

# Climate Change: Causes, Drivers and Evidence.

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**Abstract:** *This article explores the historical roots of climate change awareness, tracing back to ancient civilizations and the scientific revolution of the 19th century. It highlights key milestones in climate studies, such as the proposal of the “greenhouse effect” and the establishment of the IPCC. The article defines climate change as a prolonged alteration in climate conditions caused by natural variability or human activities, particularly the increase in greenhouse gas emissions. It emphasizes the need for a global effort to reduce emissions, transition to renewable energy, and adopt sustainable land-use practices. The Paris Agreement, aimed at limiting global warming, is also discussed as a crucial step in addressing climate change on a global scale.*

**Keyword:** IPCC, Change, Precipitation pattern, Climate change, Climate system, Anthropogenic, Temperature change, Ecosystem, Melting and Ice.

## Introduction:

Climate change is a pressing global issue that has garnered significant attention in recent decades. However, it is crucial to understand its historical context to comprehend the development of our current understanding of climate change. This review aims to trace the historical background of climate change, highlighting key milestones and scientific advancements.

**Early Recognition of Climate Variability:** The concept of climate change has roots dating back thousands of years. Ancient civilizations, such as the Mayans and Egyptians, observed patterns of climate variability, evident in their calendars and agricultural practices. Nonetheless, the understanding of climate change as a long-term phenomenon was limited.

**Scientific Revolution and the Beginning of Climate Studies:** The 19th century marked the beginning of scientific investigations into climate change. Scholars like Jean-Baptiste Fourier, who proposed the “greenhouse effect” in the early 1820s, laid the foundation for modern climate science. In the late 19th century, Svante Arrhenius linked carbon dioxide (CO<sub>2</sub>) levels with global temperature changes, establishing the idea that human activities might contribute to climate change.

**International Recognition and the Birth of Climate Change Politics:** The formation of the United Nations (UN) in 1945 and the subsequent creation of the Intergovernmental Panel on Climate Change (IPCC) in 1988 marked significant milestones in addressing climate change (Goodluck et al., 2024). The UN Framework Convention on Climate Change (UNFCCC) in 1992 aimed to stabilize greenhouse gas concentrations in the atmosphere.

**Efforts in Gathering Climate Data:** The 20th century witnessed notable advancements in climate data collection. The establishment of meteorological networks, such as the Global Historical Climatology Network (GHCN) in 1992, enabled scientists to study long-term climate trends. Additionally, technological advancements, including satellites and weather models, helped monitor global climate patterns.

**The Modern Era of Climate Science:** With accumulating evidence, the understanding of human-induced climate change solidified in the late 20th century. The fifth IPCC Assessment Report in 2014 provided unequivocal evidence of global warming and its anthropogenic causes. Today, ongoing research and advancements in climate modeling continue to enhance our understanding of climate change impacts.

## Definition of climate change

Climate change is a complex and multifaceted issue that has garnered significant attention in recent years due to its far-reaching impacts on the environment and society. According to the Intergovernmental Panel on Climate Change (IPCC), climate change is defined as “a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer, whether due to natural variability or as a result of human activity” (IPCC, 2014).

One of the key drivers of climate change is the increase in greenhouse gas emissions, particularly carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O), which are released into the atmosphere through human activities such as burning fossil fuels for energy, deforestation, and agriculture (IPCC, 2014). These gases act like a blanket, trapping heat from the sun and causing the Earth’s temperature to rise, a phenomenon known as global warming.

The consequences of climate change are wide-ranging and include rising sea levels, more frequent and severe weather events, shifts in precipitation patterns, and disruptions to ecosystems and biodiversity (NASA, 2021). For example, the melting of polar ice caps and glaciers due to rising temperatures is leading to sea-level rise, threatening coastal communities and habitats (IPCC, 2014). Extreme weather events such as hurricanes, droughts, and wildfires are becoming more common and intense, causing damage to infrastructure, agriculture, and human health (IPCC, 2014).

The impacts of climate change are not limited to the environment; they also have social, economic, and political implications. Vulnerable populations, such as low-income communities and indigenous peoples, are disproportionately affected by climate change, as they often lack the resources and infrastructure to adapt to changing conditions (IPCC, 2014). In addition, climate change can exacerbate existing inequalities and conflicts, leading to displacement, food insecurity, and social unrest (IPCC, 2014 & amafade et al., 2022).

Addressing climate change requires a coordinated global effort to reduce greenhouse gas emissions, transition to renewable energy sources, and implement sustainable land-use practices (IPCC, 2018). The Paris Agreement, adopted in 2015 by nearly 200 countries, aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5 degrees Celsius (UNFCCC, 2015).

