Climate Change Series, Effects

By John Benson

June 2025

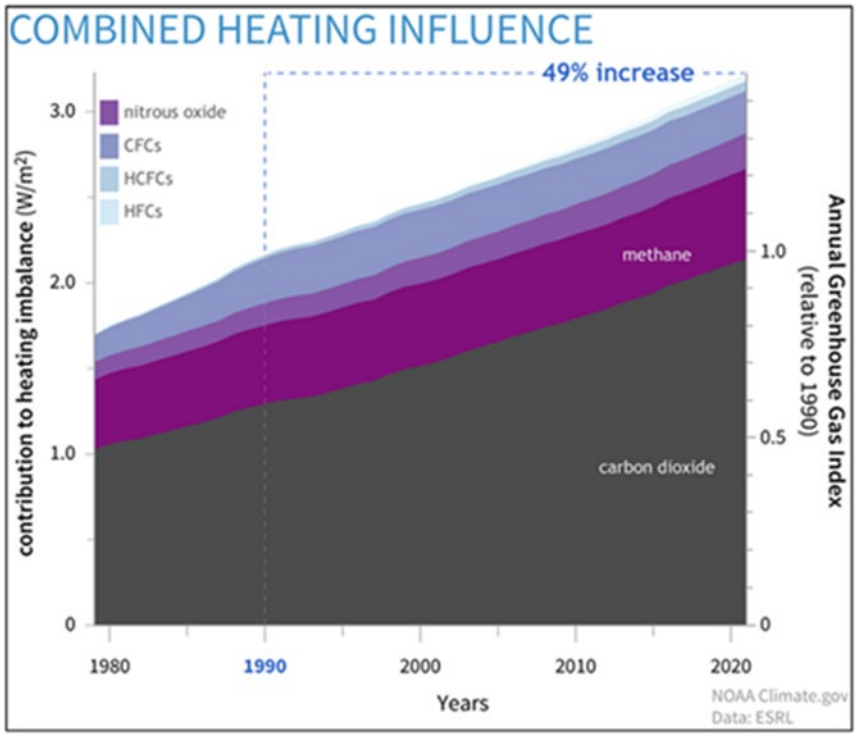
1. Introduction

This is the second post of this series. The first post is summarized and linked below.

Climate Change Series, Introduction: *The primary cause of climate change is the emission by humans of greenhouse gasses (GHG) of a certain type.*

- *The type of GHG is that emitted combusting (burning) hydrocarbon fuel without either the same amount of GHG being absorbed during the manufacture of this fuel, plus a surplus amount being absorbed to compensate for the energy required to manufacture and transport the fuel if generating this energy also produces GHG.*
- *And/or an independent process captures and sequesters GHG from a different, non-emitting source (like direct-air GHG-capture). Like the above bullet, a surplus amount of GHG should be absorbed and sequestered to compensate for the energy required to capture and sequester the GHG, if generating this energy also produces GHG.*

These gasses absorb and retain the energy from solar radiation (light), thus heating up the atmosphere. Thus, the term: "global warming."



https://www.energycentral.com/energy-biz/post/climate-change-series-introduction-j3Iz7J38bIpEn4y

The effects in the subsection below are ordered by whether they are primary effects (like warming), secondary effects (like dying vegetation) or higher-order effects (like wildfires).

1.1. Warming

As mentioned in section 1, "(greenhouse) gasses absorb and retain the energy from solar radiation (light), thus heating up the atmosphere." As can be seen in the chart on page 1, increased greenhouse gasses (GHG), increases the amount of atmospheric heating. Days that would have been tolerable outdoors several decades in the past are now life-threatening. This means that occupations that require being outdoors in the hottest parts of the day, now require a break from work on the hottest days / climates. This, in-turn, reduces the productivity of these workers and/or requires scheduling adjustments.

Global climate change is not a future problem. Changes to Earth's climate driven by increased human emissions of heat-trapping greenhouse gases are already having widespread effects on the environment: glaciers and ice sheets are shrinking, river and lake ice is breaking up earlier, plant and animal geographic ranges are shifting, and plants and trees are blooming sooner.[1]

Effects that scientists had long predicted would result from global climate change are now occurring, such as sea ice loss, accelerated sea level rise, and longer, more intense heat waves.

