


The 2023 state of the climate report: Entering uncharted territory

William J. Ripple, Christopher Wolf , Jillian W. Gregg, Johan Rockström, Thomas M. Newsome, Beverly E. Law, Luiz Marques, Timothy M. Lenton, Chi Xu, Saleemul Huq, Leon Simons and Sir David Anthony King

William J. Ripple (bill.ripple@oregonstate.edu) is affiliated with the Department of Forest Ecosystems and Society at Oregon State University (OSU), in Corvallis, Oregon, in the United States and the Conservation Biology Institute (CBI), in Corvallis, Oregon, in the United States. Christopher Wolf (christopher.wolf@oregonstate.edu) and Jillian W. Gregg are affiliated with Terrestrial Ecosystems Research Associates, in Corvallis, Oregon, in the United States. Johan Rockström is affiliated with the Potsdam Institute for Climate Impact Research, in Potsdam, Germany. Thomas M. Newsome is affiliated with the School of Life and Environmental Sciences at The University of Sydney, in Sydney, New South Wales, Australia. Beverly E. Law is affiliated with the Department of Forest Ecosystems and Society at OSU and the CBI. Luiz Marques is affiliated with the State University of Campinas—Unicamp and with the Center for Research in Energy and Materials, in Campinas, in the state of São Paulo, in Brazil. Timothy M. Lenton is affiliated with the Global Systems Institute at the University of Exeter, in Exeter, England, in the United Kingdom. Chi Xu is affiliated with the School of Life Sciences at Nanjing University, in Nanjing, China. Saleemul Huq is affiliated with the International Centre for Climate Change and Development at the Independent University Bangladesh, in Dhaka, Bangladesh. Leon Simons is affiliated with the Club of Rome Netherlands, in 's-Hertogenbosch, in The Netherlands. Sir David Anthony King is affiliated with the Department of Chemistry at Downing College, at the University of Cambridge, in Cambridge, England, in the United Kingdom. Co-lead authors William J. Ripple and Christopher Wolf contributed equally to the work.

Life on planet Earth is under siege. We are now in an uncharted territory. For several decades, scientists have consistently warned of a future marked by extreme climatic conditions because of escalating global temperatures caused by ongoing human activities that release harmful greenhouse gasses into the atmosphere. Unfortunately, time is up. We are seeing the manifestation of those predictions as an alarming and unprecedented succession of climate records are broken, causing profoundly distressing scenes of suffering to unfold. We are entering an unfamiliar domain regarding our climate crisis, a situation no one has ever witnessed firsthand in the history of humanity.

In the present report, we display a diverse set of vital signs of the planet and the potential drivers of climate change and climate-related responses first presented by Ripple and Wolf and colleagues (2020), who declared a climate emergency, now with more than 15,000 scientist signatories. The trends reveal new all-time climate-related records and deeply concerning patterns of climate-related disasters. At the same time, we report minimal progress by humanity in combating climate change. Given these distressing developments, our goal is to communicate climate facts and policy recommendations to scientists, policymakers, and the public. It is the moral duty of us scientists and our institutions to clearly alert humanity of any potential existential threat and to show leadership in taking action. This report is part of our series of concise and easily accessible yearly updates on the state of the climate crisis.

Climate-related all-time records

In 2023, we witnessed an extraordinary series of climate-related records being broken around the world. The rapid pace of change has surprised scientists and caused concern about the dangers of extreme weather, risky climate feedback loops, and the approach of damaging tipping points sooner than expected (Armstrong McKay et al. 2022, Ripple et al. 2023). This year,

exceptional heat waves have swept across the world, leading to record high temperatures. The oceans have been historically warm, with global and North Atlantic sea surface temperatures both breaking records and unprecedented low levels of sea ice surrounding Antarctica (figure 1a–1d). In addition, June through August of this year was the warmest period ever recorded, and in early July, we witnessed Earth's highest global daily average surface temperature ever measured, possibly the warmest temperature on Earth over the past 100,000 years (figure 1e). It is a sign that we are pushing our planetary systems into dangerous instability.

We are venturing into uncharted climate territory. Global daily mean temperatures never exceeded 1.5-degree Celsius (°C) above preindustrial levels prior to 2000 and have only occasionally exceeded that number since then. However, 2023 has already seen 38 days with global average temperatures above 1.5°C by 12 September—more than any other year—and the total may continue to rise. Even more striking are the enormous margins by which 2023 conditions are exceeding past extremes (figure 1). Similarly, on 7 July 2023, Antarctic sea ice reached its lowest daily relative extent since the advent of satellite data, at 2.67 million square kilometers below the 1991–2023 average (figure 1a). Other variables far outside their historical ranges include the area burned by wildfires in Canada (figure 1f), which may indicate a tipping point into a new fire regime.

Anthropogenic global heating is a key driver of many of these recent extremes. However, the specific driving processes involved can be quite complex. For example, rising Atlantic ocean temperatures may be connected to Sahel rainfall and African dust (Wang et al. 2012). Another potential contributor is water vapor (a greenhouse gas) injected into the stratosphere by an underwater volcano eruption (Jenkins et al. 2023). The recent rise may also be linked to a regulatory change mandating the use of low-sulfur fuels in ocean shipping, because atmospheric sulfate aerosols directly scatter sunlight and cause reflective clouds to form

Received: August 24, 2023. Accepted: August 30, 2023

© The Author(s) 2023. Published by Oxford University Press on behalf of the American Institute of Biological Sciences.