### **Causes and Drivers of Climate Change**

Climate change has emerged as one of the most critical challenges facing our planet today. It entails complex interactions between natural processes and human activities, resulting in significant deviations from historical climatic patterns. Understanding the causes and drivers behind climate change is crucial in formulating effective mitigation and adaptation strategies. This review aims to shed light on the main factors contributing to climate change, drawing upon scientific literature and expert opinions.

**Greenhouse Gas Emissions:** One of the primary causes of climate change is the increase in greenhouse gas (GHG) emissions, resulting mainly from human activities. Anthropogenic activities such as burning fossil fuels, deforestation, industrial processes, and agriculture release vast amounts of carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) into the atmosphere. These gases enhance the greenhouse effect, trapping heat and gradually elevating global temperatures. The Intergovernmental Panel on Climate Change (IPCC) estimates that human activities are responsible for approximately 95% of the increase in CO<sub>2</sub> concentrations since the pre-industrial era (IPCC, 2014).

**Land Use Change and Deforestation:** Another significant driver of climate change is land use change, particularly deforestation. Deforestation releases massive amounts of stored carbon into the atmosphere, exacerbating the greenhouse effect. Forests act as carbon sinks by absorbing CO<sub>2</sub> during photosynthesis. Clearing forests, primarily driven by agricultural expansion, releases stored carbon and reduces the capacity for carbon absorption in the future. This process contributes to both increased atmospheric CO<sub>2</sub> levels and loss of critical habitats.

**Industrial Processes and Ozone Depletion:** Industrial processes, particularly the production and release of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), have been found to have a direct impact on climate change. These chemicals have been heavily used in refrigeration, air conditioning, and foam-blowing industries. Once released, they accumulate in the upper atmosphere, catalyzing the depletion of the ozone layer. The weakening of the ozone layer allows for the penetration of higher levels of ultraviolet (UV) radiation, which contributes to changing climate patterns.

**Feedback Loops and Tipping Points:** Climate change is also influenced by various feedback loops and tipping points in the Earth's systems. For instance, as temperatures rise, ice in the polar regions melts, reducing reflectivity and increasing the absorption of solar energy by the oceans. This leads to further warming, more ice melt, and a reinforcing cycle. Additionally, the release of methane from thawing permafrost areas can trigger a positive feedback loop, further amplifying warming due to methane's potent greenhouse effect.

### **Evidence of Climate Change**

Global temperature changes have become one of the most significant concerns in recent years as the world grapples with the harsh realities of climate change. As researchers strive to understand the complexities of this global issue, an immense body of observational evidence has emerged. This review aims to examine and summarize key observations of global temperature changes, shedding light on the trends, causes, and implications associated with this critical aspect of global warming.

**Long-term Temperature Trends:** Examining long-term temperature trends provides crucial insights into the magnitude and pace of global warming. Multiple studies have consistently shown a clear upward trend in global average temperatures. For instance, data from the National Oceanic and Atmospheric Administration (NOAA) reveals that the global mean surface temperature has

increased by approximately 0.18°C per decade over the past 50 years (NOAA, 2021). This observation highlights the sustained warming of the earth's climate system.

**Regional and Seasonal Variations:** While global average temperatures provide a broad overview, it is essential to consider regional and seasonal variations to understand the true impact of global temperature changes. Numerous studies have documented varying regional responses to warming, with some areas experiencing more substantial temperature increases than others (IPCC, 2018). For instance, the Arctic region has witnessed rapid warming, with temperatures rising at about twice the global average rate (NASA, 2021). These observations not only emphasize the uneven distribution of temperature changes but also indicate potential consequences for ecosystems, ice sheets, and sea-level rise.

**Attribution of Temperature Changes:** Identifying the causes behind global temperature changes is crucial for developing effective mitigation and adaptation strategies. Extensive research has conclusively shown that human activities, particularly greenhouse gas emissions, are the primary drivers of current global warming trends (IPCC, 2013). Analysis by the Intergovernmental Panel on Climate Change (IPCC) determined that it is extremely likely that more than half of the observed increase in global average surface temperature since the mid-20th century can be attributed to human influence (IPCC, 2013). These findings underscore the urgency of reducing greenhouse gas emissions and transitioning towards sustainable alternatives.

**Impacts on Natural and Human Systems:** The observed global temperature changes have far-reaching consequences for both natural and human systems. Rising temperatures have led to the melting of glaciers, sea ice retreat, changes in rainfall patterns, and increased frequency of extreme weather events (NASA, 2021). These impacts affect essential sectors such as agriculture, water resources, biodiversity, human health, and overall socio-economic stability (IPCC, 2014). Understanding the observed temperature changes allows policymakers and stakeholders to prioritize adaptation measures and plan for a more resilient future.

