World Scientists' Warning of a Climate Emergency 2022

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We are now at "code red" on planet Earth. Humanity is unequivocally facing a climate emergency. The scale of untold human suffering, already immense, is rapidly growing with the escalating number of climate-related disasters. Therefore, we urge scientists, citizens, and world leaders to read this Special Report and quickly take the necessary actions to avoid the worst effects of climate change.

2022 marks the 30th anniversary of the "World Scientists' Warning to Humanity," signed by more than 1700 scientists in 1992. Since this original warning, there has been a roughly 40% increase in global greenhouse gas emissions. This is despite numerous written warnings from the Intergovernmental Panel on Climate Change and a recent scientists' warning of a climate emergency with nearly 15,000 signatories from 158 countries (Ripple et al. 2020). Current policies are taking the planet to around 3 degrees Celsius warming by 2100, a temperature level that Earth has not experienced over the past 3 million years (Liu and Raftery 2021). The consequences of global heating are becoming increasingly extreme, and outcomes such as global societal collapse are plausible and dangerously underexplored (Kemp et al. 2022). Motivated by the moral urgency of this global crisis, here, we track recent climate-related disasters, assess planetary vital signs, and provide sweeping policy recommendations.

Climate-related extreme weather

Climate change has increased the frequency and intensity of severe weather events across the world (Coronese et al. 2019). This is likely because of a variety of interconnected processes, including an overall warming trend, changing precipitation patterns, rising sea levels, and changes in the jet streams. For example, rapid Arctic warming may have made the summer jet stream in the Northern Hemisphere more prone to meandering and becoming blocked, causing heat waves, flooding, droughts, and other disasters (Mann et al. 2017). Rather than just being more frequent, some extreme weather events are now more intense or sometimes occur closer together in time and space. This compounds damage and decreases recovery time. It may increase the likelihood of extreme risks such as simultaneous global failure of crop yields across multiple major food producing regions.

We are now regularly seeing events and disasters that previously occurred only rarely. Tragically, these disasters disproportionately harm poor people in low-income regions that have had minimal contributions to the buildup of greenhouse gasses. For example, in the summer of 2022, one third of Pakistan was flooded, displacing 33 million people and affecting 16 million children. Other disasters this year include terrifying wildfires in Europe, back-to-back cyclones and subsequent flooding in eastern Australia, numerous rivers drying up in China and Europe, an extraordinarily intense hurricane striking the Southeastern United States, powerful storms and extensive flooding in Bangladesh and India, megafires and a continuation of the decadal drought in the western United States, a massive flood that closed Yellowstone National Park, and unusually severe heat waves or "heat domes" in many parts of the Northern Hemisphere (see table 1 for details and attribution). These serial and simultaneous impacts are testing society's limits as they greatly reduce resilience and ability to cope with other crises. To illustrate these impacts, we provide a photo series, documenting the human cost of climate-related disasters (figure 1, supplemental file S1).

Recent trends in planetary vital signs

Updating the planetary vital signs first published by Ripple and colleagues (2020) provides a simple but powerful way to track changes in potential climate drivers (figure 2) and

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impacts (figure 3). In total, 16 of the 35 variables that we track are at record extremes based on the time series data (supplemental table S1). We discuss some of these vital signs below.

Economics. Encouragingly, there was a strong increase in global fossil fuel divestment in 2022 (figure 2j). Despite an overall decreasing trend, direct fossil fuel subsidies increased to US$440 billion in 2021, which is a worrisome rise from levels below US$200 billion (figure 2o). The percentage of greenhouse gas emissions covered by carbon pricing was relatively flat between 2021 and 2022 (figure 2m), as was the global emissions-weighted average price per tonne of carbon dioxide (approximately US$14.20 as of 2022; figure 2n). Both the proportion of emissions covered and the price of carbon need to increase dramatically to be effective in curbing global fossil fuel use (Cramton et al. 2017).

