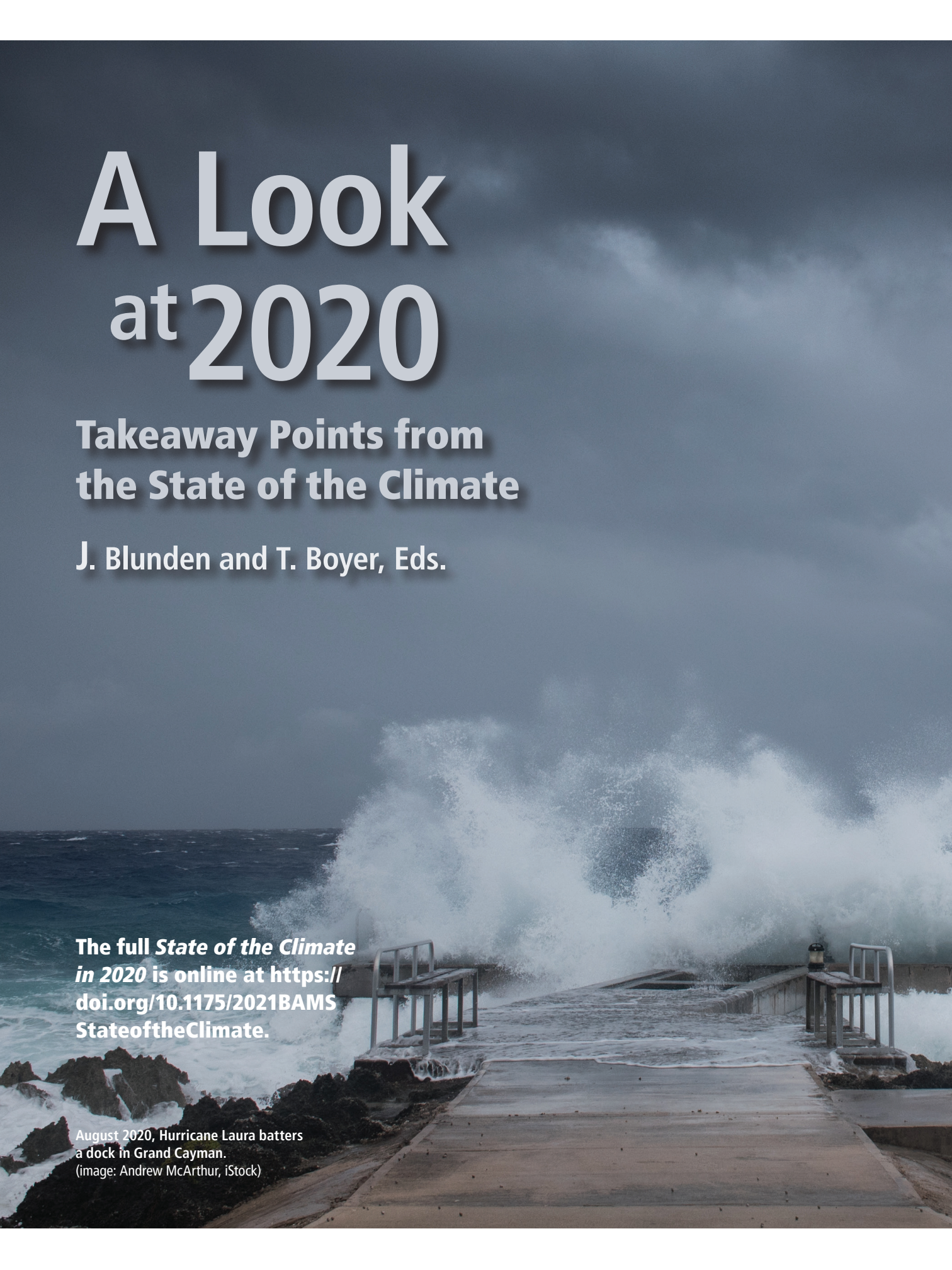
A Look at 2020

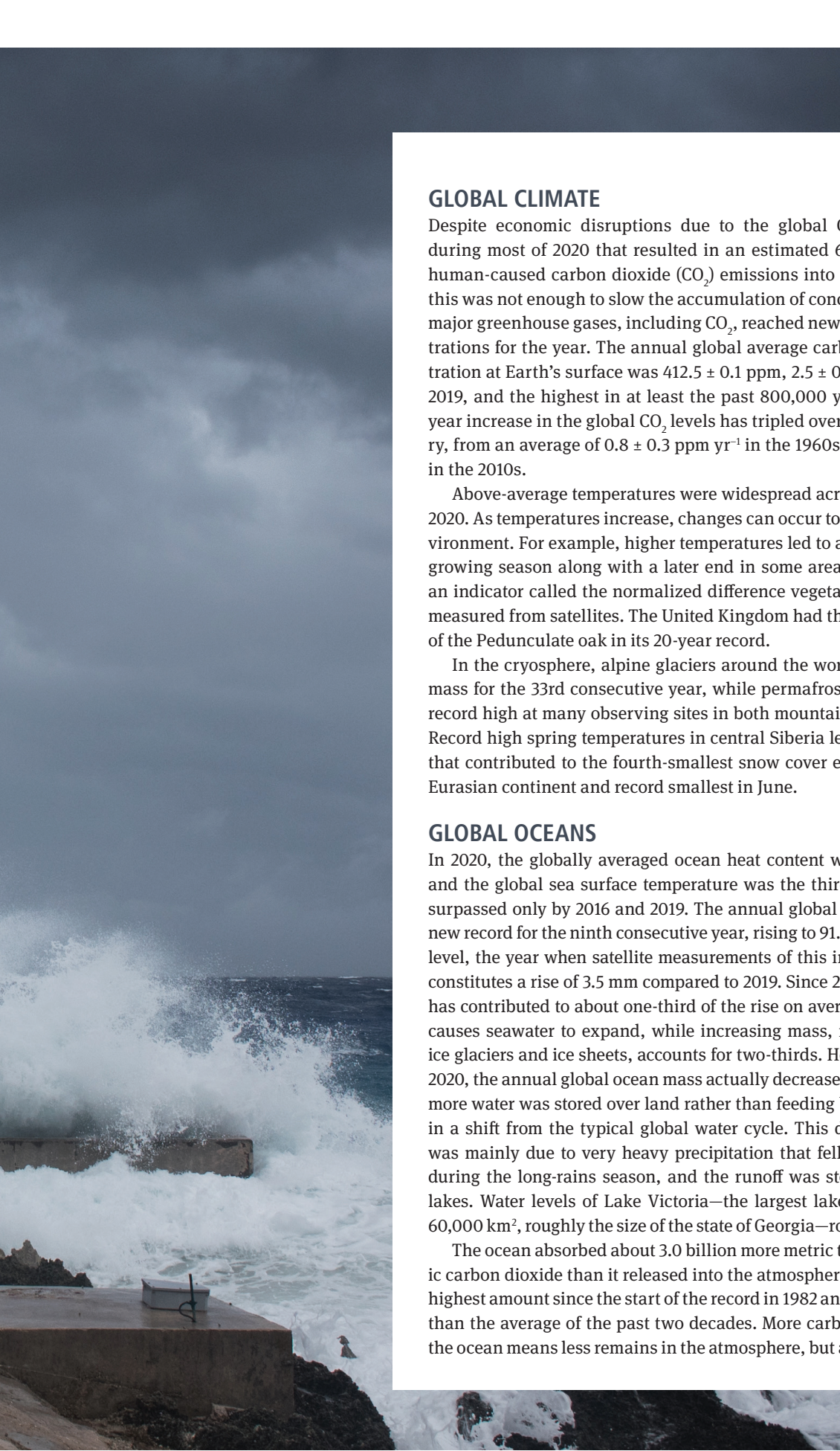
Takeaway Points from the State of the Climate

J. Blunden and T. Boyer, Eds.

The full *State of the Climate
in 2020* is online at [https://
doi.org/10.1175/2021BAMS
StateoftheClimate](https://doi.org/10.1175/2021BAMS
StateoftheClimate).