Climate change, driven by anthropogenic activities, is reshaping Earth's climate system, resulting in numerous environmental transformations. An approaching consensus among scientific organizations indicates that altering precipitation patterns represent one of the most prominent evidence of ongoing climate change (IPCC, 2013a). This review explores the observed changes in global precipitation patterns, highlights their impacts on ecosystems and societies, and underscores the relationship between these patterns and climate change.

**Changes in precipitation patterns:** Over the past century, numerous empirical studies and observational records unequivocally indicate significant alterations in global precipitation patterns. These changes comprise both spatial redistributions of precipitation and alterations in seasonal distributions (IPCC, 2013b). While higher latitudes, such as the Arctic and high mountainous regions, have experienced increased precipitation, subtropical regions have shown persistent drying trends (IPCC, 2013a). Additionally, intense rainfall events have become more frequent, leading to increased flood risks in several regions (Trenberth et al., 2007).

One of the most pronounced features of climate change-induced precipitation patterns is the expansion of dry areas and desertification. Various regions, including parts of Africa, Asia, and Australia, have witnessed long-term drying, further exacerbating water scarcity and making agriculture challenging (IPCC, 2014). Conversely, areas with increased precipitation face enhanced risks of soil erosion, landslides, and flooding, jeopardizing infrastructure, livelihoods, and vulnerable populations (IPCC, 2012).

**Ecosystem impacts:** The changing precipitation patterns have profound implications for Earth's ecosystems and biodiversity. Shifts in precipitation directly influence the growth and distribution of vegetation, altering ecosystem functions, and interactions. For instance, prolonged dry periods lead to increased wildfire risks, adversely affecting forest ecosystems and their associated carbon storage capacities (Allen et al., 2010).

Furthermore, changes in precipitation patterns can amplify water stress on ecosystems, with detrimental consequences for plant and animal species. Ecosystems that rely on stable, seasonal precipitation for breeding, migration, or seed distribution, such as wetlands or arctic habitats, may be disproportionately impacted (IPCC, 2014). Consequently, these alterations in precipitation patterns can potentially drive shifts in species composition, disrupt ecological communities, and increase the risk of species extinctions (Parmesan and Yohe, 2003).

**Societal impacts:** Changes in precipitation patterns pose significant challenges to human societies, including economic, social, and humanitarian consequences. Altered precipitation poses risks to water supplies, agriculture, and food security. Diminished water availability in drought-prone areas hampers crop production, leading to reduced harvests, price fluctuations, and potential food crises (Milly et al., 2005). Conversely, excessive precipitation events can overwhelm drainage systems, causing floods that damage infrastructure, homes, and disrupt economic activities (IPCC, 2012).

Additionally, changes in precipitation patterns affect freshwater availability, putting stress on water resources and threatening human health. Shifts in precipitation can modify the distribution and quality of freshwater, potentially escalating the transmission

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of water-borne diseases and undermining sanitation systems (Haines et al., 2006). Vulnerable communities in developing countries are particularly susceptible to these changes, risking increased social inequalities and exacerbating existing hardships (IPCC, 2014).

One of the most concerning consequences of climate change is the rising sea levels and the increasing acidity of our oceans. These interconnected phenomena serve as unmistakable evidence of the ongoing changes in our climate system. In this review, we will explore the implications of rising sea levels and ocean acidification and their significant contribution to the larger body of evidence supporting climate change. Multiple reputable scientific studies will be referenced to substantiate these claims.

**Rising Sea Levels:** As global temperatures continue to rise due to increased greenhouse gas emissions, the melting of ice caps and glaciers contributes to the rise in sea levels. The Intergovernmental Panel on Climate Change (IPCC) reports that sea levels have risen by approximately 0.2 meters since the late 19th century, with a noticeable acceleration in the rate of rise since the mid-20th century (IPCC, 2019). This has resulted in an increased frequency and severity of coastal flooding events, threatening coastal communities, infrastructure, and ecosystems (Nicholls et al., 2019).

One of the primary contributors to rising sea levels is the expansion of seawater as it warms. Warmer water occupies more space, leading to a volume increase in the ocean basins. Additionally, the influx of freshwater from melting ice and glaciers further adds to the volume of water in the oceans (IPCC, 2019). These factors combined have dire consequences, with projections indicating a potential sea-level rise of one meter or more by the end of the century (Nicholls et al., 2019). This would result in the displacement of millions of people and increased vulnerability of coastal regions to extreme weather events (Nicholls et al., 2019).

