Preface

The Fury of Nature

For obvious reasons, human beings have been fascinated and curious about the weather since before recorded history. Weather conditions dictate the kinds of activities that are possible, and how comfortable a person will be while doing them. Whether it's the temperature, the possibility of rainfall, the level of sunlight, or the speed and directions of the winds, weather shapes human life and has provided structure for the development of societies and economies. But weather is also not a constant, it is a set of changing, cyclical, and at times temperamental patterns that can either facilitate the substance of human life, or can become a threat to lives and property.

Each year, in the United States, Americans hear a lot about extreme weather. Whether it's a drought in the Southwest, or a deluge in the Northeast, or a hurricane striking the coast of Florida, or a tornado sweeping through the plains, extreme weather is a common annual topic of both public interest and news media, because extreme weather events happen very frequently. A recent study suggested that, in the 2020s, the United States has an extreme weather event that causes more than a billion in damages approximately every ten days. Further, extreme weather is more common now than it was in the past. In the 1980s, there were more than eighty days, on average, between major extreme weather events.[1]

Another thing that people hear a lot about, since the 1980s, at least, is "climate change," which refers to the way that humanity is impacting the climate of the earth, mostly through the burning of fossil fuels. Climate change has become a hot-button political topic because there is a powerful political lobby that is trying to resist making changes to lessen the impact of humanity upon the climate, because doing so reduces their capacity to profit from the harvest and sale of fossil fuels. These companies and their allied politicians have therefore characterized climate change as a progressive issue, or have tried to downplay the significance of humanity's impact on the climate. But political affiliation does nothing to change the scientific consensus on the issue, which has been growing in strength since the 1800s and still conclusively states that the human burning of fossil fuels is warming the earth, and that this warming is making extreme weather more common and more destructive.

Climate and Weather

While most Americans have no doubt heard about climate change, there is a lot of confusion over the issue that stems from the fact that many Americans don't

understand the difference between climate and weather. When there is an especially cold day, for instance, during any winter, some Americans might think that this indicates that the world can't be warming, because otherwise there would no longer be especially cold days, or periods of intense unexpected cold. This is not, however, an indication that the climate is not changing and has not changed, but rather, it is something that can be expected as the climate continues to change.

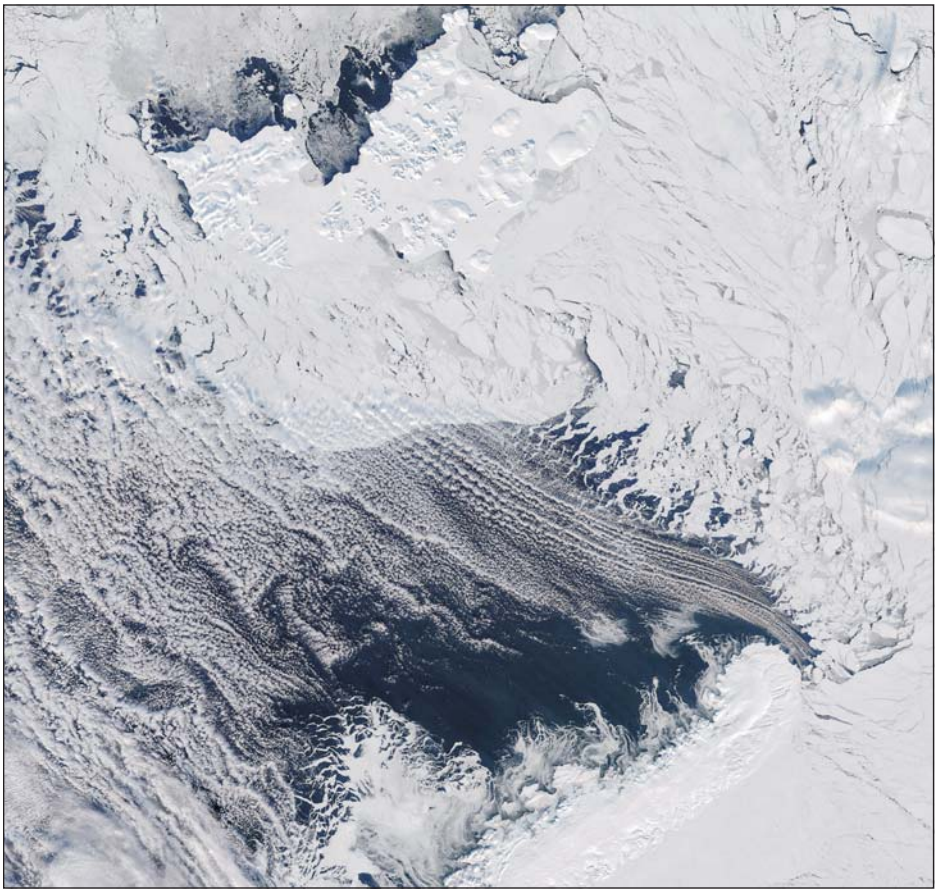
Part of what has happened, for instance, as a result of human pollution of the environment with fossil fuel combustion, is that air currents have changed. This results in changes in the location of air currents across the earth and this can mean warmer temperatures in the Arctic, while cold air is pushed (a process called "polar vortex splitting") causing extreme cold in parts of Asia and North America that are typically much more temperate. These extreme cold spells are therefore the result of *warming*, even though local populations experience this change, temporarily, as colder-than-average temperatures.[2]