Some changes (such as droughts, wildfires, and extreme rainfall) are happening faster than scientists previously assessed. In fact, according to the Intergovernmental Panel on Climate Change (IPCC) — the United Nations body established to assess the science related to climate change — modern humans have never before seen the observed changes in our global climate, and some of these changes are irreversible over the next hundreds to thousands of years.

Scientists have high confidence that global temperatures will continue to rise for many decades, mainly due to greenhouse gases produced by human activities.

The IPCC's Sixth Assessment report, published in 2021, found that human emissions of heat-trapping gases have already warmed the climate by nearly 2 degrees Fahrenheit (1.1 degrees Celsius) since 1850-1900. The global average temperature is expected to reach or exceed 1.5 degrees C (about 3 degrees F) within the next few decades. These changes will affect all regions of Earth.

Author's comment: See chart on page 1 for more information on recent warming.

The severity of effects caused by climate change will depend on the path of future human activities. More greenhouse gas emissions will lead to more climate extremes and widespread damaging effects across our planet. However, those future effects depend on the total amount of carbon dioxide we emit. So, if we can reduce emissions, we may avoid some of the worst effects.

[1] The Effects of Climate Change, National Aeronautics and Space Administration. https://science.nasa.gov/climate-change/effects/

1.2. Drought

Increased warming makes droughts more likely by evaporating ground-water and desiccating plants. This directly impacts agricultural productivity (including livestock) and thus food production and availability. Even if water for irrigation is readily available, this requires increased energy consumption to transport the water (mainly for pumping). If renewable / zero-carbon energy is available to drive water-transport (and irrigation water is available), the negatives may end there, but if GHG-producing energy generation must be used, this worsens climate change. Also, eventually excessive groundwater pumping could cause the groundwater levels to drop to where it is no longer financially viable to extract it.

For tens of millions of Americans, drought has become an ever-present natural disaster.[2]

That's particularly true in the Western United States. Because of the West's largely semi-arid and desert climates, droughts are natural occurrences across the region. However, regional climate isn't the only culprit in drought activity. Climate change, namely rising average temperatures driven by human-generated emissions of heat-trapping greenhouse gases, is contributing to droughts, too.

Global warming increases the risk of drought in several ways.

For one, water generally evaporates more quickly at higher temperatures. For that reason, hotter weather can result in drier soils. As high air temperatures sap liquid water from soils and plant leaves, transforming it into atmospheric water vapor via a process called transpiration, ground-level drying will increase in some regions. (Ironically, this additional atmospheric moisture triggers heavier downpours in other regions, which explains why the overall trend in the U.S. has been toward wetter conditions.)

Higher air temperatures not only encourage drought conditions to build but also intensify them. What might have otherwise been a mild or moderate drought in a cooler world will become, in a warmer world, more severe as a result of increased evaporation.

Warming also diminishes snowfall, an essential water resource for the estimated 1.9 billion residents of the Northern Hemisphere who depend on snowpacks, or snow reservoirs that store water during the cooler months and release it when it's needed in the warmer, drier months. Rising temperatures increase the fraction of winter precipitation that falls as rain rather than snow and also shorten the cold season, so there's less time for snow to even occur. Such was the case in 2015, the fourth-warmest year in the contiguous U.S., when a snow drought reduced the April snowpack in the Sierra Nevada Mountains to a mere 5% of its historical average water content — its lowest snowpack in 500 years.

1.3. Flooding

Climate change reduces water availability by evaporating ground-water and desiccating plants. Climate change also causes floods, since a warmer atmosphere can carry and release more water. When a warm, moist weather-cell encounters a cold-front, this can cause torrential rains that can potentially cause flooding. Also note that flooding potentially has higher-order effects, like property-damage, loss of life and soil erosion.