Energy. Because of the COVID-19 pandemic, global fossil fuel energy consumption decreased in 2020, along with carbon dioxide emissions and per capita carbon dioxide emissions (figure 2h, 2k, 2l). However, these declines were short-lived, and in 2021, all of these variables rose significantly again. Although solar and wind power consumption increased by roughly 18% between 2020 and 2021, it is still approximately 18 times lower than fossil fuel consumption (figure 2h). Despite the urgent need to immediately cease new fossil fuel development and reduce emissions, fossil fuel projects continue to be pursued on an enormous scale. There are currently 425 “carbon bombs”—existing or planned fossil fuel extraction projects with at least 1 gigaton of potential carbon dioxide emissions—and their potential emissions is roughly twice the 1.5-degree Celsius carbon budget (Kühne et al. 2022).

Global mean greenhouse gases and temperature. Three major greenhouse gases—carbon dioxide, methane, and nitrous oxide—all set new year-to-date records for atmospheric concentrations in 2022 (figure 3a–3c). In March of 2022, carbon dioxide concentration reached 418 parts per million, the highest monthly global average concentration ever recorded. In addition, 2022 is on track to be one of the hottest years on record (figure 3d). Ocean heat content rose greatly in 2021 and is now at a record high (figure 3i).

Climate impacts. Disasters associated at least partially to climate change have been steeply trending upward. Climate change has been linked to increases in both the frequency and intensity of extreme heat events. The number of extremely hot days has nearly doubled since 1980 (figure 3o). Globally, roughly 500,000 deaths between 2000 and 2019 were heat related, and the heat-related excess death ratio rose significantly from 2000–2003 to 2016–2019 (Zhao et al. 2021).

The impacts may not track linearly with global heating. As our global temperatures creep up, the frequency or magnitude of some types of climate disasters may actually leap up (Calvin 2019, Fischer et al. 2021). Our preliminary models indicate that this leaping pattern or threshold response may be the case in the United States for both the area burned by wildfires and the number of inland floods that have caused at least US$1 billion dollars in damages (see supplemental file S1, figures 3l, 3n, supplemental figures S2–S3). In addition, global wildfire activity appears to be exhibiting a rapid increase since 2009 (figure 3m). Because of rising temperatures and other factors such as severe windstorms, the propensity of certain mosquito species to transmit the dengue virus has risen substantially since 1980 (figure 3p). Rising temperatures increase the risks of feedback loops and tipping points being triggered, potentially including, for example, permafrost thawing and Amazon forest dieback (see supplemental file S1). Higher temperatures will increase the risk of cascading effects such as disease and conflict, as well as heighten the probability of and our vulnerability to other catastrophic threats (Kemp et al. 2022).

Climate policy

Most planetary boundaries that regulate the state of the Earth are beyond their safe space (Rockström et al. 2009; see the supplemental material). Therefore, climate change is not a stand-alone issue. It is part of a larger systemic problem of ecological overshoot where human demand is exceeding the regenerative capacity of the biosphere (Wackernagel et al. 2002). Humanity cannot sustain unlimited growth in a finite world. We need to address ecological overshoot, while at the same time ramping up climate action. Therefore, we continue our call for holistic and transformative change (e.g., Rees 2019, Ripple et al. 2020). Keys to curbing the ecological overshoot involve greatly reducing overconsumption and waste by the global middle class and especially the wealthy, stabilizing and gradually reducing the human population by providing education and rights for girls and women, and implementing a sustainable ecological economics that ensures social justice (Rees 2019).

The increasing frequency and intensity of climate disasters emphasizes the need for immediate mitigation and adaptation. In addition to protecting nature, including forests, and eliminating nearly all fossil fuel emissions, efforts should be made to explore the potential of effective carbon dioxide removal strategies, which can help cool the planet in the long term by countering historical emissions (supplemental figure S4). A sufficiently high carbon price can reduce emissions in certain sectors and encourage carbon dioxide removal. If designed well, it can also provide funding to support socially just climate adaptations and compensate for climate-related losses and damages, especially in the developing world. To further promote climate justice, this could be accomplished by returning some or all of the carbon price revenue directly to the people,