In general, this misunderstanding reflects a lack of understanding about the differences between climate and weather. Weather can be described as the patterns of temperature, air currents, precipitation, and humidity that affect a specific area at a specific time. Climate refers to the general long-term conditions in certain areas at certain times of the year. The National Oceanic and Atmospheric Administration (NOAA) summarizes the issue by stating that "Climate is what you expect. Weather is what actually happens," and further describes the relationship by stating that "Weather tells you what to wear each day," while "Climate tells you what types of clothes to have in your closet."[3]

Imagine, for instance, that over a period of ten years, the temperature in a specific area, in the month of January averages around 40 degrees, with 2 to 4 inches of rainfall. These are descriptions of the climate in that region for that specific time of the year, meaning the average conditions. Descriptions of climate might also take into account broad average weather conditions. For instance, it might be noted that the climate in a certain area, is typically dry with low levels of rainfall and very little chance of storms, during a certain portion of the year. This estimation is obtained by looking at average conditions over long periods. This is how climate is discussed and studied, as averages of things like temperature, precipitation, humidity, sunlight levels, wind speeds, etc. Climate can be estimated, as a set of "average conditions" over periods ranging from a few years to many decades. These long-term estimations result in what are called "climate normals," meaning the expected conditions in certain areas at certain times.[4]

Weather, by contrast, is the mix of conditions that happen each day. This means the immediate wind speed, precipitation, sunlight levels, etc. When a person checks a weather app, looking at hourly, daily, 10-day, or monthly forecasts, what they are looking at is a prediction about the weather, based on existing data from weather systems, temperatures, and other conditions around the world. Weather data from each year, then becomes part of the data the climate scientists use to study averages over longer periods, and this is how scientists know that the climate is changing, because the averages that they find, as data from

1
Causes and Effects of Extreme Weather



Sea ice loss in the Arctic can contribute to extreme weather, including heat waves and periods of extreme cold. Here, thin, broken-up sea ice and areas of open water dominate the northern Barents Sea in March 2026. Image by NASA, Terra satellite. [Public domain.]

Severe Conditions

Between 1980 and 2026, the United States recorded 430 weather events that cost more than $1 billion in damages, with a collective cost of more than $3.1 trillion. This cost is not just measured in lost property, and damaged infrastructure, but also in the way that extreme weather disrupts lives. The cost of extreme weather includes losses in productivity and disruptions in commerce. The true effect of extreme weather also cannot be measured in an entirely economic way. The more than 430 major weather events since 1980 have also claimed more than 17,000 lives and left tens of thousands displaced or their lives otherwise upended. Extreme weather is also a form of trauma, and this means that those who live through extreme weather events also suffer from the lasting trauma of their experience and the effort to rebuild their lives and communities.[1]

Each year, there are dozens of localized extreme weather events across the United States, and an average of around twenty events exceeding a billion in damages. However, one thing that climate specialists and meteorologists have raised concern about is the fact that these events are becoming more common. In the 1980s, the United States averaged less than ten extreme billion-dollar climate events each year. By the early 2010s, there were between ten and twenty, and in the 2020s, the average has been over twenty a year, and nearly thirty in especially active years.[2] This increased frequency is the result of climate change, which is the result of the burning of fossil fuels. Each year that Americans and the rest of the world's population continue to utilize fossil fuels as the primary energy source in America, global heating continues, as does atmospheric pollution. This sets the stage for more frequent and more devastating natural disasters. A 2025 study showed that the United States suffered a weather disaster costing more than $1 billion approximately once every ten days in 2025, and showed further that this increased frequency wasn't the result of a natural cycle, but was yet another product of climate change.[3]