[2] Tiffany Means, Yale Climate Connection, "Climate change and droughts: What's the connection?" May 11, 2023, https://yaleclimateconnections.org/2023/05/climate-change-and-droughts-whats-the-connection/

With higher temperatures, we have more energy in the Earth's system. Higher ocean water and air temperatures increase the possibility for evaporation and therefore cloud formation. At higher temperatures, the air can hold more moisture content. This can lead to an increase in precipitation intensity, duration and/or frequency.[3]

Temperatures increase faster at higher latitude than at the equator. It results in a smaller temperature gradient between mid-latitude and polar temperatures, which can affect the jet stream. For the North Atlantic region, research points to a potential higher frequency of extreme hydro-meteorological events, such as heavy storms in winter, or prolonged drought in summer.

Extreme flooding will continue to be concentrated in regions where humans have built on floodplains or low-lying coastal regions. As global warming increases the likelihood for more extreme weather events to occur, risks will expand beyond the high-risk areas known today. More extreme flooding must be expected, and for the towns and cities where flooding has already occurred, theirs will no longer be a 'once in a lifetime' risk but now far more frequent.

Author's comment: Note that global warming will result in widespread melting of our planet's glaciers and ice-caps (the latter mainly in Greenland and Antarctica) resulting in a massive sea-level rise. *On a pathway with high greenhouse gas emissions and rapid ice sheet collapse, models project that average sea level rise for the contiguous United States could be 2.2 meters (7.2 feet) by 2100 and 3.9 meters (13 feet) by 2150.*[4]

In the United States, almost 30 percent of the population lives in coastal areas, where sea level rise plays a role in flooding, shoreline erosion, and hazards from storms. Globally, 8 of the world's 10 largest cities are near a coast, according to the U.N. Atlas of the Oceans.

Thus, worst-case sea-level rise will result in massive displacement of populations in the US and the World. This will result in impacts far inland as wave after wave of humanity are driven inland to escape sea level rise.

The bad news is that a large majority of this migrating population will lose much of their wealth under the flood waters (the market for ocean-floor real estate is pretty limited). Since the land "safely inland (for now)" will suddenly be prime real-estate, the fleeing masses will need, and probably be inclined, to move far inland.

1.4. Severe Weather, Including Hail-Storms & Tornados

The scenarios described in the prior subsection can also cause weather more damaging than "torrential rains," like the storms described in this subsection title. Also, these storms may be more likely to cause property-damage and loss of life than flooding.

[3] Niklas Hagelberg, UN Environmental Program, "How climate change is making record-breaking floods the new normal," https://www.unep.org/news-and-stories/story/how-climate-change-making-record-breaking-floods-new-normal

[4] https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

Billion-dollar disasters of 2024 came from:[5]

- *6 tornado outbreaks (across the central and southeastern U.S.).*
- *11 severe weather/hail events (across many parts of the country).*

I rest my case.

1.5. Hurricanes

The good news that most of the heat from climate change that starts out in the atmosphere ends up in the oceans. The bad news is that this makes the storms described in this subsection's title more likely, and they are one of the most destructive storms, combining extreme winds, flooding (storm surge), and each storm can travel hundreds of miles along coasts or even inland. Since coastal areas frequently have much built infrastructure (think resorts and large port-cities), they are particularly vulnerable to these storms. For hurricanes that come on-shore from the Atlantic to the Gulf of Mexico, the warmer waters just off of the coasts results in an effect called rapid intensification. See the next paragraphs and the map below.

When a hurricane (a.k.a. tropical cyclone) experiences a period of intensification and its intensity increases by 30 knots (nautical miles per hour) or more over a 24-hr interval, it is said to undergo "rapid intensification". Rapid intensification is one of the most pressing challenges in tropical meteorology, not only because hurricanes that intensify quickly present a big problem for the public, but also because rapid intensification is notoriously difficult to predict. The prediction difficulties stem in part from a lack of scientific understanding.