All rights reserved. For permissions, please e-mail: journals.permissions@oup.com

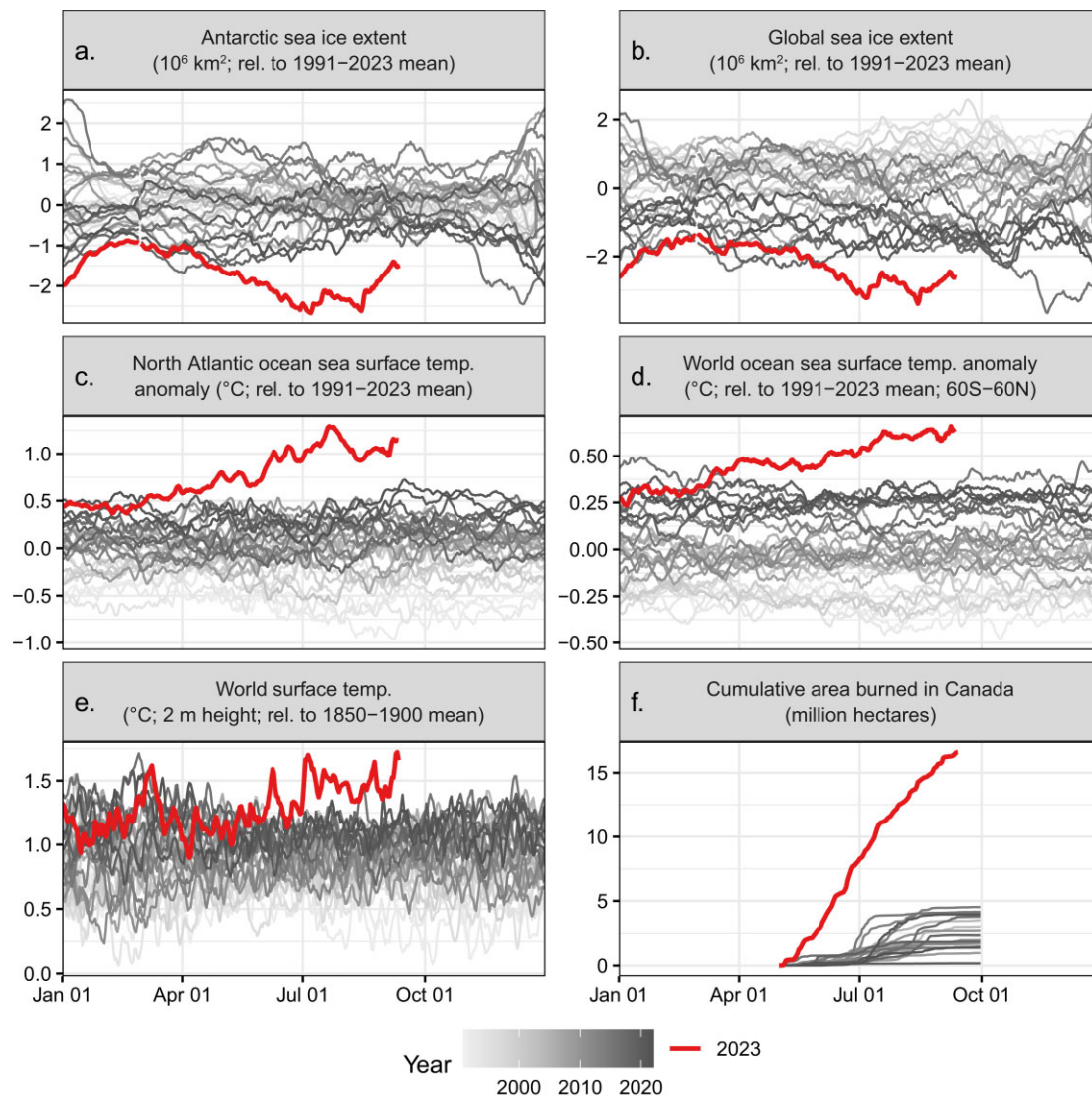


Figure 1. Unusual climate anomalies in 2023 (the red line, which appears bold in print). Sea ice extent (a, b), temperatures (c–e), and area burned in Canada (f) are presently far outside their historical ranges. These anomalies may be due to both climate change and other factors. Sources and additional details about each variable are provided in [supplemental file S1](#). Each line corresponds to a different year, with darker gray representing later years.

(see [supplemental file S1](#) for an extended discussion). The sudden rise in temperatures is also likely contributed to by the onset of an El Niño event—a naturally occurring part of the climate system, which could, itself, be affected by climate change (Cai et al. 2021). In any case, as Earth’s climate system transitions away from conditions associated with human thriving, such anomalies may become more frequent and could have increasingly catastrophic impacts (Xu et al. 2020, Lenton et al. 2023).

Recent trends in planetary vital signs

On the basis of time series data, 20 of the 35 vital signs are now showing record extremes (figures 2 and 3, [supplemental table S1](#)). As we describe below, these data show how the continued pursuit of business as usual has, ironically, led to unprecedented pressure on the Earth system, resulting in many climate-related variables entering uncharted territory (figures 1 and 3).

Energy

It appears the green recovery following COVID-19 that many had hoped for has largely failed to materialize (Zhang et al. 2023). Instead, carbon emissions have continued soaring, and fossil fuels remain dominant, with annual coal consumption reaching a near all-time high of 161.5 exajoules in 2022 (figure 2h). Although the consumption of renewable energy (solar and wind) grew a robust 17% between 2021 and 2022, it remains roughly 15 times lower than fossil fuel energy consumption (figure 2h). A major driver of economic and energy trends is Russia’s ongoing invasion of Ukraine, which has accelerated the transition to renewables in Europe but which may also cause some countries to switch from Russian-supplied gas to coal (Tollefson 2022). Already, this conflict has contributed to a massive 107% increase in fossil fuel subsidies from US\$531 billion in 2021 to US\$1097 billion in 2022 because of rising energy prices (figure 2o). Although these subsidies may partially protect consumers from price increases, they are often not well targeted and help to promote fossil fuel related energy use and profits over low-carbon alternatives (Muta and Erdogan 2023).