August 2020, Hurricane Laura batters
a dock in Grand Cayman.
(image: Andrew McArthur, iStock)





GLOBAL CLIMATE

Despite economic disruptions due to the global COVID-19 pandemic during most of 2020 that resulted in an estimated 6%–7% reduction in human-caused carbon dioxide (CO₂) emissions into Earth's atmosphere, this was not enough to slow the accumulation of concentration levels. All major greenhouse gases, including CO₂, reached new record high concentrations for the year. The annual global average carbon dioxide concentration at Earth's surface was 412.5 ± 0.1 ppm, 2.5 ± 0.1 ppm more than in 2019, and the highest in at least the past 800,000 years. The year-over-year increase in the global CO₂ levels has tripled over the past half century, from an average of 0.8 ± 0.3 ppm yr⁻¹ in the 1960s to 2.4 ± 0.4 ppm yr⁻¹ in the 2010s.

Above-average temperatures were widespread across the globe during 2020. As temperatures increase, changes can occur to the surrounding environment. For example, higher temperatures led to an earlier start to the growing season along with a later end in some areas, as determined by an indicator called the normalized difference vegetation index, which is measured from satellites. The United Kingdom had the earliest “first leaf” of the Pedunculate oak in its 20-year record.

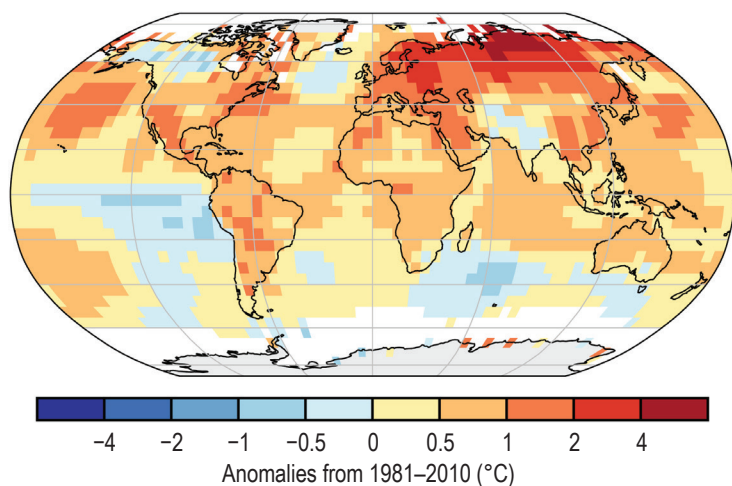
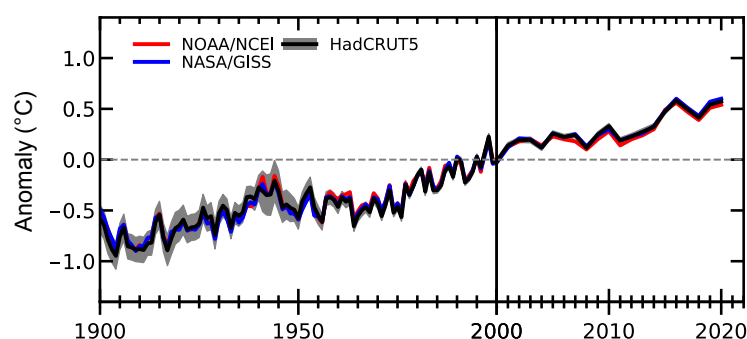
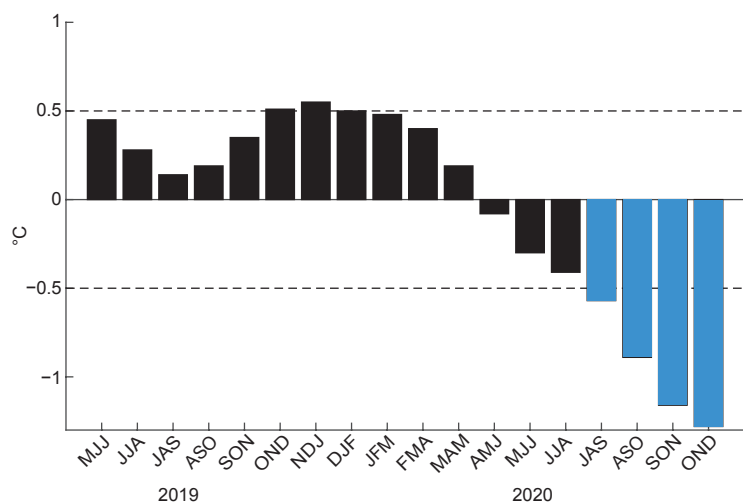
In the cryosphere, alpine glaciers around the world continued to lose mass for the 33rd consecutive year, while permafrost temperatures were record high at many observing sites in both mountain and polar regions. Record high spring temperatures in central Siberia led to rapid snowmelt that contributed to the fourth-smallest snow cover extent in May for the Eurasian continent and record smallest in June.

GLOBAL OCEANS

In 2020, the globally averaged ocean heat content was at a record high, and the global sea surface temperature was the third highest on record, surpassed only by 2016 and 2019. The annual global mean sea level set a new record for the ninth consecutive year, rising to 91.3 mm above the 1993 level, the year when satellite measurements of this indicator began. This constitutes a rise of 3.5 mm compared to 2019. Since 2005, ocean warming has contributed to about one-third of the rise on average, as the warming causes seawater to expand, while increasing mass, mostly from melting ice glaciers and ice sheets, accounts for two-thirds. However, from 2019 to 2020, the annual global ocean mass actually decreased by 1.0 mm because more water was stored over land rather than feeding back into the oceans in a shift from the typical global water cycle. This decrease in sea level was mainly due to very heavy precipitation that fell over eastern Africa during the long-rains season, and the runoff was stored in surrounding lakes. Water levels of Lake Victoria—the largest lake in Africa at nearly 60,000 km², roughly the size of the state of Georgia—rose by more than 1 m.