For example, there is no consensus on what processes cause this effect or what conditions must be met for rapid intensification to happen. Scholars that study hurricanes usually examine events where a weak, incipient hurricane enters a sustained period of intensification and strengthens into a major hurricane. Studies document that rapid intensification can also occur in a short-burst. However, sustained and short-burst modes have distinct underlying mechanisms, and we argue that the existence of multiple rapid intensification modes should be acknowledged for better understanding and predicting these effects.[6]

[5] Adam B. Smith, Climate.gov, "2024: An active year of U.S. billion-dollar weather and climate disasters," January 10, 2025, https://www.climate.gov/news-features/blogs/beyond-data/2024-active-year-us-billion-dollar-weather-and-climate-disasters

[6] Falko Judt, , Rosimar Rios-Berrios, and George H. Bryan, National Center for Atmospheric Research, "Marathon versus Sprint: Two Modes of Tropical Cyclone Rapid Intensification in a Global Convection-Permitting Simulation," October 4, 2023, https://journals.ametsoc.org/view/journals/mwre/151/10/MWR-D-23-0038.1.xml

The following are 2024 Hurricanes that hit the US.

Hurricane Helene, September 24-29, 2024: 219 deaths, $79.6 billion: *Category 4 Hurricane Helene with 140 mph sustained winds was the strongest hurricane on record to strike the Big Bend region of Florida having made landfall near Perry, Florida on September 26. Helene was the third hurricane to hit the Big Bend region in just over a year. It caused up to 15 feet of storm surge along the Big Bend coast and six feet of surge as far south as St. Petersburg. It also caused billions of dollars in damage to Georgia's agriculture sector. Helene's most severe impacts were from the historic rainfall (up to 30+ inches) and flooding across much of western North Carolina.*

Hurricane Milton, October 9-10, 2024: 32 deaths, $34.3 billion: *Category 3 Hurricane Milton with 120 mph sustained winds made landfall near Siesta Key, Florida on October 9. A storm surge of 5 to 10 feet caused damage from Naples to Charlotte Harbor. Milton's track to the south of Tampa Bay lessened storm surge impacts on the densely populated Tampa metro region.*

Hurricane Beryl, July 8, 2024: 46 deaths, $7.2 billion: *Category 1 Hurricane Beryl made landfall in Texas on July 8, producing widespread high wind damage, as the storm was re-strengthening at landfall. One significant impact was power outages that impacted millions of people for days. Beryl also produced more than 50 tornadoes across eastern Texas, western Louisiana and southern Arkansas. On July 1, Beryl became the earliest Category 5 hurricane and the second Category 5 on record during the month of July in the Atlantic Ocean.*

1.6. Wildfire

It wasn't that long ago that wildfires were mostly a western issue in the US, but that has changed dramatically. Although we still have our share of wildfires, especially large ones, these disasters seem to have migrated east. See the table and map linked below.
https://en.wikipedia.org/wiki/2025_United_States_wildfires

It is clear that every state in our union is going to need to beef-up its fire suppression and firefighting resources as global warming becomes more intense.

NASA's Terra and Aqua satellites detect active wildfires twice each day. Scientists studied this data over a 21-year span and found that extreme wildfires have become more frequent, more intense, and larger. The largest increase in extreme fire behavior was in the temperate conifer forests of the Western U.S. and the boreal forests of northern North America and Russia. Warmer nighttime temperatures are a major contributing factor, allowing fire activity to persist overnight.[7]

Fire season is getting longer, and emissions larger: *In 2021, a destructive wintertime wildfire in Colorado became part of a growing trend of wildfire activity extending well beyond the summer. By looking back at 35 years of weather data, U.S. Forest Service scientists found that fire seasons are starting earlier in the spring and extending later into autumn. Parts of the Western United States, Mexico, Brazil, and East Africa now have fire seasons that are more than a month longer than they were 35 years ago.*

[7] https://science.nasa.gov/earth/explore/wildfires-and-climate-change/

Wildfires also can be a major source of carbon dioxide emissions. Researchers found that carbon emissions from forest fires increased by 60% globally between 2001 and 2023. Fire emissions from boreal forests in Eurasia and North America nearly tripled during that same time period, driven by a warmer, drier climate.

Author's final comment: I may have said this earlier in this paper, but carbon dioxide (CO_2) is the primary greenhouse gas. Thus, the release of large amounts of CO_2 by wildfires accelerates climate change.