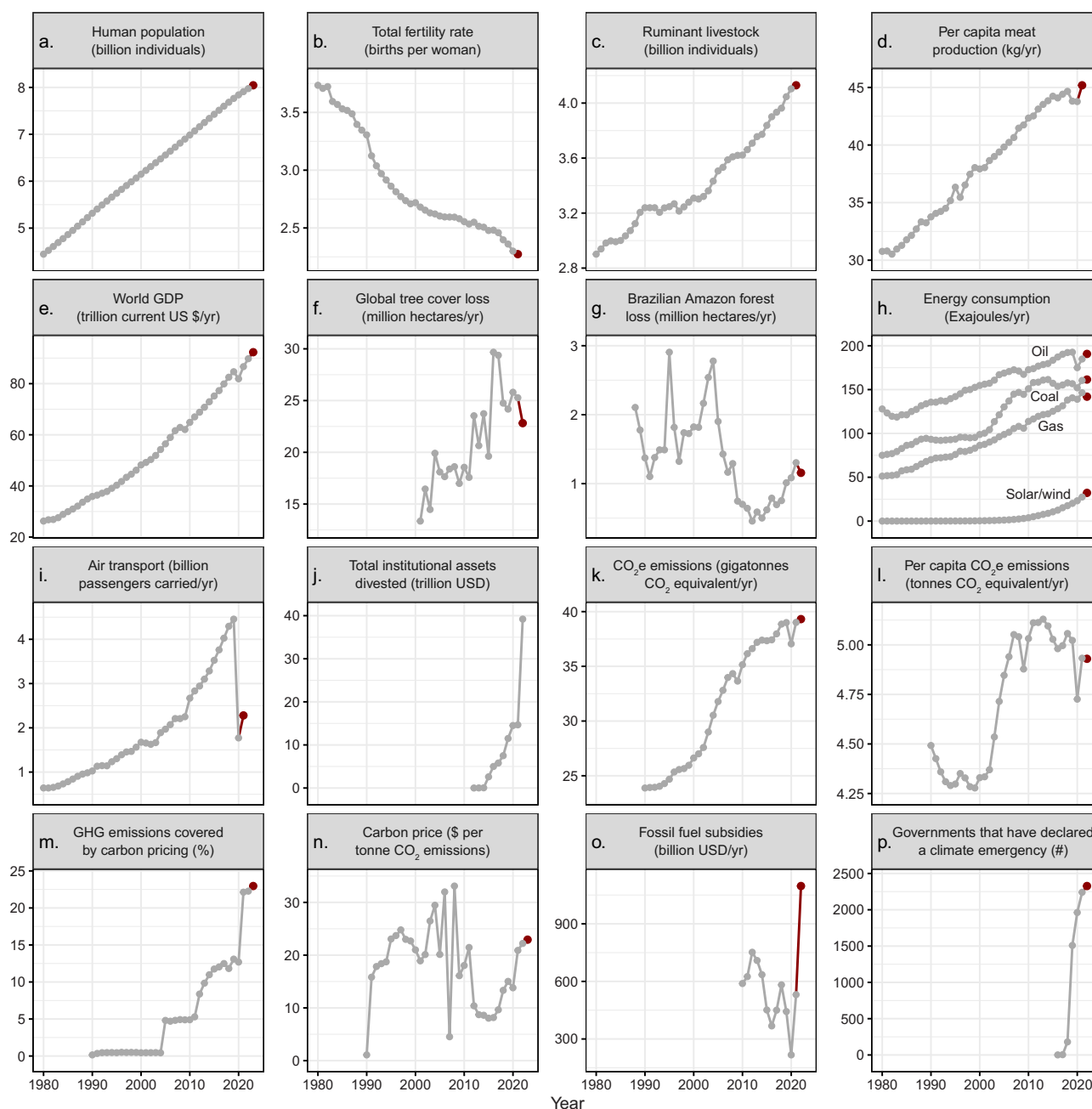


Figure 2. Time series of climate-related human activities. Data obtained since the publication of Ripple and colleagues (2021) are shown in red (dark gray in print). In panel (f), tree cover loss does not account for forest gain and includes a loss due to any cause. For panel (h), hydroelectricity and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

Forests

Between 2021 and 2022, the global tree cover loss rate declined 9.7% to 22.8 million hectares (ha) per year (figure 2f). Similarly, the Brazilian Amazon forest loss rate decreased by 11.3% to 1.16 million ha per year (figure 2g), and further reductions are likely to occur as a result of the election of a new president of Brazil and several recent legal decrees (Vilani et al. 2023). However, humanity is not on track to end and reverse deforestation by 2030, despite pledges by more than 100 world leaders in 2021 at COP26 (UNEP 2022a). Moreover, forests are increasingly threatened by powerful climate feedback loops involving processes such as insect damage, dieback, and wildfire (Flores and Staal 2022, Ripple et al. 2023). For example, the historical record-setting wildfires in Canada, which burned 16.6 million hectares this year as of 13 September

(figure 1f), were partly related to climate change. This resulted in emissions of more than a gigaton of carbon dioxide (Copernicus 2023), which is substantial, given that Canada's total greenhouse gas emissions in 2021 were roughly 0.67 gigatons of carbon dioxide equivalent (Environment and Climate Change Canada 2023). How quickly such emissions can be reabsorbed by postfire recovery is uncertain, and there is a real risk that increasing fire severity will cause unrecoverable carbon loss in a warming future (Bowman et al. 2021).

Global mean greenhouse gases and temperature

On the basis of year-to-date statistics for 2023, three important greenhouse gases—carbon dioxide, methane, and nitrous oxide—are all at record levels (figure 3a–3c). The global average carbon