**Ocean Acidification:** Ocean acidification, caused by the absorption of excess carbon dioxide (CO<sub>2</sub>) from the atmosphere, poses a significant threat to marine ecosystems. As CO<sub>2</sub> dissolves in seawater, it forms carbonic acid, leading to a decrease in ocean pH. The IPCC states that the pH of surface seawater has already decreased by around 0.1 units since the beginning of the Industrial Revolution, signifying a 25% increase in acidity (IPCC, 2019). Such acidification has profound impacts on marine life, particularly organisms that rely on calcium carbonate to build their shells or skeletons, such as corals, shellfish, and marine plankton (Doney et al., 2012).

Studies have shown that higher levels of CO<sub>2</sub> and increased acidity negatively affect the growth, development, and survival of these calcifying organisms (Doney et al., 2012). This disruption has a ripple effect throughout the marine food web, potentially causing cascading impacts on species dependent on these organisms as a food source. Such disruptions can also lead to significant economic losses, particularly in industries reliant on shellfish farming and coral reef tourism.

Climate change is having significant impacts on glaciers and polar ice caps around the world. The rise in global temperatures is causing these icy regions to melt at an alarming rate, leading to rising sea levels and other environmental consequences. One of the most noticeable impacts of climate change on glaciers and polar ice caps is the rapid retreat and thinning of ice. Studies have shown that glaciers are losing mass at an accelerated rate, with some glaciers disappearing entirely. The Greenland Ice Sheet, for example, has been losing an average of 286 billion tons of ice per year between 1993 and 2016 (Shepherd et al., 2018). This rapid melting is contributing to rising sea levels, which pose a threat to coastal communities around the world.

In addition to melting, climate change is also causing changes in the structure and stability of glaciers and ice caps. Warmer temperatures are leading to increased fracturing and calving of ice, making these icy regions more vulnerable to collapse. This can have cascading effects on the surrounding ecosystems, as well as on the global climate system. The impacts of climate change on glaciers and polar ice caps are not just limited to the physical environment. These icy regions are home to a diverse range of plant and animal species, many of which are already facing extinction due to the changing climate. The loss of ice habitats can have devastating consequences for these species, as well as for the indigenous communities that rely on them for their livelihoods.

Paleoclimate data provides crucial evidence in understanding past climate variations and the impacts of climate change. By analyzing various proxies and indicators preserved in natural archives, such as ice cores, tree rings, sediment layers, and fossil records, researchers can reconstruct past climates and assess the drivers of climate change over long timescales.

1. Ice core records have been instrumental in understanding past atmospheric conditions. For example, studies of Antarctic ice cores have revealed the relationship between greenhouse gas concentrations and global temperatures over hundreds of thousands of years (Petit et al., 1999).
2. Tree ring records offer insights into past climate variability and can help reconstruct temperature and precipitation patterns over centuries (Briffa et al., 1998). These records provide valuable information on regional climate changes and long-term trends.

3. Sediment cores from ocean floors contain valuable information about past climate conditions, including sea surface temperatures, ocean circulation patterns, and carbon cycling (Lisiecki & Raymo, 2005). These records help researchers understand the complex interactions within the Earth's climate system.
4. Fossil records provide evidence of past climate conditions and the responses of plant and animal species to environmental changes. By studying fossilized remains, scientists can infer past temperatures, precipitation levels, and ecosystem dynamics (Williams et al., 2004).
5. Pollen analysis from sediment cores can reveal changes in vegetation patterns and climate conditions over time. By studying pollen assemblages, researchers can reconstruct past landscapes and infer past climate variations (Goodluck & Joseph, 2024).
6. Oxygen isotope ratios in ice cores and marine sediments can provide insights into past temperature variations and ice volume changes. By analyzing these isotopic signatures, scientists can reconstruct past climate conditions and understand the mechanisms driving climate change (Rohling et al., 2009).
7. Radiocarbon dating techniques allow researchers to accurately date organic materials and reconstruct past climate events. By dating various samples from natural archives, scientists can create precise chronologies of past climate changes and their impacts (Hughen et al., 2004).

Climate change is a pressing global issue that requires urgent action to mitigate its impacts and build resilience. Understanding its historical context is crucial for implementing policies and strategies for a sustainable future. Human-induced factors like greenhouse gas emissions, land-use change, and industrial processes significantly contribute to climate change. Recognizing the role of feedback loops and tipping points underscores the urgency to mitigate climate change. Global temperature changes, precipitation patterns, glaciers, polar ice caps, and rising sea levels are all evidence of climate change. Paleoclimate data is essential for understanding long-term trends and drivers of climate change, while rising sea levels and ocean acidification are crucial evidence of climate change's impacts on Earth's ecosystems. Urgent actions are needed to reduce greenhouse gas emissions and protect vulnerable communities and marine ecosystems.

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