Causes of Extreme Weather

Extreme weather comes in many forms. There are several extreme weather events that are associated with storms, including tornadoes, hurricanes, and certain kinds of winter storms, like blizzards. Extreme weather also occurs in cases of excessive precipitation, which can lead to flooding and can damage communities and properties, or a lack of precipitation, leading to drought and water shortages. In certain conditions, extreme heat and dryness can facilitate the development of wildfires, which can destroy vast areas. In colder climate, extreme weather might involve ice, snow, and extreme life-threatening cold. The kind of extreme weather

Causes and Effects of Climate Change

United Nations, 2025

Fossil fuels—coal, oil and gas—are by far the largest contributor to global climate change, accounting for around 68 per cent of global greenhouse gas emissions and nearly 90 per cent of all carbon dioxide emissions.

As greenhouse gas emissions blanket the Earth, they trap the sun's heat. Because of this, the planet is warming up and the climate is changing. The world is now warming faster than at any point in recorded history. Warmer temperatures over time are changing weather patterns and disrupting the usual balance of nature. This poses many risks to human beings and all other forms of life on Earth.

Causes of Climate Change

Generating power

A large chunk of global emissions comes from burning fossil fuels to produce electricity and heat. Most electricity is still generated by burning coal, oil, or gas, which produces carbon dioxide and nitrous oxide—powerful greenhouse gases that blanket the Earth and trap the sun's heat. Globally, a third of electricity comes from wind, solar and other renewable sources which, as opposed to fossil fuels, emit little to no greenhouse gases or pollutants into the air.

Manufacturing goods

Manufacturing and industry produce emissions, mostly from burning fossil fuels to generate the energy needed to make things like cement, iron, steel, electronics, plastics, clothes, and other goods. Mining and other industrial processes also release gases, as does the construction industry. Machines used in the manufacturing process often run on coal, oil, or gas. Some materials, like plastics, are made from chemicals sourced from fossil fuels. The manufacturing industry is one of the largest contributors to greenhouse gas emissions worldwide.

Cutting down forests

Cutting down forests to create farms or pastures, or for other reasons, generates emissions, since trees, when they are cut, release the carbon they had been storing. Each year approximately 10 million hectares of forest are destroyed. Since forests absorb carbon dioxide, destroying them also limits nature's ability to keep emissions out of the atmosphere. Deforestation, together with agriculture and other land use changes, is responsible for roughly a third of global greenhouse gas emissions.

Atmospheric and Wind Events

Tornadoes and hurricanes are both types of extreme storms, involving violently rotating winds. Hurricanes, however, form over the water, while tornadoes form over land. Most hurricanes are linked to warm tropical storms, while tornadoes can form in a variety of conditions, and are not necessarily connected to tropical storm systems. While tornadoes can be massive, to human observers, they are small-scale circulations that are rarely more than a few hundred feet across. By contrast, hurricanes can reach massive proportions, with swirling winds covering an average of 300 miles, but sometimes growing to over 1,000 miles in diameter.[1]

In addition to the rotating wind events, there are other atmospheric and wind events in which the winds are not rotating, but can be just as damaging and deadly. These include derechos, which are straight-line wind storms linked to fast-moving severe thunderstorms. There are also the famous "Nor'easters" on the East Coast, in which strong winds come blowing in off the Atlantic Ocean from cyclones over the ocean, bringing heavy rains and northeasterly wind, or even snowstorms. Then there are haboobs, or dust storms, which are windstorms carrying dust and sand and driven by thunderstorm-like atmospheric conditions, when they occur in arid regions.[2]

Each year, in the United States, wind events cause billions of damage and claim dozens of lives, and the United States experiences more tornadoes than anywhere in the world. The US government, through the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS), and the National Severe Storms Laboratory (NSSL) tries to help Americans avoid the danger posed by wind events through national and local alerts and by providing information on storm preparedness.