Figure 1. The impacts of climate-related droughts (left column) and floods (right column). Left column (top to bottom): "Children in dust storm" (Ethiopia, 2016; photograph: Anouk Delafortrie/EU/ECHO), a water hole that may have become empty because of drought (Mozambique, 2016; photograph: Aurélie Marrier d'Unienville/IFRC), drought-affected corn field in Paulding County, Ohio (United States, 2012; photograph: US Department of Agriculture/ Christina Reed), "Drought in Kenya's Ewaso Ngiro river basin" (Kenya, 2017; photograph: Denis Onyodi/Denis Onyodi/KRCS). Right column (top to bottom): houses are nearly submerged by flooding (Bangladesh, 2020; photograph: Moniruzzaman Sazal/Climate Visuals Countdown), "A girl, duck in hand wades through the water in Rwangara" (Uganda, 2020; photograph: Climate Centre), "two children a boy and a girl on a flooded riverbank" (Bangladesh, 2018; photograph: Moniruzzaman Sazal/Climate Visuals Countdown), "Residents wade through flooded streets to escape flood waters" (United Kingdom, 2008; John Dal). All photos are licensed under Creative Commons and all quotes are from the Climate Visuals project (https://climatevisuals.org). See supplemental file S1 for details and more pictures.

especially in low-income areas that are most vulnerable to climate impacts. More generally, other policy instruments could include investments in innovation and climate finance (supplemental figure S5), positive subsidies, and feed-in tariffs that guarantee an above-market price for renewable energy producers.

A call to action

Recent years have seen an unprecedented trend in scientists speaking out on the climate crisis. We applaud this trend and view it as a natural consequence of scientists being citizens concerned about the preservation of the planet for future generations (Nelson and Vucetich 2009). When backed by sound and transparent scientific arguments, the potential for scientists to educate the public and speak truth to power can be a driving force for the needed policy shifts. Indeed, vocal and articulate scientists played a key role in bringing issues such as nuclear annihilation and ozone depletion to the fore. In this spirit, we implore our fellow scientists to speak out on climate and other environmental issues. In addition to speaking out, some researchers have argued that the situation is so dire that we are at the point where peaceful civil disobedience by scientists is needed (Capstick et al. 2022).

As has been demonstrated by the surge in yearly climate disasters, we are now in a major climate crisis and global catastrophe with far worse in store if we continue with business as usual. As such, there is more at stake today than at any time since the advent of the stable climate system that has supported us for more than 10,000 years. Here we stand at the precipice, with the opportunity to make such an immense difference for life on Earth. Approximately one hundred billion people have lived and died over the 2-million-year history of humans on Earth (Curtin 2007), and there are potentially