The ocean absorbed about 3.0 billion more metric tons of anthropogenic carbon dioxide than it released into the atmosphere in 2020. This is the highest amount since the start of the record in 1982 and almost 30% higher than the average of the past two decades. More carbon dioxide stored in the ocean means less remains in the atmosphere, but also leads to increas-

Global temperature reaches near-record high despite development of a moderate La Niña



In the eastern tropical Pacific Ocean, where the phases of the El Niño–Southern Oscillation are indexed using sea surface temperatures (SSTs), slightly above-average SSTs early in the year cooled to a moderate La Niña by the end, with SSTs more than 1°C below normal. Typically, the highest annual global surface temperatures are observed during warm-phase El Niño conditions, but even in La Niña phase for much of the year, the annually averaged temperature across land and ocean surfaces in 2020 was still among the three highest in records dating as far back as the mid-1800s. [Figs. 4.1 and 2.1a, and Plate 2.1a in *State of the Climate in 2020*; see discussion there in sections 4b and 2b(1), respectively.]

ing acidification of the waters, which can greatly harm or shift ecosystems.

THE TROPICS

Across the central and eastern equatorial Pacific Ocean, SST shifts from slightly above normal to below average signaled a transition to La Niña by August, which strengthened to a moderate state—more than 1°C below the 1991–2020 average—by the end of the year. La Niña impacted climate patterns around the globe, as noted in several sections in this article.

In total, 102 named tropical cyclones were observed during the combined Northern Hemisphere and Southern Hemisphere storm seasons, well above the 1981–2010 average of 85. Three tropical cyclones across the globe reached Saffir–Simpson Hurricane Wind Scale category 5 intensity level—Amphan in the north Indian Ocean, Harold in the southwest Pacific, and Goni in the western North Pacific. The North Atlantic hurricane basin recorded a record 30 named storms, surpassing the previous record of 28 in 2005. Seven of those storms became major hurricanes, matching 2005 for a record number.

THE ARCTIC

The average surface air temperature over Arctic land areas in 2020 was the highest in the 121-year record, with notably high temperatures over north-central Siberia during most of the year. This was the seventh straight year with an annual temperature more than 1°C higher than the 1981–2010 average. On 20 June, a temperature of 38°C was observed at Verkhoyansk, Russia (67.6°N), provisionally the highest temperature ever measured within the Arctic Circle. The Arctic continues to warm at a faster pace than lower latitudes.

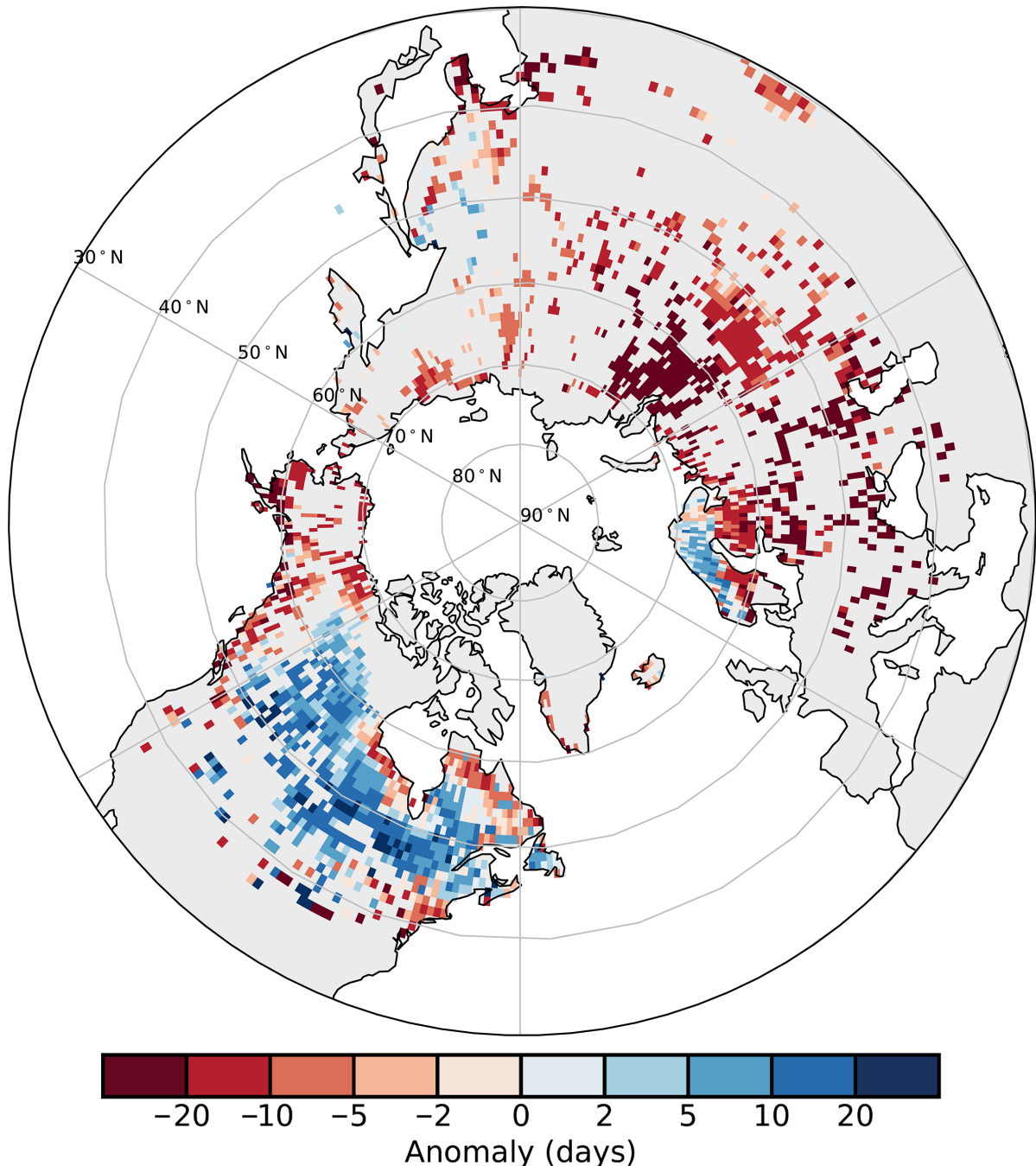
With the warmth came fires. The Arctic experienced its highest fire year in terms of the amount of carbon released into the atmosphere, surpassing the record set in 2019 by 34%. The majority of the fires occurred in northeastern Siberia where the abnormally high temperatures occurred. For the past five years, more fires have occurred each year in the Arctic compared to the previous year.