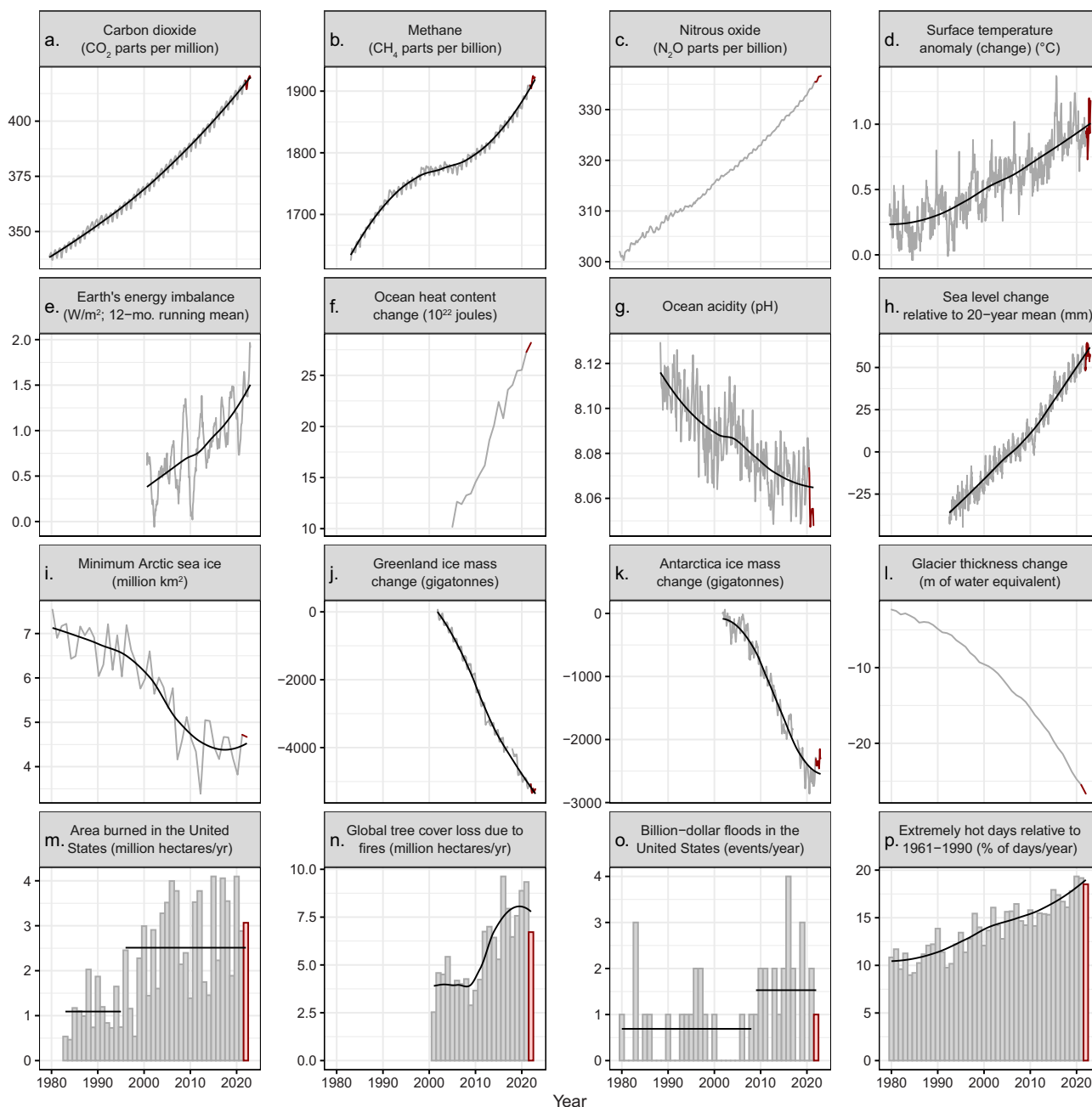


Figure 3. Time series of climate-related responses. Data obtained before and after the publication of Ripple and colleagues (2021) are shown in gray and red (dark gray in print) respectively. For area burned (m) and billion-dollar flood frequency (o) in the United States, the black horizontal lines show changepoint model estimates, which allow for abrupt shifts (see the supplement). For other variables with relatively high variability, local regression trendlines are shown in black. The variables were measured at various frequencies (e.g., annual, monthly, weekly). The labels on the x-axis correspond to the midpoints of years. Billion-dollar flood frequency (o) 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](#).

dioxide concentration is now approximately 420 parts per million, which is far above the proposed planetary boundary of 350 parts per million (Rockström et al. 2009). In addition, 2023 is on track to be one of the hottest years on record (figures 1e and 3d). Although fossil fuel-related greenhouse gas emissions are the main driver of rising temperatures, a global decline in sulfur dioxide emissions is likely a contributing factor (supplemental figure S2). Sulfur dioxide forms sulfates in the atmosphere, which are the strongest anthropogenic cooling agent, hiding part of the greenhouse gas warming (see supplemental file S1 for extended discussion).

Oceans and ice

Ocean acidity, glacier thickness, and Greenland ice mass all fell to record lows (figure 3g, 3j, and 3l), whereas sea level rise and ocean heat content rose to record highs (figure 3f, 3h). The increase in heat content and the rapid rise in sea surface temperatures (figure 1c, 1d) are especially troubling, because they could have many serious impacts, including the loss of sea life, coral reefs dying because of bleaching, and a rise in the intensity of large tropical storms (Reid et al. 2009). There are also growing concerns

Untold Human Suffering in Pictures



Figure 4. Photograph series depicting the impacts of climate-related disasters. First row (left to right): Homeowners sort through debris after wildfires destroyed their home in the state of California (United States, 2008; FEMA/Michael Mancino), “[National] guardsman carrying a woman in waist deep floodwaters” (United States, 2017; Zachary West/National Guard; CC BY 2.0). Second row: “young girls are caught by a sandstorm on their way to school” (Afghanistan, 2019, Solmaz Daryani/Climate Visuals Countdown; Creative Commons), “mature woman seated in her home, submerged in deep water, smoking a cigarette” (Brazil, 2015; Fabrice Fabola, CC BY-SA 2.0). Third row: aftermath of Cyclone Idai (Mozambique, 2019; Denis Onyodi: IFRC/DRK/Climate Centre, CC BY-NC 2.0), “residents walk on a road littered with debris after Super Typhoon Haiyan battered Tacloban city” (The Philippines, 2013; Erik de Castro/Reuters; CC BY 2.0). All quotes are from the Climate Visuals project (<https://climatevisuals.org>). See [supplemental file S1](#) for details and more pictures.

that the Atlantic meridional overturning circulation could pass a tipping point and start to collapse this century, possibly between 2025 and 2095 (Ditlevsen and Ditlevsen 2023), which would significantly alter global precipitation and temperature patterns with potentially major harmful consequences for ecosystems and society, including reduced natural carbon sinks (Armstrong McKay et al. 2022).

Climate impacts and extreme weather

Climate change is contributing significantly to human suffering (figure 4). Climate-related impacts in 2022 included another billion-dollar flood in the United States, which occurred in Kentucky and Missouri between 26 and 28 July, and the third highest frequency of extremely hot days (figure 3o, 3p). Between 2021 and 2022, the area burned by wildfires globally decreased 28%

Table 1. Recent climate-related disasters since November 2022.

