SAMPLE

Earth's Dynamic Systems: Climate vs Weather

Understanding the Difference

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Present-day climate change includes both global warming—the ongoing increase in global average temperature—and its wider effects on Earth's climate system. In a broader sense, climate change also includes previous long-term changes to Earth's climate. The modern-day rise in global temperatures is driven by human activities, especially fossil fuel (coal, oil and natural gas) burning since the Industrial Revolution. Fossil fuel use, deforestation, and some agricultural and industrial practices release greenhouse gases.

These gases absorb some of the heat that the Earth radiates after it warms from sunlight, warming the lower atmosphere. Earth's atmosphere now has roughly 50% more carbon dioxide, the main gas driving global warming, than it did at the end of the pre-industrial era, reaching levels not seen for millions of years. Climate change has an increasingly large impact on the environment. Heat waves and wildfires are becoming more common.

Amplified warming in the Arctic has contributed to thawing permafrost, retreat of glaciers and sea ice decline. Higher temperatures are also causing more intense storms, droughts, and other weather extremes. Rapid environmental change in mountains, coral reefs, and the Arctic is forcing many species to relocate or become extinct. Even if efforts to minimize future warming are successful, some effects will continue for centuries. These include ocean heating, ocean acidification and sea level rise.

Climate change threatens people with increased flooding, extreme heat, increased food and water scarcity, more disease, and economic loss. Human migration and conflict can also be a result. The World Health Organization calls climate change one of the biggest threats to global health in the 21st century. Societies and ecosystems will experience more severe risks without action to limit warming.

Chapter 1: The Discovery of Climate vs Weather

Additional warming will increase these impacts and can trigger tipping points, such as melting all of the Greenland ice sheet. Under the 2015 Paris Agreement, nations collectively agreed to keep warming "well under 2 °C". However, with pledges made under the Agreement, global warming would still reach about 2.8 °C (5.0 °F) by the end of the century. There is widespread support for climate action worldwide, and most countries aim to stop emitting carbon dioxide.

Fossil fuels can be phased out by ending their subsidies, conserving energy and switching to energy sources that do not produce significant carbon pollution. These energy sources include wind, solar, hydro, and nuclear power. Cleanly generated electricity can replace fossil fuels for powering transportation, heating buildings, and running industrial processes. Carbon can also be removed from the atmosphere, for instance by increasing forest cover and farming with methods that store carbon in soil.

Before the 1980s, it was unclear whether the warming effect of increased greenhouse gases was stronger than the cooling effect of airborne particulates in air pollution. Scientists used the term inadvertent climate modification to refer to human impacts on the climate at this time. In the 1980s, the terms global warming and climate change became more common, often being used interchangeably.

Scientifically, global warming refers only to increased global average surface temperature, while climate change describes both global warming and its effects on Earth's climate system, such as precipitation changes. Climate change can also be used more broadly to include changes to the climate that have happened throughout Earth's history as result of natural processes. The term anthropogenic climate change is sometimes used to describe climate change resulting from human activities.

Global warming—used as early as 1975—became the more popular term after NASA climate scientist James Hansen used it in his 1988 testimony in the U.S. Senate. Since the 2000s, usage of climate change has increased. Various scientists, politicians and media may use the terms climate crisis or climate emergency to talk about climate change, and may use the term global heating instead of global warming. Over the last few million years the climate cycled through ice ages.

One of the hotter periods was the Last Interglacial, around 125,000 years ago,

where temperatures were between 0.5 °C and 1.5 °C warmer than before the start of global warming. This period saw sea levels 5 to 10 metres higher than today. The most recent glacial maximum 20,000 years ago was some 5-7 °C colder. This period has sea levels that were over 125 metres (410 ft) lower than today. Temperatures stabilized in the current interglacial period beginning 11,700 years ago.

This period also saw the start of agriculture. Historical patterns of warming and cooling, like the Medieval Warm Period and the Little Ice Age, did not occur at the same time across different regions. Temperatures may have reached as high as those of the late 20th century in a limited set of regions. Climate information for that period comes from climate proxies, such as trees and ice cores. Around 1850 thermometer records began to provide global coverage.

Between the 18th century and 1970 there was little net warming, as the warming impact of greenhouse gas emissions was offset by cooling from sulfur dioxide emissions. Sulfur dioxide causes acid rain, but it also produces sulfate aerosols in the atmosphere, which reflect sunlight and cause global dimming. After 1970, the increasing accumulation of greenhouse gases and controls on sulfur pollution led to a marked increase in temperature. Ongoing changes in climate have had no precedent for several thousand years.

Multiple datasets all show worldwide increases in surface temperature, at a rate of around 0.2 °C per decade. The 2016-2025 decade warmed to an average 1.26 °C [1.13-1.36 °C] compared to the pre-industrial baseline (1850-1900). Not every single year was warmer than the last: internal climate variability processes can make any year 0.2 °C warmer or colder than the average.

From 1998 to 2013, negative phases of two such processes, Pacific decadal oscillation (PDO) and Atlantic multidecadal oscillation (AMO) caused a short slower period of warming called the "global warming hiatus". After the "hiatus", the opposite occurred, with 2024 well above the recent average at more than +1.5 °C. This is why the temperature change is defined in terms of a 20-year average, which reduces the noise of hot and cold years and decadal climate patterns, and detects the long-term signal.

A wide range of other observations reinforce the evidence of warming. The upper atmosphere is cooling, because greenhouse gases are trapping heat near the Earth's surface, and so less heat is radiating into space. Warming reduces average snow cover and forces the retreat of glaciers. At the same time, warming also causes greater evaporation from the oceans, leading to more atmospheric humidity, and more and heavier precipitation.

Plants are flowering earlier in spring, and thousands of animal species have been permanently moving to cooler areas.

Different regions of the world warm at different rates. The pattern is independent of where greenhouse gases are emitted, because the gases persist long enough to diffuse across the planet. Since the pre-industrial period, the average surface temperature over land regions has increased almost twice as fast as the global average surface temperature. This is because oceans lose more heat by evaporation and oceans can store a lot of heat.

The instruments, as so often, came before the science they made possible.

Sealed liquid thermometers, made reliable in the 1650s by the Accademia del Cimento in Florence, gave temperature a number; Torricelli's mercury barometer of 1643 showed that the air itself had weight, and that its weight changed with the weather. From these two instruments grew a network habit that defines meteorology to this day: people writing down readings, day after day, in the same place. By the 1840s the electric telegraph let observers compare notes faster than the weather could travel, and the first storm warnings followed within a generation. Every modern dataset of climate is built on that patient, repetitive habit of measurement, which is why the instrumental record is short and precious, and why proxies must carry the story further back.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.