As sea ice extent shrinks over time, brighter, more reflective sea ice is replaced by dark-

er, less reflective water at the surface, and more incoming solar radiation is absorbed by the ocean rather than being reflected back to space. This additional radiation warms

the seas. In August, the time of year with the least amount of ice cover in the Arctic, the Laptev and Kara Seas—which border northern Siberia and where extreme warmth pre-

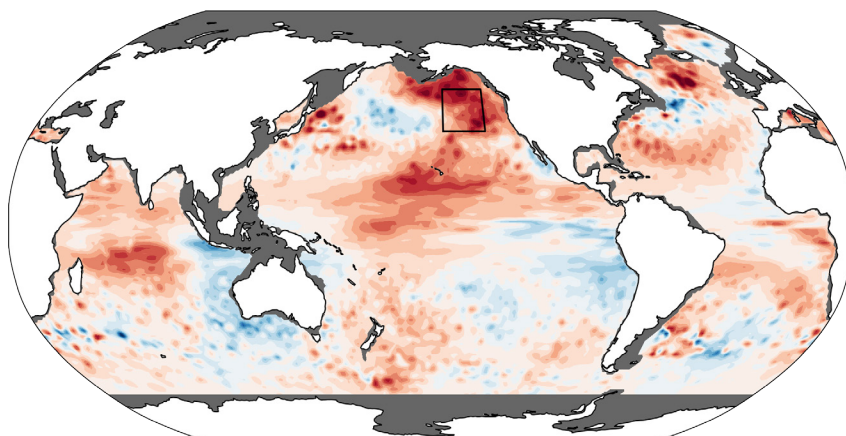
Above-average temperatures led to fewer days of frozen lakes in the Northern Hemisphere



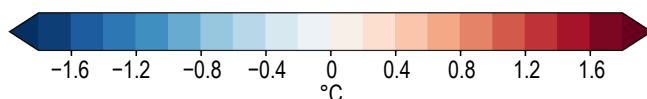
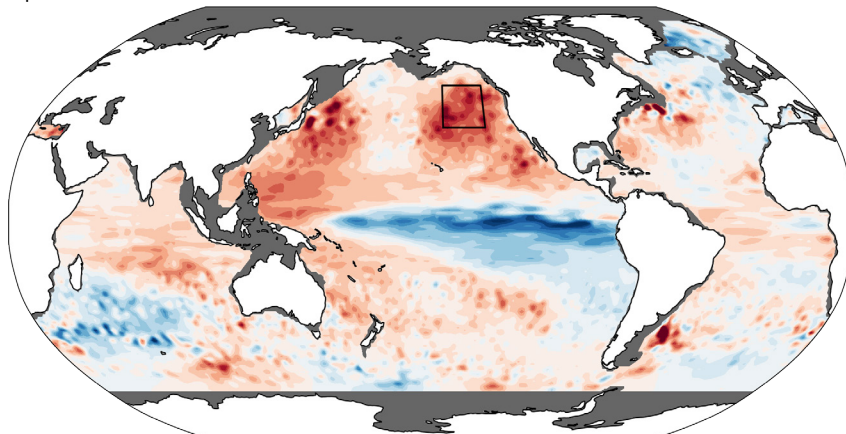
On average, lakes in the Northern Hemisphere were frozen 8.5 fewer days than their respective long-term means during the cold season, from November 2019 through April 2020, although there were some major geographical differences. The majority of lakes in North America were frozen more days (blue) than average in 2020, while most lakes in Eurasia were frozen fewer days (red). In Finland, they were frozen 42 days less on average, and some lakes that typically freeze in December did not do so until February. [Fig. 2.16c in *State of the Climate in 2020*; see discussion there in section 2c(4).]

Major heatwave occurs in the northeast Pacific, again

Jun–Aug 2019



Sep–Nov 2020



In summer 2019, a major marine heat wave developed in the northeast Pacific Ocean, marking the second such event here in the past decade. By August it encompassed an area spanning from the Gulf of Alaska to the Hawaiian Islands. The top map shows the above-average sea surface temperature during the summer period, June–August 2019. The event was so unusual that the summer SSTs were more than 2.5°C above normal, breaking a 40-year record. The event lasted through 2020, covering an ocean area roughly 6 times the size of Alaska in September. The bottom map shows the SST departures from average during September–November of 2020, indicating that the heat wave persisted. Harmful algal blooms developed along the U.S. West Coast, and coral reefs near Hawaii started to bleach under the heat stress. Off the coast of Oregon, warmer waters brought albacore tuna closer to shore, making them more accessible to recreational anglers, leading to record-breaking landings in September. Overall, nearly all of the global oceans, except for the North Atlantic south of Greenland and the equatorial Pacific—shown by the dark blue band in the bottom map indicating below-average temperatures in that region—experienced a marine heat wave in 2020. Here, a heat wave is defined as SSTs in the top 10% of all measurements at that location and time of year for five or more consecutive days. (Figs. SB3.1a,b in *State of the Climate in 2020*; see discussion there in Sidebar 3.1.)

vailed in 2020—had sea surface temperatures as much as 5.5°C above the 1982–2010 average for the month due to exceptionally low summer sea ice extent.

ANTARCTICA AND THE SOUTHERN OCEAN

An atmospheric river—a long, narrow region in the atmosphere that transports water vapor from subtropical and midlatitudes—brought extreme warmth to parts of Antarctica during austral summer. On 6 February, Esperanza Station reached 18.3°C, the highest temperature ever recorded on the continent, surpassing the previous record set in 2015 by 1.1°C. The warmth also led to the largest late-summer surface melt event in the 43-year record, affecting more than 50% of the Antarctic Peninsula and impacting elevations as high as 1,700 m.

In August, daily sea ice extent in the waters surrounding Antarctica shifted from below to above average, marking the end of persistent below-average sea ice extent since austral spring 2016. The emerging La Niña event in the equatorial Pacific Ocean was linked to this shift.

The Antarctic polar vortex was unusually strong and persistent in 2020, with polar temperatures in the stratosphere at record low levels throughout November and December. This strong vortex was linked to the longest-lived ozone hole over the Antarctic, which lasted to the end of December. Record-low ozone values in late austral spring and early summer led to unusually high levels of UV radiation across the Antarctic region.

REGIONAL CLIMATES

North America. Annual temperatures were above the 1981–2010 average for the United States, Canada, and Mexico. Mexico re-

Hurricane Laura causes massive damage in Louisiana



Hurricane Laura was the strongest hurricane to make landfall in the United States in 2020, coming ashore near Cameron, Louisiana, as a category 4 storm with maximum sustained winds of 130 kt on 27 August—the strongest for a Louisiana hurricane since the Last Island Hurricane of 1856. The storm caused dozens of fatalities along its path and an estimated \$19 billion in damage to Louisiana alone, including the destruction of the Lake Charles' Weather Forecast Office's WSR-88D Doppler radar, as shown in the photo above (image courtesy of Brett Adair, Live Storms Media). (Fig. SB4.2 in *State of the Climate in 2020*; see discussion there in Sidebar 4.1.)

ported its warmest year on record, on par with 2017 and 2019, while the United States reported its fifth warmest. Although still warmer than its 1981–2010 average, Alaska reported its coolest year since 2012. The annual temperature for Alaska has increased at an average rate of 0.50°C decade⁻¹ over the past half century.

The United States was dominated by warm, dry air in the West and an active storm track that brought wet conditions to much of the East. Drought covered nearly half of the contiguous United States by the end of the year, with more than 22% of the country experiencing extreme and exceptional drought—the two worst categories.

Most of Mexico was drier than average in 2020 due to the late onset of a weak North American monsoon and a lack of tropical cyclones on the Pacific side. However, The Yucatan Peninsula was wetter than average due to tropical cyclones that impacted eastern Mexico.

In Canada, the Avalon Peninsula in Newfoundland was hit by a strong blizzard. Wind speeds reached hurricane force at 160 km h^{-1} along the coast, and a new snowfall record of more than 75 cm was recorded at St. John's International Airport. The storm contributed to the snowiest January on record for St. John's.

Central America and the Caribbean. The temperature varied across Central America in 2020. The annual mean temperature for Liberia, Costa Rica, was 3°C below average, while Puerto Barrios, Guatemala, observed an annual temperature that was 2°C above average.

