Strand 1 Background Article
Increased Greenhouse Gases Contribute to Climate Change

SECTION TOPICS

- Definition of climate (and the difference between climate and weather)
- Evidence that climate change is happening
- Why climate change is concerning
- Why climate change is occurring

CLIMATE CHANGE

On a cold wintry night, a stranded airline passenger in the snowed-in airport complains, “If climate change is happening, how do you explain all this snow?” The passenger makes a common error, confusing the related concepts of weather and climate. Weather describes the particular state of the atmosphere, such as temperature, cloudiness, precipitation, or wind, for a short period of time. Weather fluctuates seasonally, daily, even by the minute. Climate, in contrast, is the state of the atmosphere over a relatively long period of time, described by averages and trends. When scientists refer to climate change, they are describing changes that are seen in averages over long periods of time. The average annual snowpack in New England, for example, has fallen over the past century. The weather in New England may still include snow and cold temperatures on any given winter day, but the climate, as described by data such as the number of cold days per winter or the average yearly snowpack, shows clear signs of warming and change.

The average warming of Earth’s climate over the past century is unequivocal. Evidence includes increases in global average air and ocean temperatures, extensive melting of mountain glaciers and snow cover, and a rising average sea level. Rising temperatures allow more moisture to be held in the atmosphere, leading to changes in precipitation patterns that have been seen around the globe. Extreme weather events, such as drought, heat waves, and intense storms, have also become more frequent. Data from balloon-borne, ground-level, and underwater instruments, coupled with information from satellites, all support the conclusion that global temperatures are rising.

Average global temperatures have increased 1.2 to 1.4 degrees Fahrenheit over the past century. This change may not be noticeable on an individual day because weather fluctuates so much on a rapid basis. Taken as an average increase over longer periods of time, however, even a temperature change of a single degree has profound effects on human societies. Rising sea levels threaten to flood human population centers in coastal regions. Drought can cause crop failure, though warmer temperatures increases crop productivity in some regions by lengthening the growing season. Reduction in snowpack limits the availability of fresh water for those who rely on meltwater from mountains, an estimated one-sixth of the world’s population. Scientists predict that human societies will, on average, be negatively affected by continuing climate change. Ironically, these changes have been driven by human activity itself. Scientists generally agree that most of the observed increases in temperature over the past century are very likely due to an increase in human-produced greenhouse gases.

SECTION TOPICS

- What greenhouse gases are
- Explanation of the greenhouse effect
- How the greenhouse effect influences climate
- Carbon dioxide as a greenhouse gas
- Methane as a greenhouse gas

GREENHOUSE GASES

Greenhouse gases are gases that trap heat in Earth's atmosphere. These gases can be naturally occurring or human-produced and include water vapor, carbon dioxide, and methane. Such gases are essential to survival on Earth. When the sun radiates energy toward Earth, about 26 percent of the energy gets scattered and reflected back into space by clouds and the atmosphere. Earth's surface absorbs most of the solar energy that gets through, then converts it to heat energy, releasing some as infrared radiation. In total, about 21 percent of the solar energy that hits the top of the atmosphere is absorbed by Earth's surface and reradiated as infrared energy. Greenhouse gases in the atmosphere act like a blanket, trapping some of this infrared radiation and warming Earth and its atmosphere, a process known as the greenhouse effect. Without greenhouse gases, the average temperature would be 60ºF cooler, and life on Earth would look very different than it does today.

Scientists measure greenhouse gases in a variety of ways. To determine concentrations of carbon dioxide in the atmosphere from the past, climatologists gather data from air pockets trapped in ice cores, carbon-isotope signatures in tree rings, and even air trapped in human artifacts like old, airtight wine bottles and sealed brass buttons from old uniforms. More modern readings come from pumping air through a carbon dioxide analyzer, a device that measures how much infrared radiation is absorbed in a sample of air. Since carbon dioxide absorbs some infrared radiation, higher absorption means higher concentrations of carbon dioxide. The concentration of carbon dioxide in the air is then represented in units of parts per million (ppm)—a reading of 372 ppm means that out of a million molecules of dry air, 372 of them are carbon dioxide molecules.

Using a wide variety of measurements from around the globe, scientists have determined that global greenhouse gas emissions increased by 70 percent from 1970 to 2004, and these changes have caused the temperature of Earth to increase, altering climate worldwide. By far the largest component of these emissions is carbon dioxide, which has exponentially increased in the atmosphere since the preindustrial age. Most of this increase comes from the burning of fossil fuels, which releases carbon dioxide into the atmosphere. In the United States, burning coal, petroleum, and natural gas provides us with electricity, power for our cars, and the energy to run factories; but the byproducts of these activities include about 6 billion metric tons of carbon dioxide released into the atmosphere. Rising levels of carbon dioxide have most likely been the main contributor to global temperature increases over the past century.