Tropical Storms and Hurricanes

Warm ocean waters and thunderstorms overseas are the recipe for the formation of hurricanes, swirling wind storms that form over the oceans. Usually, hurricanes begin as tropical waves, which are areas of low pressure moving through the moist tropical air. This low-pressure system excites local showers and thunderstorms, as it moves westward. As this occurs, warm air rises into the storm, while an area of low-pressure forms beneath the storm. These further push air into the system, which rises, cools, and forms clouds and thunderstorms. As the storm builds and spins, it is classified as a "tropical storm." When wind speeds reach 74 miles per hour (mph), it is called a "hurricane" or a "tropical cyclone," which refers to the same weather event. As a way of representing the power of these events, the NOAA states that "during just one hurricane, raging winds can churn out about

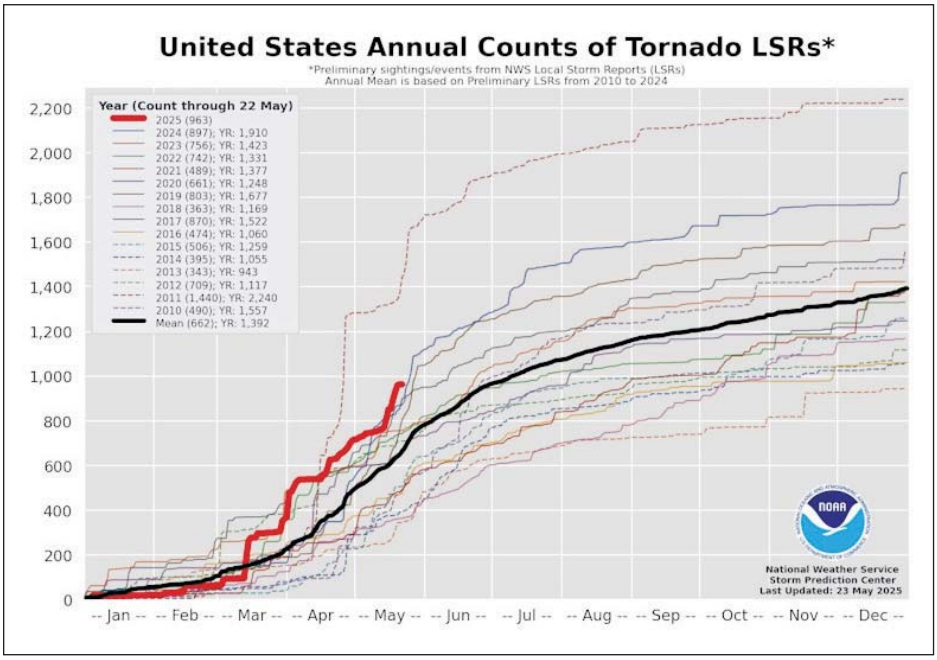
In 2025, Tornado Alley Has Become Almost Everything East of the Rockies—And It's Been a Violent Year

By Daniel Chavas
The Conversation, May 23, 2025

Violent tornado outbreaks, like the storms that tore through parts of St. Louis and London, Kentucky, on May 16, have made 2025 seem like an especially active, deadly and destructive year for tornadoes.

The U.S. has had more reported tornadoes than normal—over 960 as of May 22, according to the National Weather Service's preliminary count.

That's well above the national average of around 660 tornadoes reported by that point over the past 15 years, and it's similar to 2024—the second-most active year over that same period.



The National Weather Service tracks reported tornadoes based on local storm reports, allowing for comparisons throughout the year. The red line shows 2025 through May 22. NOAA National Storm Prediction Center

And there is already evidence that the strongest storms are getting stronger. For example, a July 2025 analysis found that human-caused climate change increased the intensity of 2024's Atlantic hurricanes by 3%–12%. This may seem trivial, but a 5% increase in hurricane winds yields about a 50% increase in damage: Hurricane damage increases exponentially with an increase in winds (see NOAA's damage multiplier table in Fig. 3)

For 2024's devastating Hurricane Helene, another study found an 11% increase in winds because of climate change, accounting for 44% of the $81 billion in damage caused by Helene.