| Timeframe | Climate disaster |
|--------------------------|---|
| November–December 2022 | Record-breaking heat waves in Argentina and Paraguay contributed to power outages, wildfires, and poor harvests. This extreme heat was estimated to have been made 60 times more likely because of climate change. |
| December 2022–March 2023 | Heavy rainfall caused by atmospheric rivers led to multiple floods in the Western United States. There were at least 22 fatalities and property damages were estimated to be US\$3.5 billion. Climate change may be increasing the likelihood of such catastrophic floods, although its effect on these particular storms is less clear. |
| February 2023 | Cyclone Gabrielle caused extreme rainfall in Aotearoa New Zealand's Te Ika-a-Māui (North Island), potentially resulting in billions of dollars in damages and 225,000 homes losing power. This intense rainfall may be partly caused by a warming climate. |
| March–May 2023 | Record-breaking temperatures were recorded in parts of Southeast Asia, China, and South Asia. The extreme heat caused deaths and school closures in India and led to more than 100 students requiring treatment for dehydration in the Philippines. It was likely at least partly because of climate change. For example, climate change has increased the likelihood of such an event to occur over Bangladesh and India by a factor of at least 30. |
| January–July 2023 | Intense wildfires in Canada burned roughly 10 million hectares, displacing 30,000 people at their peak, and worsening air quality across large portions of Canada and the United States. These extreme wildfires may be partly because of climate change, although many other factors are likely involved. |
| May 2023 | Tropical cyclone Mocha is reported to have killed at least 145 people in Myanmar and affected roughly 800,000 people in the region. Climate change may have made such storms more intense. |
| May–June 2023 | Tropical storm Mawar caused flooding and loss of power in parts of Guam. Mawar is the strongest cyclone ever recorded in the northern hemisphere in May. Climate change may be causing an increase in the intensity of tropical cyclones (Wu et al. 2022). |
| June 2023 | Deadly heat led to more than a dozen deaths in the Southern and Midwestern United States. Climate change is leading to an increase in the frequency and duration of such heat waves. |
| July 2023 | Up to six people died in Southwest Japan because of extremely heavy rainfall that caused floods and landslides. Climate change is likely making such heavy rainfall events more severe. Days later, floods and landslides, which may have been partly related to climate change, killed more than 26 people and led to thousands being evacuated in South Korea. |
| July 2023 | Heavy monsoon rain caused flash floods and landslides in northern India that killed more than 100 people. Climate change is likely making monsoons in this region more variable, causing frequent landslides and floods. Heavy monsoon rains also damaged rice crops in India, raising concerns about global food prices and food security and prompting an export ban on nonbasmati varieties. |
| June–August 2023 | Extreme heat in the United States killed at least 147 people. In the absence of climate change, the extreme heat seen in July 2023 in the United States would have been extremely unlikely to occur. |
| July–August 2023 | Beijing, China experienced its heaviest rainfall in at least 140 years, resulting in major flooding that affected nearly 1.29 million people, damaged 147,000 homes, and caused at least 33 deaths. Intense flooding is likely becoming more common because of climate change. |
| August 2023 | In Hawaii, United States, catastrophic wildfires on the island of Maui killed at least 111 people, with more than 1,000 people likely missing, as of 18 August 2023. Climate change may have decreased rainfall and increased temperatures in this region, potentially contributing to these fires. |
| September 2023 | Storm Daniel caused extreme flooding in Libya and parts of southeastern Europe, resulting in thousands of fatalities and more than 2 billion US dollars in damages. Climate change may be increasing the intensity of such storms. |

Note: 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](#). Some of these disasters may be at least partly because of climate-related changes in jet streams (Stendel et al. 2021, Rousi et al. 2022).

(from 9.34 million ha to 6.72 million ha), but wildfire activity in the United States rose by 6.3% (from 2.88 million ha to 3.07 million ha) over the same period (figure 3m, 3n). Many climate impacts are expected to further intensify in the coming years, and we may have already experienced abrupt increases in certain types of extreme weather, possibly surpassing the rate of temperature rise (figures 3m, 3o, S3, S4; Calvin 2020).

In 2023, climate change likely contributed to a number of major extreme weather events and disasters. Several of these events demonstrate how climate extremes are threatening wider areas that have not typically been prone to such extremes; for example, severe flooding in northern China, around Beijing, killed at least 33 people. Other recent disasters include deadly flash floods and landslides in northern India, record-breaking heat waves in the United States, and an exceptionally intense Mediterranean storm

that killed thousands of people, primarily in Libya (see table 1 for details and attribution). As these impacts continue to accelerate, more funding to compensate for climate-related loss and damage in developing countries is urgently needed. The United Nations' new loss and damage global fund established at COP27 is a promising development, but its success will require robust support by wealthy countries.

Scientists' warning recommendations

Motivated by recent events and trends, we continue to issue specific warnings and recommendations involving topics ranging from food security to climate justice. Coordinated efforts in each of these areas could help to support a broader agenda focused on holistic and equitable climate policy.