Methane is another significant carbon-based greenhouse gas that has increased in the atmosphere due to human activities. Some methane comes from natural processes, such as bacterial decay in wetlands and digestion in termites, but more than 60 percent of the methane emitted globally is from human sources and activities, such as landfills, natural gas and petroleum systems, agricultural activities, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial process. Agriculture accounts for a substantial portion of this methane, as ruminants—animals like cows, goats, sheep, and camels—produce methane as part of their digestive process. The belching and flatulent activity of livestock is the foremost contributor of methane in the United States. Decaying landfills and natural gas and petroleum systems also produce significant amounts of methane. Although more carbon dioxide is emitted each year, methane is still a powerful contributor to the greenhouse effect because it traps more than 20 times as much heat in the atmosphere as carbon dioxide does. Scientists generally agree that methane production from human sources and activities has been a significant contributor to the warming temperatures of the last century.

SECTION TOPICS

- Forests
    - Absorption of carbon dioxide
    - Effects of deforestation
- Dams
- Example of the Amazon

THE EFFECT OF FORESTS AND DAMS ON GREENHOUSE GASES

Besides direct production of greenhouse gases, human activities can have indirect, yet substantial effects on climate change. For example, land-use decisions interact with the climate. Only about half of the carbon dioxide that humans emit into the atmosphere stays in the atmosphere. The other half is absorbed by oceans via air-sea gas exchange and on land by plants as they grow. Trees act as a carbon sink, collecting an enormous amount of carbon dioxide from the atmosphere and storing carbon in their leaves, trunks, and roots. Forests in the United States, for example, offset an estimated 20 percent to 46 percent of the country's annual greenhouse gas emissions. Deforestation removes trees as a carbon sink, and if the cleared vegetation is burned or left to decay, the stored carbon returns to the atmosphere as carbon dioxide, a greenhouse gas. Loss of forests contributes 25 percent to 30 percent of the global greenhouse gas emissions each year.

Dam and reservoir construction also has a significant impact on climate change. When dams are built, forests are cleared to make way for roads, removing trees that could be absorbing carbon dioxide from the atmosphere. Even more significant, forests are drowned by the resulting reservoirs. These vast lakes produce methane from the dead leaves and other biomass that settles to the bottom. Scientists and politicians are currently debating the impact of dams and reservoirs on climate change. Some argue that hydropower as a renewable resource is preferable to burning fossil fuels to produce electricity. Critics contend that dams and reservoirs may actually be more damaging to the climate, citing recent studies of a new dam in Brazil, which, in its first three years of operation, had four times the greenhouse gas output of a coal-powered plant producing the same amount of power. This ongoing debate is a contentious one, particularly since about 85 percent of Brazil's electricity comes from hydropower.

The Amazon rain forest is the largest tropical forest in world, and as such is a giant carbon pool, a vast resource for storing greenhouse gases that collect in the atmosphere. It is also home to many dam and reservoir projects and is experiencing rapid deforestation each year, partly due to the dam and reservoir projects but predominantly due to ranchers clearing land for cattle. Brazil lost an estimated 2,705 square miles of Amazonian forest in 2009, an area the size of half the state of Connecticut. Still, because the country has made remarkable efforts to reduce deforestation in efforts to combat climate change, these losses, while significant, were the lowest in Brazil in 20 years.

SECTION TOPICS

- What climate models are
- How climate models work
- What climate models can tell us

PREDICTING THE FUTURE WITH CLIMATE MODELS

What does the future hold for climate change? Scientists use climate models to predict how temperatures, precipitation patterns, and extreme weather events will change in the future. Climate models use the principles of physics, fluid motion, and chemistry in developing mathematical equations to describe climate systems. Scientists test these models by seeing how well they can describe recent climate patterns as well as climate changes of the past. They then use the models to test different scenarios based on greenhouse gas emissions in the future, estimating how changes in human practices might affect climate. Based on these models, scientists try to predict future temperatures, precipitation patterns, changes in sea level, and chances of extreme weather events.

Climate science is an inherently complex field, integrating atmospheric science, biology, geology, hydrology, paleo-climatology, astronomy, and more. With so many interacting variables to consider and incomplete observations of the global carbon cycle, scientists' predictions are inevitably imperfect. Still, an overwhelming preponderance of evidence suggests that climate is changing at an unprecedented level. Climate models indicate that without changes to human activities, global surface temperatures will rise an estimated 3 to 7 degrees by the end of the century. Accompanying such warming will be increased drought in some regions, increased precipitation in others, and a significant rise in sea level that will particularly affect coastal communities. In fact, even if greenhouse gas concentrations stay at the level they were in 2000, scientists still predict that warming and sea level rise will occur, due to feedback loops in climate systems that have already begun to warm. In a feedback loop, warmer temperatures change an environment in ways that create even more heat. For example, in the Arctic, melting sea ice means there is less white surface to reflect the sun's energy, replaced instead with darker seas, rocks, soil, and vegetation that absorb more of the sun's energy. This increases the temperature, melting even more sea ice, thereby perpetuating the cycle.

One thing that climate models cannot do is predict how government policies and human behavior will change over the next century, altering the amount of greenhouse gas emissions we put into the atmosphere. Current trends suggest that greenhouse gas concentrations in the atmosphere will continue to increase as standards of living and fossil fuel use rise around the world. Only dramatic changes to human policies and practices will alter this course.

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