In the Caribbean basin, the annual average temperature over the region was the second highest since the start of the record in 1891. Annual average maximum temperatures were record high for stations in The Bahamas, Dominica, and Trinidad and Tobago. Aruba, Martinique, and Saint Lucia each reported their all-time highest monthly maximum temperature—all in September. Two all-time daily maximum temperature records were also set that month: Dominica (35.7°C) and Grenada (34.0°C) with records starting in 1975 and 1986, respectively.

Drought also impacted parts of the Caribbean from October 2019 to mid-2020, causing water shortages, bush fires, and crop damage. In St. Vincent and the Grenadines, this drought was considered the worst in 50 years.

South America. Most of South America had above-average temperatures during the year. The 2020 mean temperature for central South America was the second highest

for the region in the 61-year record. Only 2015 had a higher temperature departure, which was mainly due to the influence of a strong warm-phase El Niño in the tropical Pacific Ocean at the end of the year. In 2020, a moderate cool-phase La Niña was present. During a strong heat-wave in October, the city of São Paulo, Brazil, recorded four of its five all-time daily maximum temperatures.

The Bolivian lowlands suffered one of its most severe droughts on record during autumn. Drought also spanned

the Chaco and Pantanal in Bolivia, Paraguay, and southern Brazil. The Paraguay River shrank to its lowest levels in half a century, leading to difficulties accessing potable water and limited river traffic, and the number of fires in the Brazilian Pantanal in 2020 surpassed 2019 by over 240%.

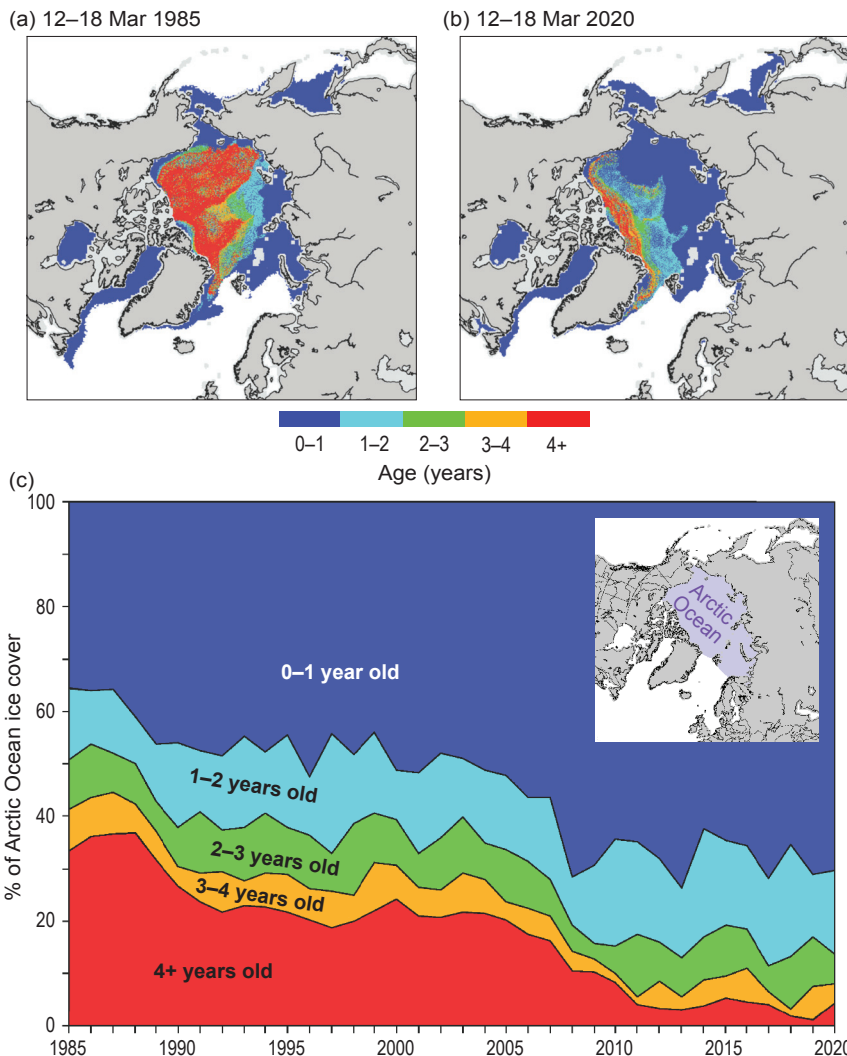
Above-normal rainfall across the semiarid area of northeastern Brazil during March–May helped end a 6-year drought in that region. During Ecuador’s rainy season, which extends from January to April, nearly 600 landslides

and over 230 floods were reported across both the coastal and Amazon region. More than 70 fatalities were associated with these events. Heavy rain also impacted the coastal and Andean regions of Peru. On 22–23 January, the southern coast of Peru received record-breaking rainfall of 26 mm in a region where it normally does not rain.

Africa. Large parts of northern and equatorial Africa observed above-normal annual temperatures in 2020. Seychelles, an archipelago in the Indian Ocean off East Africa, observed its highest annual temperature in the record dating to 1972. In West Africa, Nuguru, Nigeria, observed about 80 days of maximum temperatures exceeding 40°C in 2020, surpassing its previous record of 77 days in 2019. Most of South Africa, Namibia, and southern Angola had below-normal annual temperatures.

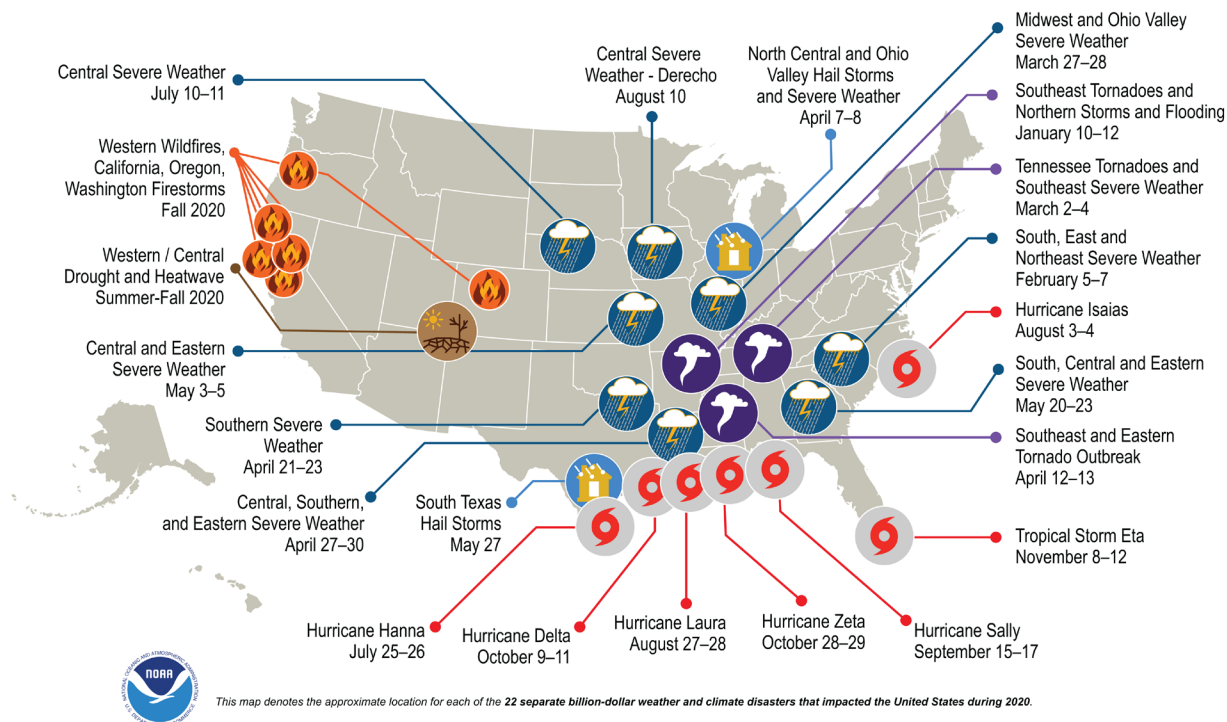
A widespread desert locust infestation during 2019–20 impacted equatorial and northern East Africa, as heavy rains and prevailing winds were favorable for breeding and movement of swarms across Kenya, Ethiopia, northeastern Somalia, Uganda, South Sudan, and northern Tanzania. The massive infestation destroyed thousands of square kilometers of cropland and pasture lands, resulting in 1 million people in need of food aid in Ethiopia alone. The World Bank estimated that related losses may be as much as US\$8.5 billion for the East Africa region and Yemen.