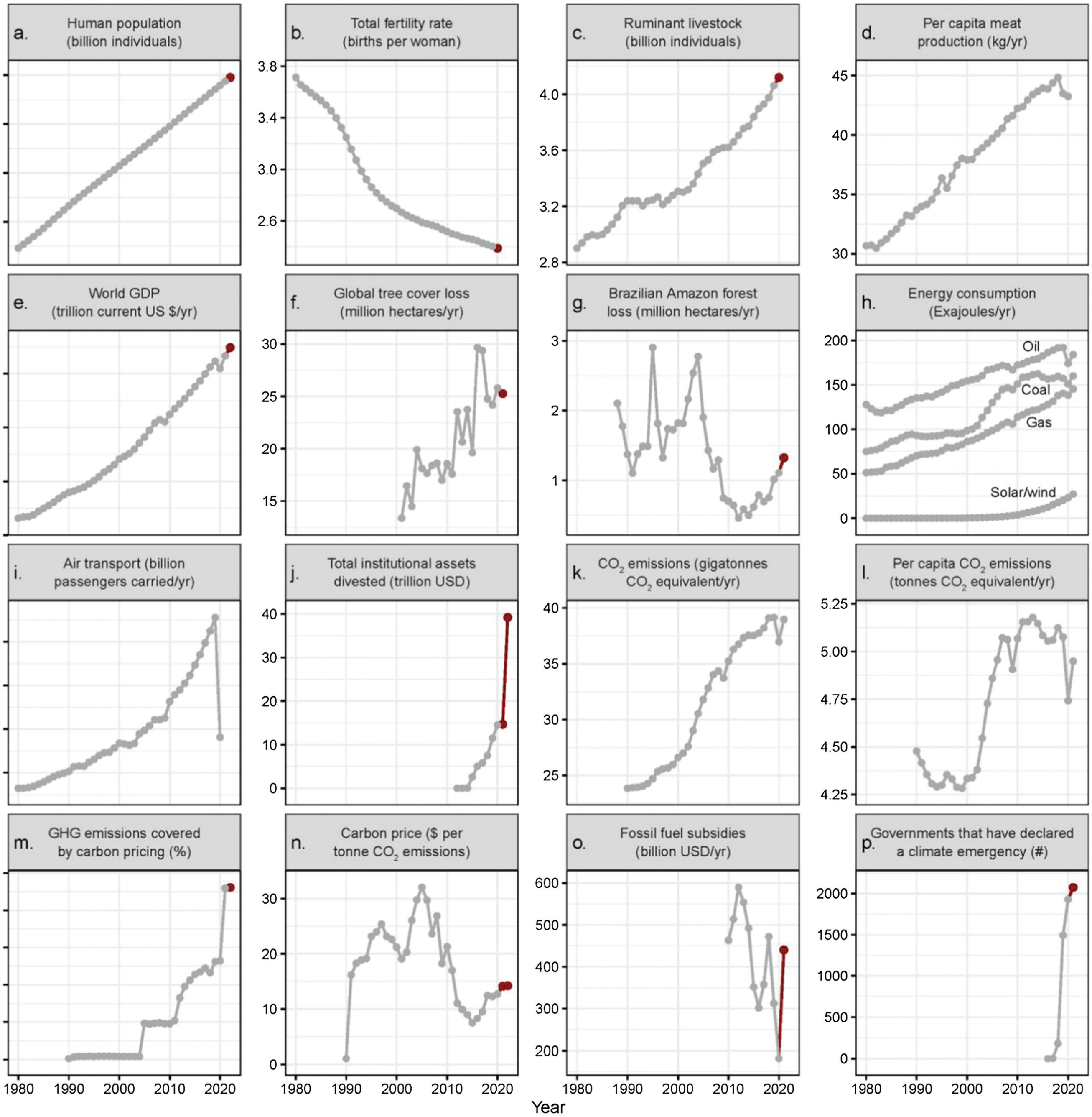

Figure 2. Time series of climate-related human activities. Data obtained since the publication of Ripple and colleagues (2021) are shown in red (dark gray in print). In panel (f), tree cover loss does not account for forest gain and includes loss due to any cause. For panel (h), hydroelectricity and nuclear energy are shown in supplemental figure S1. In panel (j), assets divested reflects total assets under management based on institutional commitments. Sources and additional details about each variable are provided in supplemental file s1.

trillions of human beings who will someday exist whose fate depends on the choices we make today. The very future of humanity depends on the creativity, moral fiber, and perseverance of the 8 billion of us on the planet now. Rather than lose hope, we must equitably reduce ecological overshoot and immediately pursue massive-scale climate change mitigation and adaptation. This is the only way we can limit the near-term damage, preserve nature, avoid untold human suffering, and give future generations the opportunities they deserve.

Project websites

The World Scientists' Warning of a Climate Emergency paper (Ripple et al. 2020) now has more than 14,700