An Increase in Cat 5 Storms Globally

High-quality satellite-based data shows an increase in the number of Category 5 storms. Of the 217 Cat 5s globally during the 44-year period 1982 to 2025, 59% occurred in the last half of the period (Fig. 1), and there has been an increase in the number of Cat 5s since accurate global satellite data became available in 1982 (and technically, this is statistically significant at better than the 1% level—meaning that this is a real trend and not random variability). And if we look at the strongest tropical cyclones by ocean basin since 1980 (Fig. 2), the records for nine out of 11 of these ocean basins were set in the last half of the 46-year period ending in 2025.

Five Studies Showing Tropical Cyclones Are Already Getting Stronger

According to a 2020 paper by MIT scientist Kerry Emanuel, "Evidence That Hurricanes Are Getting Stronger," global warming should cause an increase in the

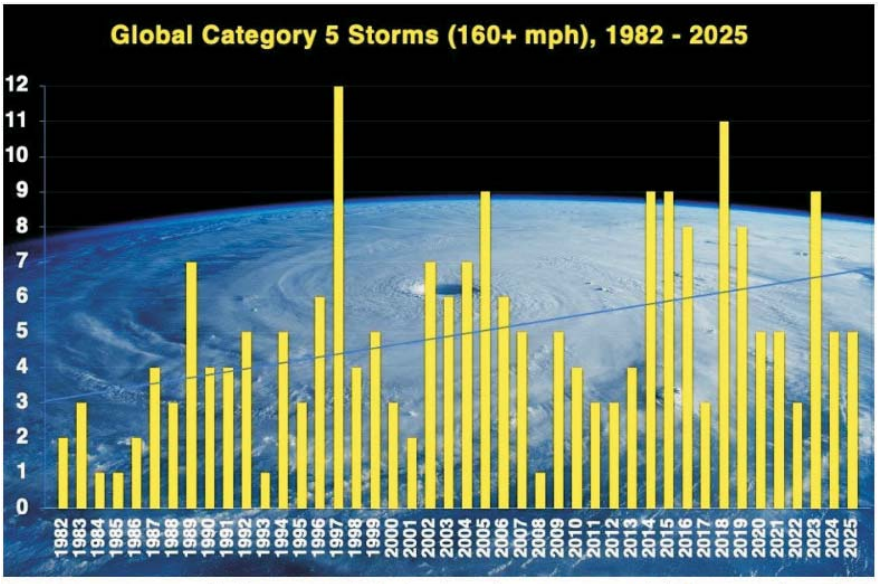


Figure 1. Category 5 storms globally, 1982-2025. The blue line shows a linear increasing trend, which is statistically significant at better than the 1% level.

Climate Change-Fueled Hurricanes Are Increasingly Destructive and Costly for U.S. Communities

By Devon Lespier, Kalina Gibson, and Cathleen Kelly
Center for American Progress, June 9, 2025

Introduction and Summary

Stronger, more frequent, and costly hurricanes are reshaping lives across the United States—increasing fatalities, destroying homes and businesses, disrupting schools and hospitals, and forcing entire communities to rebuild from scratch. The ripple effects of these storms stretch far beyond their widening perimeters: As nearshore coastal habitats are battered or washed away, the local economies that depend on them and the flood protections they provide are weakened as well. These more intense and destructive storms are becoming the new normal, underscoring the real and rising costs of a changing climate for more and more Americans.

Climate Change Is Amplifying Hurricanes' Destruction

Hurricanes have long been a danger to U.S. communities, but they are increasingly destructive as the planet heats up.[2] Hurricanes are giant "heat engines" that draw energy from warm ocean water.[3] As global temperatures rise, so do sea surface temperatures —providing more fuel for storms to grow stronger, wetter, and more dangerous than they were just a few decades ago. Rising global temperatures warm ocean surfaces and intensify evaporation, allowing tropical storms to pull in more heat and moisture. The most damaging hurricanes in the United States are now occurring three times more often than they did a century ago, and since 1980, the proportion of major hurricanes in the Atlantic Ocean has dou-

Hurricanes, Typhoons, and Tropical Cyclones Are All Variations of the Same Weather Phenomenon

Tropical cyclones are large, rotating weather systems with a low-pressure center, originating over warm tropical or subtropical waters.[1] When maximum sustained winds reach 74 mph, the event is classified as a hurricane in the North Atlantic, central North Pacific, and eastern North Pacific and as a typhoon in the western North Pacific. In the South Pacific and Indian Ocean, the generic term "tropical cyclone" is used, regardless of the system's wind speed.