Older, thicker sea ice in the Arctic continues to be replaced by younger, thinner ice.



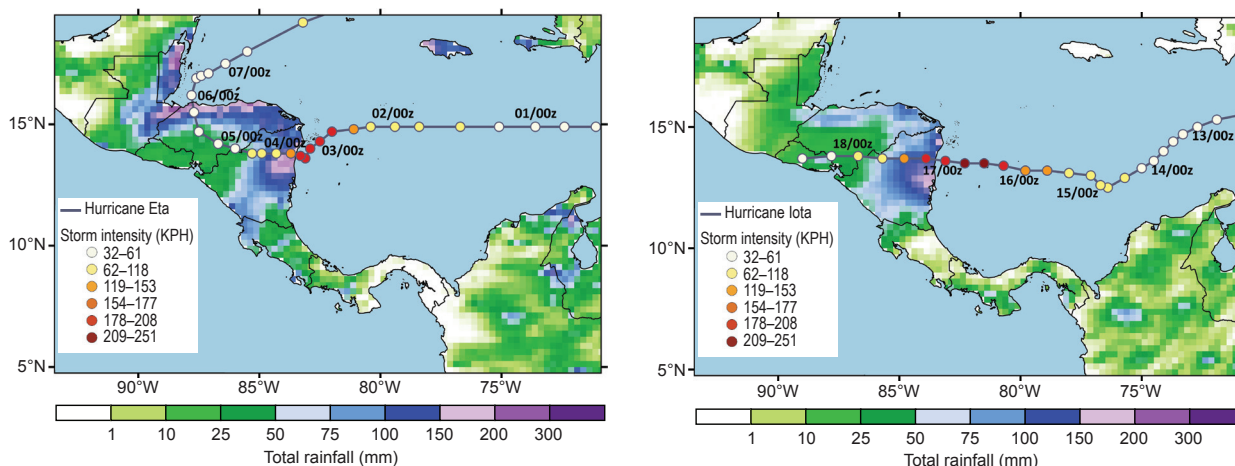
In March, when sea ice reached its annual maximum extent, thin, first-year ice comprised ~70% of the ice; the thickest ice—more than 4 years old—had declined by more than 86% since 1985 to make up just 2% of total ice in 2020. When the minimum sea ice extent was reached in September, it was the second smallest in the 42-year satellite record, behind 2012. The Northern Sea Route along the Siberian coast was open for about 2.5 months, from late July through mid-October, compared to less than a month typically. (Fig. 5.10 in *State of the Climate in 2020*; see discussion there in section 5d.)

The United States saw a record number of billion-dollar disasters in 2020



There were 22 weather and climate events across the United States during 2020 with losses that each exceeded \$1 billion. This shatters the previous annual record of 16 events that occurred in both 2011 and 2017. Together, total losses were \$95 billion. Western wildfires consumed nearly 10.3 million acres from California to Colorado; this was the largest acreage consumed across the contiguous United States since at least 2000. Over the past five years, since 2016, the total cost of U.S. billion-dollar disasters was more than \$600 billion. (Fig. 7.5 in *State of the Climate in 2020*; see discussion there in section 7b.)

Back-to-back Hurricanes Eta and Iota impacted Nicaragua and surrounding countries



Among the last storms of the North Atlantic hurricane season, powerful category 4 Hurricanes Eta (left) and Iota (right) impacted Central America in November, making landfall along the eastern coast of Nicaragua in nearly the same location within a two-week period. Over 7 million people across all Central American countries were affected; in Nicaragua alone, 98 fatalities were reported along with more than US\$700 million in damage and economic losses. (Figs. SB7.1 and SB7.2 in *State of the Climate in 2020*; see discussion there in Sidebar 7.1.)

Extremely heavy rains in April triggered widespread flooding and landslides in Ethiopia, Somalia, Rwanda, and Burundi. The Lake Victoria region was the wettest in its 40-year record and, as noted in the “Global Oceans” section, the lake itself rose more than 1 m due to the excessive rain. In West Africa, excessive rainfall and resulting massive floods during 2020 affected hundreds of thousands of people across Nigeria, Ghana, Ivory Coast, Burkina Faso, Mali, Senegal, and The Gambia. In Niger, sustained torrential rains in August and September caused the Niger River to overflow, shutting down the capital, Niamey.

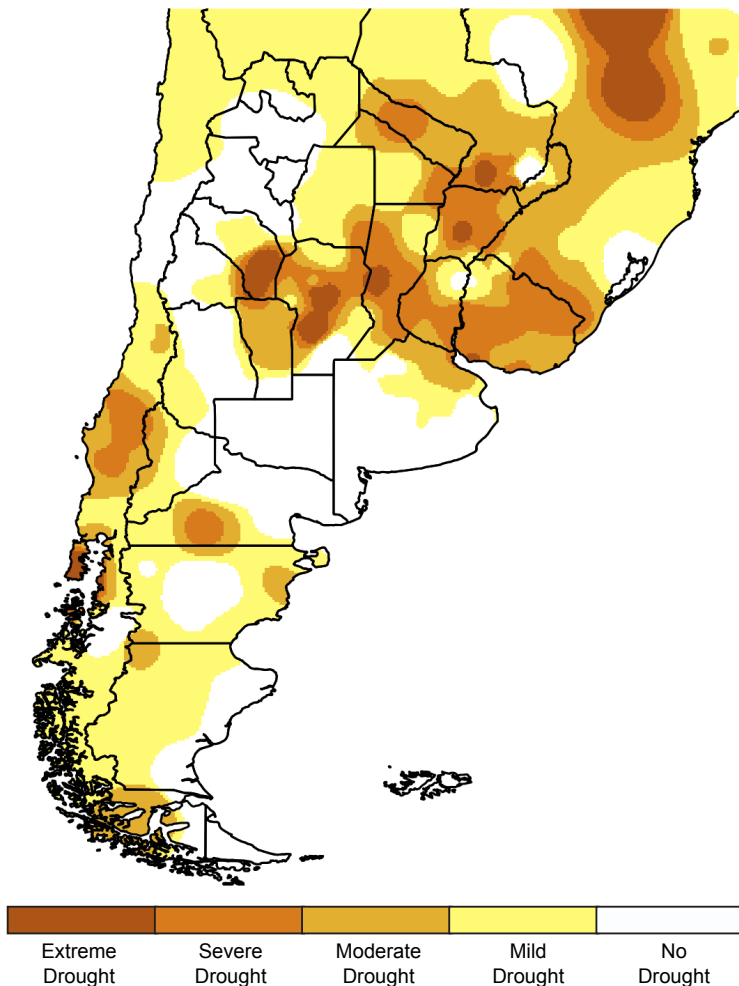
In November, a very severe cyclonic storm—Gati—made landfall over Somalia with estimated winds of 140 km h⁻¹, the first storm of such intensity to do so. Bosaso, in northeast Somalia, received 128 mm of rainfall in one day, exceeding the city’s average annual rainfall total for the region of 100 mm.