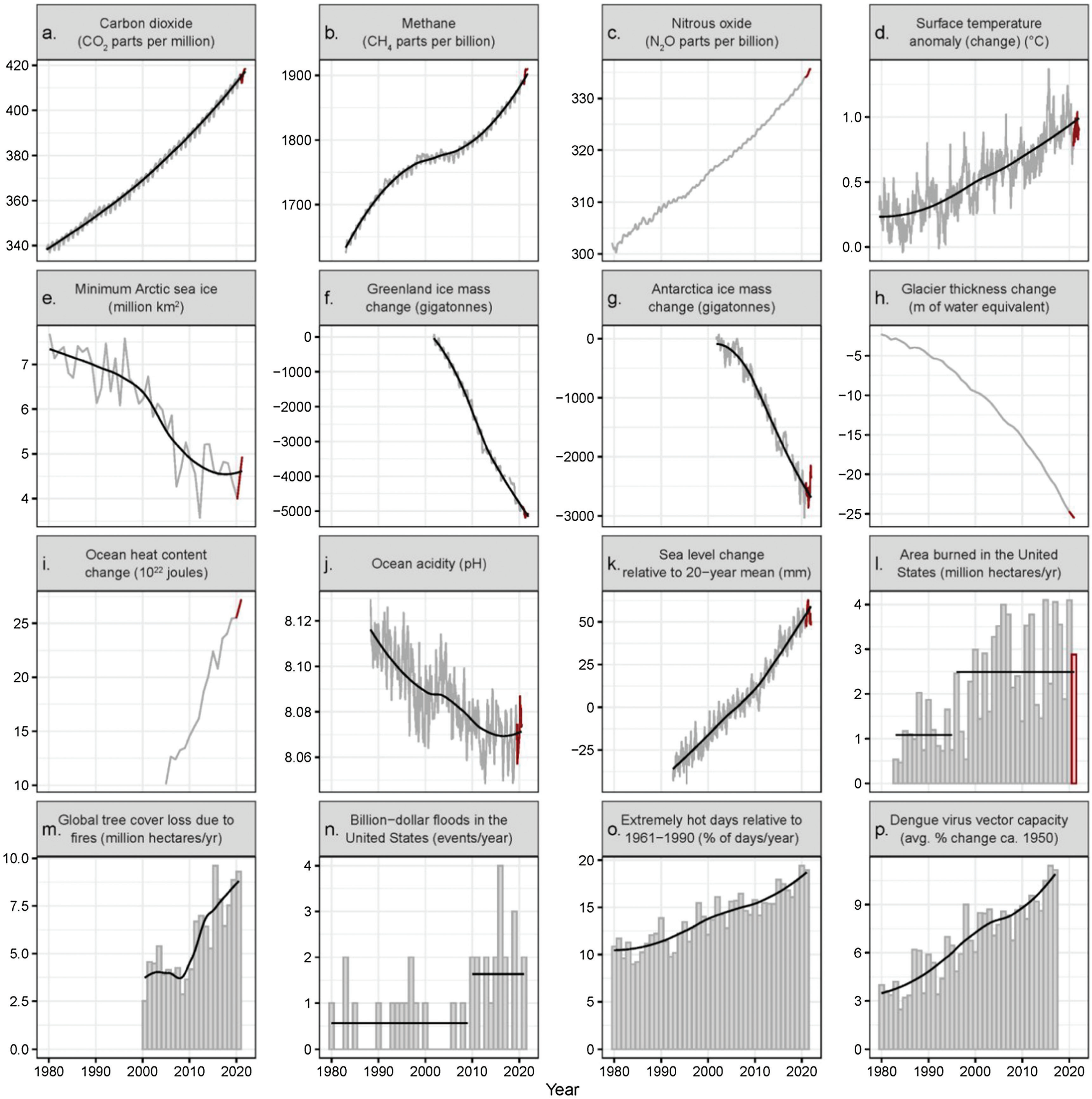

Figure 3. Time series of climate-related responses. Data obtained after the publication of Ripple and colleagues (2021) are shown in red (dark gray in print). For area burned (l) and billion-dollar flood frequency (n) in the United States, black horizontal lines show changepoint model estimates, which allow for abrupt shifts (see supplement). For other variables with relatively high variability, local regression trendlines are shown in black. Variables were measured at various frequencies (e.g., annual, monthly, weekly). Labels on the x-axis correspond to midpoints of years. Billion-dollar flood frequency (n) is likely influenced by exposure and vulnerability in addition to climate change. Sources and additional details about each variable are provided in supplemental file S1.

signatories from 158 countries, and we continue to collect signatures from scientists. To sign or learn more, visit the Alliance of World Scientists website at https://scientistswarning.forestry.oregonstate.edu. To read about science-based advocacy and view "A Scientist's Warning," a new documentary film on scientists speaking out, visit www.scientistswarningfilm.org.

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*Table 1. Recent climate disasters in 2022.**