In 2023, Canada's warmest and driest conditions since 1980 stoked extreme fires that lasted for five months. NASA researchers found that these fires released about 640 million metric tons of carbon.

And this year (2025) some other news about Canada came in.

Massive wildfires burning out of control in western and central Canada are forcing thousands to flee as dire forecasts for the country's fire season come to fruition. The intensifying blazes are also sending hazardous smoke toward major cities in the United States.[8]

The premiers of Manitoba and Saskatchewan have declared states of emergency, and much of Canada, from the Northwest Territories and Alberta to Ontario, are at "extreme" risk of wildfires on Friday (May 30) — the highest level on Environment Canada's fire risk scale.

There are just over 170 wildfires burning across Canada as of Thursday (May 29), according to the Canadian Interagency Forest Fire Center, and about half are uncontrolled. The country raised its National Preparedness Level to level 5 of 5 on Thursday, which is unusually high for this early in the fire season. Last year, Canada didn't reach that level until July 15.

In Manitoba, around 17,000 people are under evacuation orders, including the city of Flin Flon, Pimicikamak Cree Nation and the northern community of Cross Lake, along with Mathias Colomb Cree Nation, according to CNN's Canadian news partner CBC News.

The province's state of emergency will remain in effect for a month and may be extended if conditions warrant, said Manitoba Premier Wab Kinew…

Computer models show smoke from the western Canadian blazes will spread into the Upper Midwest and Great Lakes Friday and throughout the weekend, potentially affecting the cities of Green Bay, Wisconsin, Milwaukee, Chicago and Detroit.

The smoke will likely be in the lower to middle levels of the atmosphere, which could lower visibility and crater air quality in some areas.

[8] Andrew Freedman, CNN, "Smoke to pour into the US as Canada wildfires force province's largest evacuation in 'living memory'," May 30, 2025, https://www.msn.com/en-us/weather/topstories/smoke-to-pour-into-the-us-as-canada-wildfires-force-province-s-largest-evacuation-in-living-memory/ar-AA1FJg2Y?ocid=BingNewsBrowse

Authorities in Minnesota issued an air quality alert for the northern half of the state, warning that fine particle levels are expected to reach "a level considered unhealthy for everyone." A similar alert is in effect in far northern Michigan and throughout Wisconsin for Friday.

2. U.S. Regional Effects

Climate change is bringing different types of challenges to each region of the country. Some of the current and future impacts are summarized below. These findings are from the Third and Fourth National Climate Assessment Reports, released by the U.S. Global Change Research Program.

Northeast. *Heat waves, heavy downpours, and sea level rise pose increasing challenges to many aspects of life in the Northeast. Infrastructure, agriculture, fisheries, and ecosystems will be increasingly compromised. Farmers can explore new crop options, but these adaptations are not cost- or risk-free. Moreover, adaptive capacity, which varies throughout the region, could be overwhelmed by a changing climate. Many states and cities are beginning to incorporate climate change into their planning.*

Northwest. *Changes in the timing of peak flows in rivers and streams are reducing water supplies and worsening competing demands for water. Sea level rise, erosion, flooding, risks to infrastructure, and increasing ocean acidity pose major threats. Increasing wildfire incidence and severity, heat waves, insect outbreaks, and tree diseases are causing widespread forest die-off.*

Southeast. *Sea level rise poses widespread and continuing threats to the region's economy and environment. Extreme heat will affect health, energy, agriculture, and more. Decreased water availability will have economic and environmental impacts.*

Midwest. *Extreme heat, heavy downpours, and flooding will affect infrastructure, health, agriculture, forestry, transportation, air and water quality, and more. Climate change will also pose a range of risks to the Great Lakes.*

Southwest. *Climate change has caused increased heat, drought, and insect outbreaks. In turn, these changes have made wildfires more numerous and severe. The warming climate has also caused a decline in water supplies, reduced agricultural yields, and triggered heat-related health impacts in cities. In coastal areas, flooding from sea-level rise and erosion are additional concerns.*