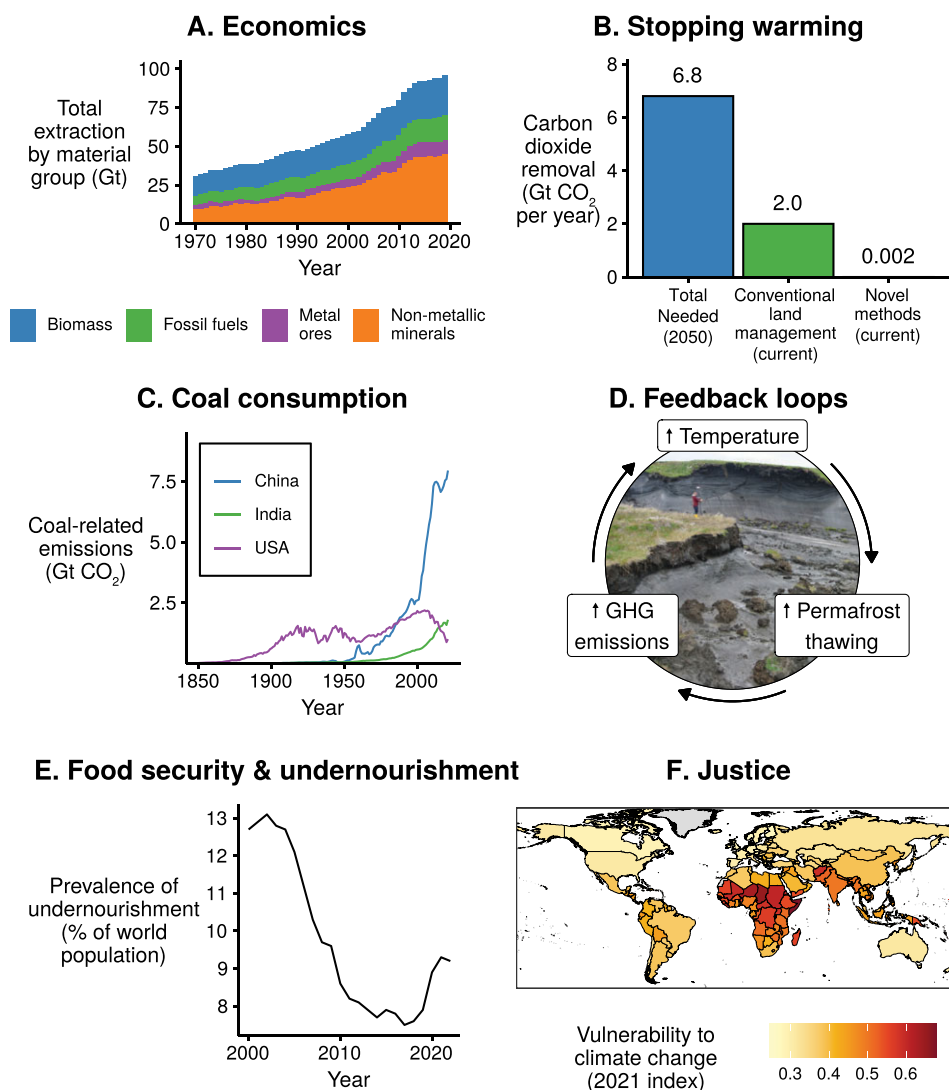


Figure 5. Climate action special topics. Many models assume that GDP growth can be mostly decoupled from emissions and other consumption-related environmental impacts (a) and that carbon capture methods can be quickly scaled up (b). If these assumptions are not realistic and the use of coal and other fossil fuels is not immediately curtailed (c), then Earth system feedback loops (d) could lead to rapidly accelerating climate impacts, including undernourishment (e) and climate disasters, which will be especially severe in less wealthy countries that have had little historical emissions (f). See [supplemental file S1](#) for data sources and details. Photograph: Boris Radosavljevic (CC BY 2.0).

Economics

Economic growth, as it is conventionally pursued, is unlikely to allow us to achieve our social, climate, and biodiversity goals. The fundamental challenge lies in the difficulty of decoupling economic growth from harmful environmental impacts (figure 5a). Although technological advancements and efficiency improvements can contribute to some degree of decoupling, they often fall short in mitigating the overall ecological footprint of economic activities (Hickel et al. 2021). The impacts vary greatly by wealth; in 2019, the top 10% of emitters were responsible for 48% of global emissions, whereas the bottom 50% were responsible for just 12% (Chancel 2022). We therefore need to change our economy to a system that supports meeting basic needs for all people instead of excessive consumption by the wealthy (O'Neill et al. 2018).

Stopping warming

The elevated rates of climate disasters and other impacts that we are presently seeing are largely a consequence of historical and ongoing greenhouse gas emissions. To mitigate these past emissions and stop global warming, efforts must be directed toward eliminating emissions from fossil fuels and land-use change and increasing carbon sequestration with nature-based climate solutions. However, it is crucial to explore other possible strategies to efficiently remove additional carbon dioxide, which can contribute to long-term planetary cooling. Negative emissions technologies are in an early stage of development, posing uncertainties regarding their effectiveness, scalability, and environmental and societal impacts (figure 5b; Anderson and Peters 2016). As such, we should not rely on unproven carbon removal techniques. Although research efforts should be accelerated, depending

heavily on future large-scale carbon removal strategies at this juncture may create a deceptive perception of security and postpone the imperative mitigation actions that are essential to tackle climate change now.

Stopping coal consumption

In addition to its destructive effects on ecosystems and global health, coal accounts for more than 80% of carbon dioxide added to the atmosphere since 1870 and roughly 40% of current carbon dioxide emissions (Burke and Fishel 2020). As of 2022, global coal consumption is near record levels (figure 2h). In 2021, coal-related carbon dioxide emissions were greatest in China (53.1%), followed by India (12.0%), and the United States (6.7%; figure 5c). Coal usage in China has accelerated rapidly in the past decades, and the country now still produces nearly a third of all fossil fuel carbon dioxide and methane emissions (supplemental table S2; Normile 2020). In response to this situation, we support the Powering Past Coal Alliance and recommend the adoption of the international Coal Elimination Treaty to phase out coal and, more broadly, the Fossil Fuel Non-Proliferation Treaty (van Asselt and Newell 2022). These treaties could provide support for less wealthy countries in transitioning away from coal and other fossil fuels, including funding to build out renewable energy capacity and retrain and transition workers from the fossil fuel industry.

Feedback loops

Climate feedback loops directly affect the relationship between emissions and warming. For example, warming causes permafrost soils to thaw, emitting methane and carbon dioxide that result in further warming (figure 5d). As such, reinforcing feedback loops amplify the effects of greenhouse gas emissions, leading to additional warming. Therefore, understanding feedback loops and their interactions can inform climate mitigation and adaptation strategies. Despite their importance, the combination of multiple amplifying feedback loops are not well understood, and the potential strengths of some dangerous feedback loops are still highly uncertain (Ripple et al. 2023). Because of this uncertainty, we call for an Intergovernmental Panel on Climate Change (IPCC) special report that focuses on the perilous climate feedback loops, tipping points, and—just as a precaution—the possible but less likely scenario of runaway or apocalyptic climate change.

Food security and undernourishment

After declining for many years, the prevalence of undernourishment is now on the rise (figure 5e). In 2022, an estimated 735 million people faced chronic hunger—an increase of roughly 122 million since 2019 (FAO et al. 2023). This rise, which has pushed humanity far off track from achieving zero hunger by 2030, is due to multiple factors, including climate extremes, economic downturns, and armed conflict (FAO et al. 2023). Climate change has reduced the extent of global agricultural productivity growth (Ortiz-Bobea et al. 2021), so there is danger that hunger will escalate in the absence of immediate climate action. In particular, there may be serious and underestimated future risks of synchronized harvest failures caused by increased waviness of the jet stream (Kornhuber et al. 2023). Because of the growing risks of concurrent major crop losses in multiple regions of the world, adaptation-focused efforts are needed to improve crop resilience and resistance to heat, drought, and other climate stressors (Raza et al. 2019). A shift toward plant-based diets, particularly in wealthy countries, could improve global food security and help mitigate climate change (Figure 2d; Cassidy et al. 2013).