Extreme Heat and Climate Change

Center for Climate and Energy Solutions, 2026

Extreme heat—periods of unusually high temperatures that threaten human health, ecosystems, and infrastructure—is becoming more frequent and intense as the climate warms. Communities across the United States are already experiencing longer heat seasons, more dangerous heat index days, and greater risks to vulnerable populations.

Historical Conditions and Future Projections for Heat

Across the globe, hot days are getting hotter and occurring more frequently. The year 2024 was the hottest year on record, with global average temperatures more than 1.5 °C above the 1850-1900 average. The past 10 years, from 2015 to 2024, were the hottest on record globally. In cities across the United States, the average rate of extreme heat events increased from two per year in the 1960s to ten per year between 2010 and 2020. Additionally, as of 2024, the average length of heat-wave season in the U.S. has increased by 46 days since the 1960s.

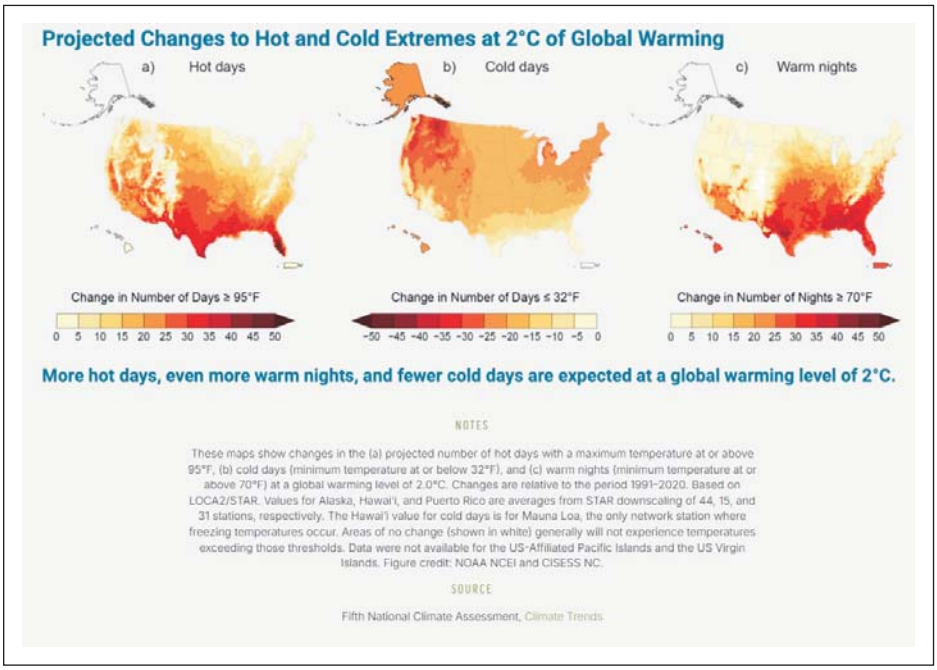
Looking ahead, the Fifth National Climate Assessment estimates that most areas of the United States will experience 15–30 more days over 95°F per year with 2°C of global warming. Some places, like Florida, could experience up to 50 more days over 95°F per year under this scenario, while the Northeast may only experience an increase of 5–15 days over 95°F per year.

Heat waves are more dangerous when combined with high humidity. The heat index measures the combination of temperature and humidity. A 2019 study projected that nationwide over the coming century, the annual number of days with a heat index above 100°F will double and days with a heat index above 105° F will triple, compared to the end of the 20th century.

Impacts of Extreme Heat

Rising temperatures across the country pose a threat to people, ecosystems, and the economy through impacts on public health, worker productivity, built infrastructure, agriculture, and energy systems. Extreme heat also interacts with other climate hazards, amplifying risks across sectors.

Extreme heat can increase the risk of other types of disasters and exacerbate the consequences of existing environmental disparities. Heat can worsen drought conditions, and hot, dry weather can, in turn, increase wildfire risk. Buildings, roads, and infrastructure absorb heat, leading to temperatures that can be 1 to 7° F hotter



in urban areas than in outlying areas—a phenomenon known as the urban heat island effect, which disproportionately impacts frontline communities.

Public Safety and Health Impacts

Extreme heat is the leading cause of weather-related deaths in the United States, resulting in an average of 238 fatalities a year between 1995 and 2024. Between 2000 and 2025, heat deaths in the United States increased by more than 50%.