Europe and the Middle East. On 2 January, Sunndalsøra, Norway, reached 19.0°C, the highest temperature ever recorded during winter in Scandinavia, and 25°C above the monthly average. In February, almost all areas in Europe

observed temperatures more than 3°C higher than average. Biarritz in southern France reached a temperature of 26.6°C, which is higher than the monthly average for July and August. The exceptional warmth even reached high up into the Alps, leading to several February maximum temperature records. A temperature of 3.9°C was measured at Sonnblick Mountain in Austria (3106 m altitude), the highest since the start of the record in 1886. During a heatwave in August, the Netherlands counted a record of eight consecutive tropical days, where daily maximum temperatures rose above 30°C. Warmth came to Scandinavia at the end of the year as well. On 18 November, a temperature of 15.1°C was measured at both stations Norrköping and Oskarshamn, the highest temperature observed in Sweden so late in the year. And at Mariehamn Airport in Finland, a new national November record of 16.6°C was set on the 6th.

On 4 January, 74 mm of precipitation was measured within 2 hours in Tel Aviv, Israel, which is around 20% of its annual rainfall. Heavy rain fell on the island of Evia in central Greece on 8–9 August. Within a few hours, 200–300 mm were recorded on parts of the island, which is about 80% of its annual precipitation. On 3 October, the United Kingdom received an average of 31.7 mm, which made it the wettest day in the record dating to 1891. Not all areas were wet. The Middle East experienced an extreme drought during autumn, with most places

Drought affected large areas of southern South America in 2020



Drought conditions plagued southern South America during 2020. The standard precipitation index encompassing all of 2020 shows drought all across the region. The darker colors show more intense drought conditions. A decadal “mega drought” in south-central Chile continued through its 11th year, with extreme conditions in the most populated areas. Argentina reported its driest year since 1995. Northern and central Argentina and Uruguay were affected by one of their worst droughts on record. That drought, which began in 2019, continued during a weak summer rainy season in 2020. [Fig. 7.17 in *State of the Climate in 2020*; see discussion there in section 7d(3).]

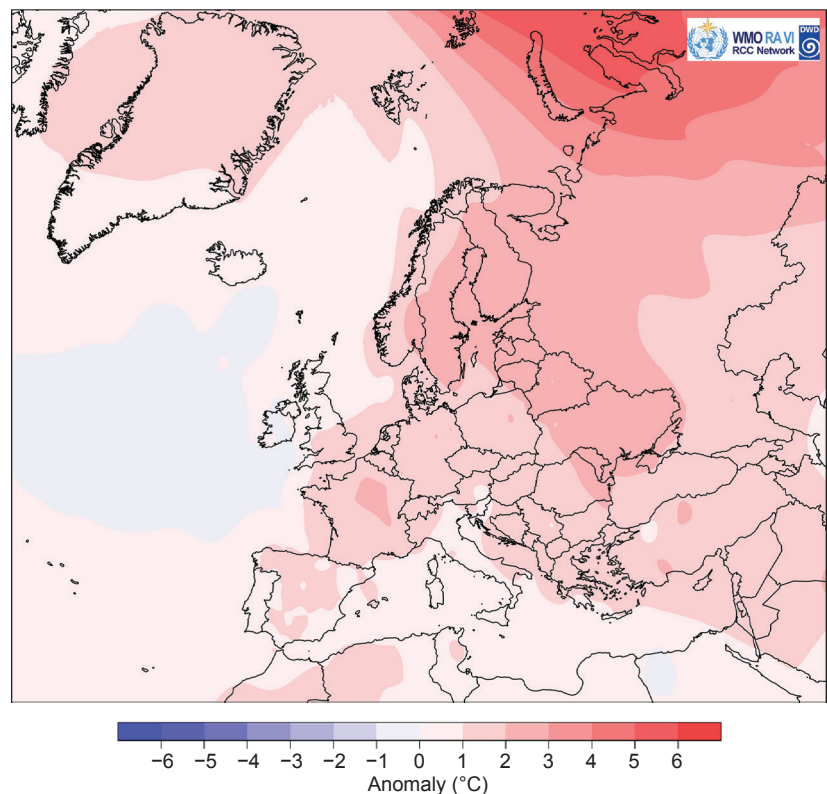
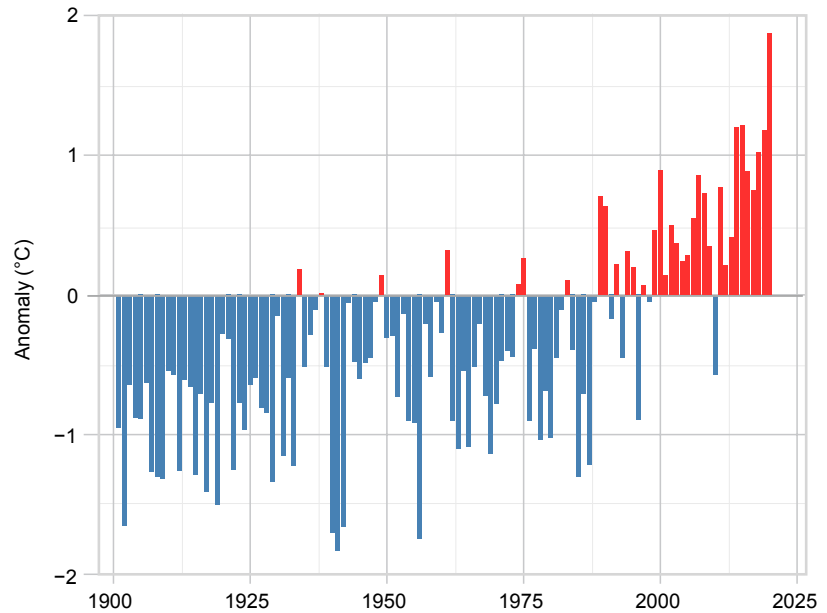
reporting 0%–20% of their typical precipitation in September and no precipitation at all in October.