Justice

The impacts of climate change are already catastrophic for many. However, these impacts are not unfolding uniformly across the entire globe. Instead, they disproportionately affect the world's most impoverished individuals, who, ironically, have had the least role in causing this issue (figure 5f; Harlan et al. 2015). To achieve socioeconomic justice and universal human well-being, it is crucial to strive for a convergence in per capita resource and energy consumption worldwide. This entails working toward balanced and equitable levels of energy and resource consumption for both the global north and south (Hickel et al. 2021).

Conclusions

The effects of global warming are progressively more severe, and possibilities such as a worldwide societal breakdown are feasible and dangerously underexplored (Kemp et al. 2022). By the end of this century, an estimated 3 to 6 billion individuals—approximately one-third to one-half of the global population—might find themselves confined beyond the livable region, encountering severe heat, limited food availability, and elevated mortality rates because of the effects of climate change (Lenton et al. 2023). Big problems need big solutions. Therefore, we must shift our perspective on the climate emergency from being just an isolated environmental issue to a systemic, existential threat. Although global heating is devastating, it represents only one aspect of the escalating and interconnected environmental crisis that we are facing (e.g., biodiversity loss, fresh water scarcity, pandemics). We need policies that target the underlying issues of ecological overshoot where the human demand on Earth's resources results in overexploitation of our planet and biodiversity decline (figures 5a, S5; McBain et al. 2017). As long as humanity continues to exert extreme pressure on the Earth, any attempted climate-only solutions will only redistribute this pressure.

To address the overexploitation of our planet, we challenge the prevailing notion of endless growth and overconsumption by rich countries and individuals as unsustainable and unjust (Rockström et al. 2023). Instead, we advocate for reducing resource overconsumption; reducing, reusing, and recycling waste in a more circular economy; and prioritizing human flourishing and sustainability. We emphasize climate justice and fair distribution of the costs and benefits of climate action, particularly for vulnerable communities (Gupta et al. 2023). We call for a transformation of the global economy to prioritize human well-being and to provide for a more equitable distribution of resources (Hickel et al. 2021). We also call to stabilize and gradually decrease the human population with gender justice through voluntary family planning and by supporting women's and girls' education and rights, which reduces fertility rates and raises the standard of living (Bongaarts and O'Neill 2018). These environmentally conscious and socially equitable strategies necessitate far-reaching and holistic transformations in the long run that could be achieved through gradual but significant steps in the short term (i.e., radical incrementalism; Halpern and Mason 2015).

As scientists, we are increasingly being asked to tell the public the truth about the crises we face in simple and direct terms. The truth is that we are shocked by the ferocity of the extreme weather events in 2023. We are afraid of the uncharted territory that we have now entered. Conditions are going to get very distressing and potentially unmanageable for large regions of the world, with the 2.6°C warming expected over the course of the century, even if the self-proposed national emissions reduction commitments of

the Paris Agreement are met (UNEP 2022b). We warn of potential collapse of natural and socioeconomic systems in such a world where we will face unbearable heat, frequent extreme weather events, food and fresh water shortages, rising seas, more emerging diseases, and increased social unrest and geopolitical conflict. Massive suffering due to climate change is already here, and we have now exceeded many safe and just Earth system boundaries, imperiling stability and life-support systems (Rockström et al. 2023). As we will soon bear witness to failing to meet the Paris agreement's aspirational 1.5°C goal, the significance of immediately curbing fossil fuel use and preventing every further 0.1°C increase in future global heating cannot be overstated. Rather than focusing only on carbon reduction and climate change, addressing the underlying issue of ecological overshoot will give us our best shot at surviving these challenges in the long run. This is our moment to make a profound difference for all life on Earth, and we must embrace it with unwavering courage and determination to create a legacy of change that will stand the test of time.

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](#). A list of the scientist signatories for Ripple and colleagues (2020) as of 29 March 2023 appears in supplemental file [S2](#). These signatures are not for the current report.

The article "World scientists' warning of a climate emergency" (Ripple et al. 2020) now has more than 15,000 signatories from 163 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.

Acknowledgments

We thank William H. Calvin, Katherine Graubard, Karen Wolfgang, and Holly Jean Buck for providing helpful suggestions. We thank Susan Christie for assistance with this project. Partial funding was received from the CO2 Foundation and Roger Worthington.