Timeframe	Climate disaster
January–September 2022	Many rivers in Europe have run low or dried up partly because of the worst drought in 500 years and intense heat waves. Climate change has likely played a significant role in this crisis by increasing the frequency and intensity of droughts and heat waves.
February 2022	La Niña and climate change contributed to record-breaking rainfall on the east coast of Australia. This led to flooding that damaged thousands of properties and killed eight people.
February–March 2022	Record-breaking flooding occurred along the northeastern coast of Australia, leading to standing water, which, in turn, promoted the spread of mosquitoes that carry the Japanese encephalitis virus. Such flooding is likely becoming more common because of climate change.
February–July 2022	The number of people affected by drought in Kenya, Somalia, and Ethiopia who have limited access to safe water increased from 9.5 million to 16.2 million. This increasing drought severity may be at least partly due to climate change (Ghebrezgabher et al. 2016).
March 2022	A severe drought in the Southern Plains of the United States put the winter wheat crop at risk. Although droughts are complex phenomena with many possible causes, increasing drought intensity has been linked to climate change (Mukherjee et al. 2018).
March–April 2022	A deadly heat wave occurred in India and Pakistan, killing at least 90 people and contributing to widespread crop losses and wildfires. It was estimated that climate change made this event 30 times more likely to occur.
April 2022	Climate change likely contributed to extreme rainfall in Eastern South Africa, which triggered flooding and landslides that killed at least 435 people and affected more than 40,000 people.
April–June 2022	Widespread dust storms in the Middle East led to thousands of people being hospitalized; such dust storms may be increasing in frequency because of climate change.
May 2022	Extremely heavy rainfall in northeastern Brazil resulted in landslides and flooding that killed at least 100 people. Climate change may be responsible for the increasing frequency of extreme rainfall.
June 2022	A severe storm in Yellowstone (United States) caused the Gardner River and Lamar River to overflow, destroying parts of various roads in Yellowstone National Park. Such extreme flooding could be increasing in frequency because of climate change.
June 2022	Several countries in Western Europe experienced a record-breaking heat wave. This heat wave contributed to major wildfires in Spain and Germany. Many other parts of the Northern Hemisphere also experienced extreme heat; for example, temperatures reached 104.4 degrees Fahrenheit in Isesaki, Japan—an all-time record for the country. Similarly, a heat dome in the United States contributed to record-breaking temperatures. Other affected countries include Finland, Iran, Norway, and Italy. In general, extreme heat is becoming more common because of climate change (Luber and McGeehin 2008).
June 2022	Following extreme heat, China experienced record-breaking rainfall, which may be linked to climate change.
June 2022	Bangladesh experienced the worst monsoon flooding in 100 years, killing at least 26 people. This flooding is likely at least partly due to climate change causing monsoons to become more variable.
June–July 2022	Extreme rainfall led to flooding in some parts of New South Wales, Australia. Sydney is currently on track to experience the wettest year on record. It is likely that climate change contributed at least partly to this rainfall and flooding.
June–August 2022	Deadly floods in Pakistan have killed more than 1,000 people and affected roughly 33 million people, including 16 million children, since mid-June. Impacts include surging rates of dengue fever, gastric infections, and malaria. These floods may be at least partly related to climate change causing monsoon rainfall to become more intense.
June–August 2022	China experienced an extraordinary heat wave, which may be the most severe that has ever been recorded globally. Such events are likely becoming more common because of climate change. The extreme heat contributed to large-scale crop failures and wildfires, in addition to exacerbating a major drought that caused 66 rivers to dry up and led to a significant decline in hydroelectricity generation.
August–September 2022	California and other parts of the Western United States faced extremely hot temperatures because of a heat dome, which caused seven firefighters to be hospitalized with heat-related injuries. The effects of the heat dome may have been worsened by climate change.
September–October 2022	In the United States, Hurricane Ian caused damage across many parts of Florida and the Carolinas, killing more than 100 people and leaving at least 2.5 million without electrical power. Ian is one of the costliest and strongest hurricanes to ever hit the United States. Climate change is likely causing strong and rapidly intensifying storms such as Ian to become more common.

*Here, we list numerous recent disasters that may be at least partly related to climate change. This list is not intended to be exhaustive. Because of the recent nature of these events, our sources often include news media articles. For each event, we generally provide references indicating that the likelihood or strength of such an event may have increased because of anthropogenic climate change. References to scientific articles are given directly in the table, and links to news articles are provided in supplemental file S1.
Note: Some of these climate disasters may be at least partly related to changes in jet streams (Stendel et al. 2021, Rousi et al. 2022).

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Supplemental material

Supplemental data are available at *BIOSCI* online.

The methods and details of planetary vital sign variables used in this report along with other discussion appear in supplemental file S1 of this article. A list of the scientist signatories for Ripple and colleagues (2020) as of 25 August 2022 appears in supplemental file S2 of this article. Note that these signatures are not for the current article.

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