Asia. Annual average temperatures during 2020 were above normal across most of Asia. Japan and Russia each observed its highest annual temperature on record. In northern Siberia, annual temperatures were more than 5°C above average across vast territories, and more than 6°C above average in the Taimyr Peninsula. The average winter temperature for all of Russia was 5°C above normal.

In East Asia, Hong Kong, China, reported 50 hot nights, where the daily minimum temperature did not dip below 28.0°C, and 47 very hot days, where the daily maximum temperature reached at least 33.0°C, both of which set new annual records. July 2020 was the hottest of any month in Hong Kong, China, since records began in 1884.

The 2020 southwest Asian monsoon season (June–September) was the wettest since 1981, coincident with the emergence of La Niña, which generally contributes to increased monsoon rainfall. The mei-yu/baiu/changma season (July–August), a typical rainy season over the Yangtze and Huaihe River valleys of China, started earlier and ended later than normal, doubling its typical duration by 2 months in 2020. Exceptionally strong and prolonged precipitation occurred from central China to southern Japan in June–July, and the May–October total rainfall averaged over the area was the most since the start of the record in 1961. Associated severe flooding affected about 45.5 million people and caused direct economic losses of more than 100 billion Chinese yuan (US\$15.5 billion). Fire activity in tropical Asia—including Indonesia—was one of the lowest on record, related to wet conditions as La Niña started to evolve during the fire season.

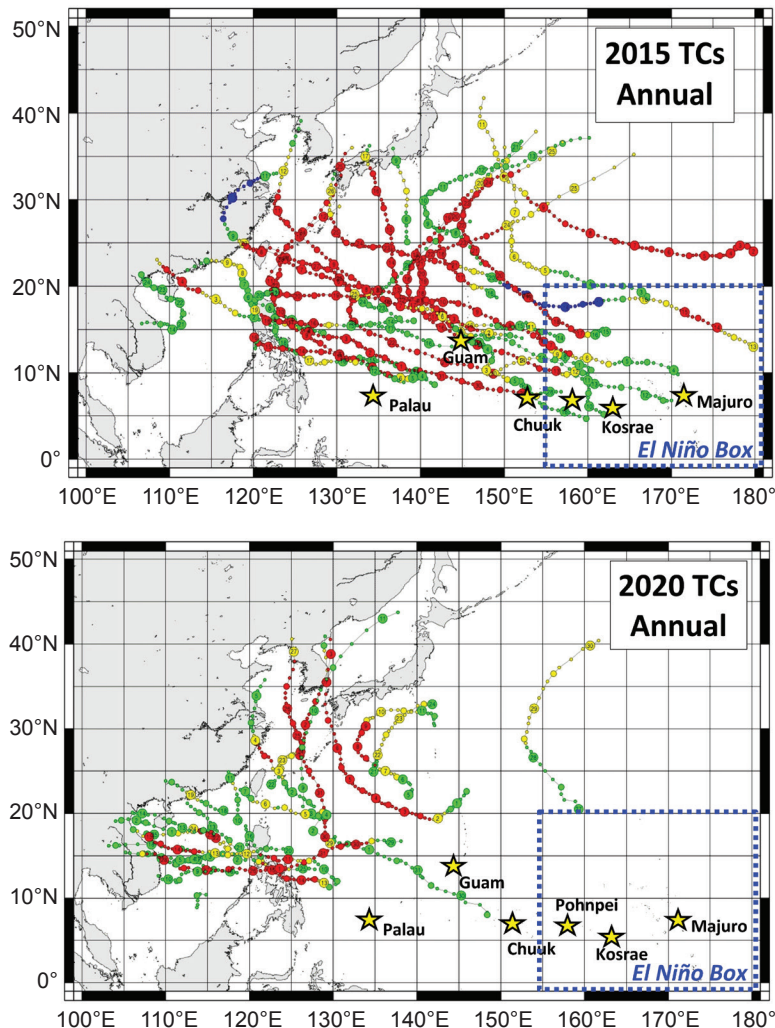
The European continent observed its warmest year on record



In Europe, 2020 was the warmest year on record, with all five of the warmest years occurring since 2014. Many countries across the continent reported their highest annual temperatures on record, including Belarus, Belgium, European Russia, Estonia, Finland, France, Kazakhstan, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland, and Ukraine. (Figs. 7.36 and 7.37 in *State of the Climate in 2020*; see discussion there in section 7f.)

As is typical, several tropical cyclones impacted Asia in 2020. Super Typhoon Goni was the strongest storm on record anywhere in the world to make landfall. More than 1 million people were evacuated from its path in the Philippines. Eight tropical cyclones directly affected Vietnam. Typhoon Molave was one of the most intense storms to reach the country in the past 20 years.

La Niña contributed to weak typhoon activity in the northwest Pacific and Micronesia



The northwest Pacific and Micronesia region saw a distinct absence of tropical cyclone (typhoon) activity in 2020. This is a classic La Niña signature. The typhoon tracks of 2015 (strong El Niño) and of 2020 (moderate La Niña) shown here illustrate the dramatic changes that can occur to the distribution of tropical cyclones in the western North Pacific from the state of ENSO. The islands of Micronesia (yellow stars) are profoundly affected, with tropical cyclones occurring in the “El Niño Box” almost exclusively during El Niño years. (Fig. SB7.5 in *State of the Climate in 2020*; see discussion there in section 7h.)

Oceania. The El Niño–Southern Oscillation (ENSO) plays a large role in the weather and climate of Oceania. Most locations across Micronesia were drier than average during the first half of 2020 and wetter than average at all locations in the second half. For the year, Kosrae was record wet, while Kapingamarangi and Saipan observed near-record low annual rainfall totals. On Kapingamarangi, there were severe shortages of potable water in the latter half of 2020, requiring delivery of water supplies by ship.

Rainfall was suppressed along the equator in the Pacific east of approximately 160°E from April onward, associated with the transition toward La Niña conditions. Below-normal rainfall was particularly evident in the western South Pacific later in the year, with strong suppression of rainfall in a broad region to the north of Papua New Guinea and the Solomon Islands.

The last days of 2019 and first days of 2020 saw particularly hazardous fire weather in eastern Australia, where multiple fires had been burning since austral spring 2019. The emergence of La Niña was a welcome change for the Australian region, with this phase of ENSO contributing to increased rainfall over the continent, after a very significant 2019/20 fire season. Even with increased rainfall, this was Australia’s fourth-warmest year in its 111-year record. Warmth was widespread and persistent through the year—the national mean temperature was among the 10 highest on record for 7 of the 12 months of the year. Both November and spring as a whole had record high temperatures.

Aotearoa New Zealand reported its seventh-warmest year since records began in 1909, in part due to its warmest winter on record. Annual mean temperatures were above average across much of the North Island and many parts of the South Island; La Niña conditions contributed to higher temperatures in the latter part of the year. From late December 2019 through February 2020, several areas across New Zealand observed record or near-record dry spells, that is, at least 15 consecutive days with less than 1 mm of rain each day. A 64-day dry spell was recorded in Blenheim, a town on the northern tip of the South Island, making it the longest dry spell on record for the town.