Hot days are associated with increases in heat-related illnesses, including cardiovascular and respiratory complications and kidney disease. Heat stress occurs in humans when the body is unable to cool itself effectively. Usually, the body cools itself through sweating, but when humidity is high, sweat evaporates more slowly, potentially leading to heat stroke. High humidity and elevated nighttime temperatures are likely key ingredients in causing heat-related illness and mortality. When extreme heat persists into the night, it can cause discomfort and lead to health problems, especially for people who lack access to cooling, often in low-income communities. Other groups that are particularly vulnerable to heat stress include older adults, infants and children, people with chronic health conditions, and outdoor workers.

Our blog article "Equity in Resilience: Addressing the unequal health impacts of extreme heat" further details how extreme heat disproportionately impacts specific populations and suggests steps state and local governments can take to respond to heat in their communities equitably.

Extreme temperatures can also negatively impact air quality. Hot, sunny days can increase ground-level ozone production, a harmful pollutant that is the main

Heavy Rain on Snow Is Testing Aging Dams Across Michigan and Wisconsin—This Is the Future in a Warming World

By Richard B. Rood
The Conversation, April 22, 2026

Michigan and parts of Wisconsin are in the midst of a historic flooding event in spring 2026. Days of heavy rainfall on top of snow have sent lakes and rivers over their banks and threatened several dams in both states, forcing people to evacuate homes downstream.

By April 20, 2026, nearly half of Michigan's counties were under a state of emergency. In Cheboygan, Michigan, large pumps were brought in to lower pressure on a century-old dam in the city.

The region's aging water infrastructure was never designed for the volume of water it is facing. That's a troubling sign for the future, with flooding becoming more common as global temperatures rise.

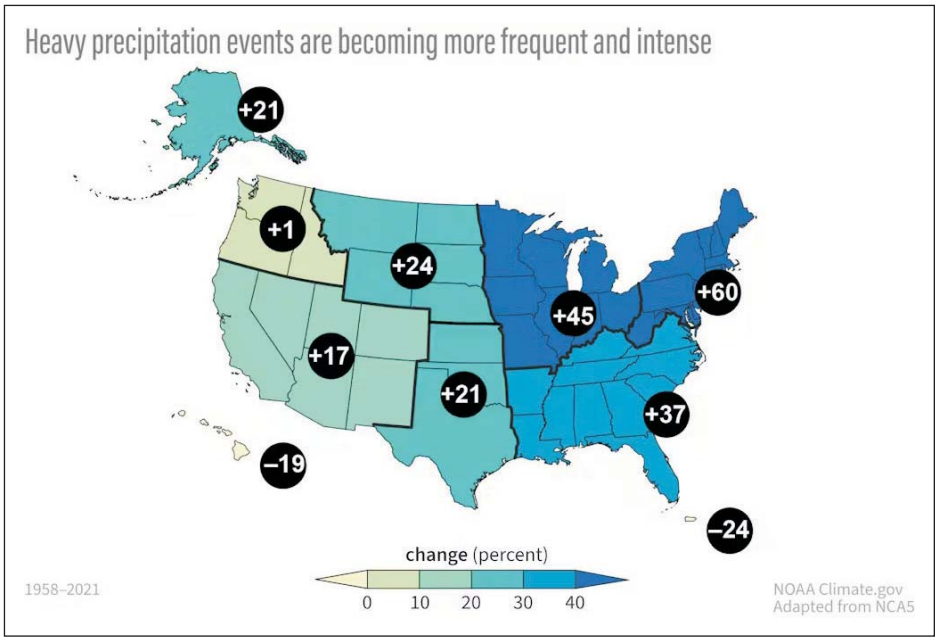
In many areas, the damage has been exacerbated by a culture of building homes and cabins on the shores of inland lakes and along riverine lakes behind small, often privately owned dams. Many of these dams were built over 100 years ago, with some long forgotten.

I am a professor emeritus of meteorology at the University of Michigan whose work focuses on helping communities adapt to climate change. The warming climate is worsening the flood risk, and disasters like the one Michigan is experiencing are setting higher benchmarks for safety as communities plan future infrastructure.

Where Is All the Water Coming From?

For much of Michigan and Wisconsin, as well as northern Illinois, 2026 has been the wettest March and April on record.