References cited

- Anderson K, Peters G. 2016. The trouble with negative emissions. *Science* 354: 182–183.
- Armstrong McKay DI, Staal A, Abrams JF, Winkelmann R, Sakschewski B, Loriani S, Fetzer I, Cornell SE, Rockström J, Lenton TM. 2022. Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science* 377: eabn7950.
- Bongaarts J, O'Neill BC. 2018. Global warming policy: Is population left out in the cold? *Science* 361: 650–652.
- Bowman DM, Williamson GJ, Price OF, Ndalila MN, Bradstock RA. 2021. Australian forests, megafires and the risk of dwindling carbon stocks. *Plant, Cell, and Environment* 44: 347–355.
- Burke A, Fishel S. 2020. A coal elimination treaty 2030: Fast tracking climate change mitigation, global health, and security. *Earth System Governance* 3: 100046.
- Cai W et al. 2021. Changing El Niño–Southern Oscillation in a warming climate. *Nature Reviews Earth and Environment* 2: 628–644.
- Calvin WH. 2020. *Extreme Weather: And What to Do about It*. CO2 Foundation.
- Cassidy ES, West PC, Gerber JS, Foley JA. 2013. Redefining agricultural yields: From tonnes to people nourished per hectare. *Environmental Research Letters* 8: 034015.
- Chancel L. 2022. Global carbon inequality over 1990–2019. *Nature Sustainability* 5: 931–938.
- Copernicus. 2023. A record-breaking boreal wildfire season. Copernicus. <https://atmosphere.copernicus.eu/record-breaking-boreal-wildfire-season>.
- Ditlevsen P, Ditlevsen S. 2023. Warning of a forthcoming collapse of the Atlantic meridional overturning circulation. *Nature Communications* 14: 4254.
- Environment and Climate Change Canada. 2023. Canadian environmental sustainability indicators: Greenhouse gas emissions. Environment and Climate Change Canada. www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html.
- [FAO, IFAD, UNICEF, WFP, WHO] Food and Agriculture Organization of the United Nations, the International Fund for Agricultural Development, the United Nations Children's Fund, the World Food Program, the World Health Organization. 2023. *The State of Food Security and Nutrition in the World 2023: Urbanization, Agrifood Systems Transformation and Healthy Diets across the Rural–Urban Continuum*. FAO.
- Flores BM, Staal A. 2022. Feedback in tropical forests of the Anthropocene. *Global Change Biology* 28: 5041–5061.
- Gupta J, et al. 2023. Earth system justice needed to identify and live within Earth system boundaries. *Nature Sustainability* 6: 630–638.
- Halpern D, Mason D. 2015. Radical incrementalism. *Evaluation* 21: 143–149.
- Harlan SL, Pellow DN, Roberts JT, Bell SE, Holt WG, Nagel J. 2015. Climate justice and inequality. Pages 127–163 in Dunlap RE Brulle RJ, eds. *Climate Change and Society: Sociological Perspectives*. Oxford University Press.
- Hickel J, Brockway P, Kallis G, Keyßer L, Lenzen M, Slameršak A, Steinberger J, Ürge-Vorsatz D. 2021. Urgent need for post-growth climate mitigation scenarios. *Nature Energy* 6: 766–768.
- Jenkins S, Smith C, Allen M, Grainger R. 2023. Tonga eruption increases chance of temporary surface temperature anomaly above 1.5°C. *Nature Climate Change* 13: 127–129.
- Kemp L, et al. 2022. Climate endgame: Exploring catastrophic climate change scenarios. *Proceedings of the National Academy of Sciences* 119: e2108146119.
- Kornhuber K, Lesk C, Schleussner CF, Jägermeyr J, Pfleiderer P, Horton RM. 2023. Risks of synchronized low yields are underestimated in climate and crop model projections. *Nature Communications* 14: 3528.
- Lenton TM, et al. 2023. Quantifying the human cost of global warming. *Nature Sustainability* 2023: s41893-023-01132-6.
- McBain B, Lenzen M, Wackernagel M, Albrecht G. 2017. How long can global ecological overshoot last? *Global and Planetary Change* 155: 13–19.
- Muta T, Erdogan M. 2023. The Global Energy Crisis Pushed Fossil Fuel Consumption Subsidies to an All-Time High in 2022. *International Energy Agency*. www.iea.org/commentaries/the-global-energy-crisis-pushed-fossil-fuel-consumption-subsidies-to-an-all-time-high-in-2022.
- Normile D. 2020. China's bold climate pledge earns praise—but is it feasible? *Science* 370: 17–18.
- O'Neill DW, Fanning AL, Lamb WF, Steinberger JK. 2018. A good life for all within planetary boundaries. *Nature Sustainability* 1: 88–95.
- Ortiz-Bobea A, Ault TR, Carrillo CM, Chambers RG, Lobell DB. 2021. Anthropogenic climate change has slowed global agricultural productivity growth. *Nature Climate Change* 11: 306–312.

- Raza A, Razzaq A, Mehmood SS, Zou X, Zhang X, Lv Y, Xu J. 2019. Impact of climate change on crops adaptation and strategies to tackle its outcome: A review. *Plants* 8: 34.
- Reid PC, et al. 2009. Impacts of the oceans on climate change. Pages 1–150 in Sims DW, ed. *Advances in Marine Biology*, vol. 56. Elsevier.
- Ripple WJ, Wolf C, Newsome TM, Barnard P, Moomaw WR. 2020. World scientists' warning of a climate emergency. *BioScience* 70: 8–12.
- Ripple WJ, et al. 2021. World scientists' Warning of a climate emergency 2021. *BioScience* 71: 894–898.
- Ripple WJ, Wolf C, Lenton TM, Gregg JW, Natali SM, Duffy PB, Rockström J, Schellnhuber HJ. 2023. Many risky feedback loops amplify the need for climate action. *One Earth* 6: 86–91.
- Rockström J, et al. 2009. Planetary boundaries: Exploring The safe operating space for humanity. *Ecology and Society* 14: 26268316.
- Rockström J, et al. 2023. Safe and just Earth system boundaries. *Nature* 619: 102–111.
- Rousi E, Kornhuber K, Beobide-Arsuaga G, Luo F, Coumou D. 2022. Accelerated western European heatwave trends linked to more-persistent double jets over Eurasia. *Nature Communications* 13: 1–11.
- Stendel M, Francis J, White R, Williams PD, Woollings T. 2021. The jet stream and climate change. Pages 327–357 in Letcher TM, ed. *Climate Change: Observed Impacts on Planet Earth*, 3rd ed. Elsevier.
- Tollefson J. 2022. What the war in Ukraine means for energy, climate and food. *Nature* 604: 232–233.
- [UNEP] United Nations Environment Programme. 2022a. *Making Good on the Glasgow Climate Pact: A Call to Action to Achieve One Gigaton of Emissions Reductions from Forests by 2025*. UNEP.
- [UNEP] United Nations Environment Programme. 2022b. *Emissions Gap Report 2022: The Closing Window: Climate Crisis Calls for Rapid Transformation of Societies*. UNEP.
- van Asselt H, Newell P. 2022. Pathways to an international agreement to leave fossil fuels in the ground. *Global Environmental Politics* 22: 28–47.
- Vilani RM, Ferrante L, Fearnside PM. 2023. The first acts of Brazil's new president: Lula's new Amazon institutionalism. *Environmental Conservation* 50: 148–151.
- Wang C, Dong S, Evan AT, Foltz GR, Lee S-K. 2012. Multidecadal covariability of North Atlantic sea surface temperature, African dust, Sahel rainfall, and Atlantic hurricanes. *Journal of Climate* 25: 5404–5415.
- Wu L, Zhao H, Wang C, Cao J, Liang J. 2022. Understanding of the effect of climate change on tropical cyclone intensity: A Review. *Advances in Atmospheric Sciences* 39: 205–221.
- Xu C, Kohler TA, Lenton TM, Svenning J-C, Scheffer M. 2020. Future of the human climate niche. *Proceedings of the National Academy of Sciences* 117: 11350–11355.
- Zhang F, Lu J, Chen L. 2023. When green recovery fails to consider coal pushback: Exploring global coal rebounds, production, and policy retrenchment post COVID-19. *Energy Research and Social Science* 101: 103142.