In March, much of that precipitation fell as snow, including in an enormous blizzard that brought 3 feet of snow to parts of Michigan. In mid-April, persistent rains began. The rain, on top of all that snow, sent floodwaters running into rivers, streets and homes. The water carries large amounts of ice that damages shores, infrastructure and homes.



Extreme downpours are becoming intense across the United states. This map shows the percentage change in total precipitation falling on the heaviest 1% of rainy days from 1958 to 2021. NOAA/adapted from Fifth National Climate Assessment.

The moisture for much of these storms has been funneled northward from the warm Gulf of Mexico, thanks in part to a high-pressure system sitting over the southeastern U.S.

The Problem of Warming Winters

The kind of flooding Michigan and Wisconsin are experiencing in 2026 is what forecasters expect to see more of as global temperatures rise.

Winters have been warming faster than other seasons across the U.S. In Michigan and Wisconsin, winter months used to be reliably below freezing, but that's changing. In the Cheboygan area, near the tip of Lower Michigan, March temperatures used to be below freezing on all but a few days. By the 1991-2020 period, the region averaged 10 days above or close to the freezing point—about twice as many as the 1951-1980 period.

The air coming in from the south is also warmer than in the past. Nationally, 2026 was the warmest March on record in 132 years of record-keeping in the contiguous U.S., with an average temperature more than 9 degrees Fahrenheit (5 degrees Celsius) higher than the 30-year average. So, in addition to snowmelt starting earlier, melting is happening faster.

Michigan's average wintertime temperature rose by more than 4 F (2.3 C) from 1951 to 2023. Though winter 2026 in Michigan was colder than the 1991-2020 average, the Gulf of Mexico, where the moisture originated, was warmer than average, accelerating the snowmelt.

- The number of extremely warm winter days has increased since 1970 in most (86% or 210) of the locations analyzed.
- On average, these 210 locations now experience six more extremely warm winter days than they did in the 1970s.
- Upper Midwestern cities have seen the sharpest rise in very warm winter days, with an average of seven more such days now than during the 1970s. The Upper Midwest's many ski areas may be affected by more extreme winter warmth.

The following cities have seen the largest increase in unusually warm winter days since 1970:

Location	Unusually warm winter days threshold (°F)	Change in unusually warm winter days, 1970-2025
Miami, Fla.	83°	+20 days
San Jose, Calif.	67°	+13 days
Beaumont, Texas	77°	+13 days
McAllen, Texas	86°	+12 days
Milwaukee, Wisc.	45°	+11 days
Green Bay, Wisc.	41°	+11 days

Only 19 (8%) of the locations analyzed now experience fewer unusually warm winter days—about two fewer days on average—than in 1970. These stations were concentrated in the Northwest and Southwest.

Winter Is Losing Its Chill—Fast

Climate Central's analysis of U.S. weather station data is consistent with national trends. According to NOAA's Climate Extremes Index, over the last 30 years (1996-2025), winter maximum temperatures have been exceptionally warm for

Websites

Climate Central

climatecentral.org

Climate Central is a nonprofit news organization that collects and provides coverage of climate science. Established in 2008, climate science is operated by an independent group of climate scientists and journalists, and the organization also funds original research on climatology and alternative energy. Climate Central's website provides a variety of information on weather and climate issues to researchers and the public.

Cooperative Institute for Severe and High-Impact Weather Research and Operations

www.ou.edu/ciwro

The Cooperative Institute for Severe and High Impact Weather Research and Operations (CIWRO) is an educational organization bringing together research and resources on severe weather impact and science. The institute provides access to original research through the university's web portal.

Extreme Weather Survivors

extremeweathersurvivors.org

Extreme Weather Survivors (EWS) is a national network that helps to connect people impacted by extreme weather disasters with resources and aid. The network covers issues related to storms, pollution, wildfires, floods, drought, and extreme heat. The organization also provides information about extreme weather impacts and resources through their website.

National Integrated Drought Information System

cpo.noaa.gov/national-integrated-drought-information-system/

The National Integrated Drought Information System (NIDIS), was established in 2006 to collect and provide information on droughts and potential droughts situations. The NIDIS is part of the National Oceanic and Atmospheric Administration (NOAA), and provides information through a series of regional drought early warning systems. The NIDIS also provides access to research and reports to researchers and students.

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