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A STUDY ON GLOBAL WARMING AND ITS CONSEQUENCES

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ABSTRACT

Global warming is the unusually rapid increase in Earth's average surface temperature over the past century primarily due to the greenhouse gases released as people burn fossil fuels. The global average surface temperature rose 0.6 to 0.9 degrees Celsius (1.1 to 1.6° F) between 1906 and 2005, and the *rate* of temperature increase has nearly doubled in the last 50 years. Temperatures are certain to go up further.

Earth's temperature begins with the Sun. Roughly 30 percent of incoming sunlight is reflected back into space by bright surfaces like clouds and ice. Of the remaining 70 percent, most is absorbed by the land and ocean, and the rest is absorbed by the atmosphere. The absorbed solar energy heats our planet. As the rocks, the air, and the seas warm, they radiate "heat" energy (thermal infrared radiation). From the surface, this energy travels into the atmosphere where much of it is absorbed by water vapor and long-lived greenhouse gases such as carbon dioxide and methane.When they absorb the energy radiating from Earth's surface, microscopic water or greenhouse gas molecules turn into tiny heaters— like the bricks in a fireplace, they radiate heat even after the fire goes out. They radiate in all directions. The energy that radiates back toward Earth heats both the lower atmosphere and the surface, enhancing the heating they get from direct sunlight. This absorption and radiation of heat by the atmosphere—the natural greenhouse effect—is beneficial for life on Earth. If there were no greenhouse effect, the Earth's average surface temperature would be a very chilly -18°C (0°F) instead of the comfortable 15°C (59°F) that it is today.

KEYWORDS:

Global, Warming, Earth

INTRODUCTION

The atmosphere today contains more greenhouse gas molecules, so more of the infrared energy emitted by the surface ends up being absorbed by the atmosphere. Since some of the extra energy from a warmer atmosphere radiates back down to the surface, Earth's surface temperature rises. By increasing the concentration of greenhouse gases, we are making Earth's atmosphere a more efficient greenhouse.

Using this ancient evidence, scientists have built a record of Earth's past climates, or "paleoclimates." The paleoclimate record combined with global models shows past ice ages as well as periods even warmer than today. But the paleoclimate record also reveals that the current climatic warming is occurring *much more rapidly* than past warming events.

As the Earth moved out of ice ages over the past million years, the global temperature rose a total of 4 to 7 degrees Celsius over about 5,000 years. In the past century alone, the temperature has climbed 0.7 degrees Celsius, roughly ten times faster than the average rate of ice-age-recovery warming.

Models predict that Earth will warm between 2 and 6 degrees Celsius in the next century. When global warming has happened at various times in the past two million years, it has taken the planet about 5,000 years to warm 5 degrees. The predicted rate of warming for the next century is at least 20 times faster. This rate of change is extremely unusual.

In Earth's history before the Industrial Revolution, Earth's climate changed due to natural causes not related to human activity. Most often, global climate has changed because of variations in sunlight. Tiny wobbles in Earth's orbit altered when and where sunlight falls on Earth's surface. Variations in the Sun itself have alternately increased and decreased the amount of solar energy reaching Earth. Volcanic eruptions have generated particles that reflect sunlight, brightening the planet and cooling the climate. Volcanic activity has also, in the deep past, increased greenhouse gases over millions of years, contributing to episodes of global warming.

NASA satellites record a host of vital signs including atmospheric aerosols (particles from both natural sources and human activities, such as factories, fires, deserts, and erupting volcanoes), atmospheric gases (including greenhouse gases), energy radiated from Earth's surface and the Sun, ocean surface temperature changes, global sea level, the extent of ice sheets, glaciers and sea ice, plant growth, rainfall, cloud structure, and more.

On the ground, many agencies and nations support networks of weather and climate-monitoring stations that maintain temperature, rainfall, and snow depth records, and buoys that measure surface water and deep ocean temperatures. Taken together, these measurements provide an ever-improving record of both natural events and human activity for the past 150 years.

Scientists integrate these measurements into climate models to recreate temperatures recorded over the past 150 years. Climate model simulations that consider only natural solar variability and volcanic aerosols since 1750—omitting observed increases in greenhouse gases—are able to fit the observations of global temperatures only up until about 1950. After that point, the decadal trend in global surface warming cannot be explained without including the contribution of the greenhouse gases added by humans.

Though people have had the largest impact on our climate since 1950, natural changes to Earth's climate have also occurred in recent times. For example, two major volcanic eruptions, El Chichon in 1982 and Pinatubo in 1991, pumped sulfur dioxide gas high into the atmosphere. The gas was converted into tiny particles that lingered for more than a year, reflecting sunlight and shading Earth's surface. Temperatures across the globe dipped for two to three years.

Although Earth's temperature fluctuates naturally, human influence on climate has eclipsed the magnitude of natural temperature changes over the past 120 years. Natural influences on temperature—El Niño, solar variability, and volcanic aerosols—have varied approximately plus and minus 0.2° C (0.4° F), (averaging to about zero), while human influences have contributed roughly 0.8° C (1° F) of warming since 1889. (Graphs adapted from Lean et al., 2008.)

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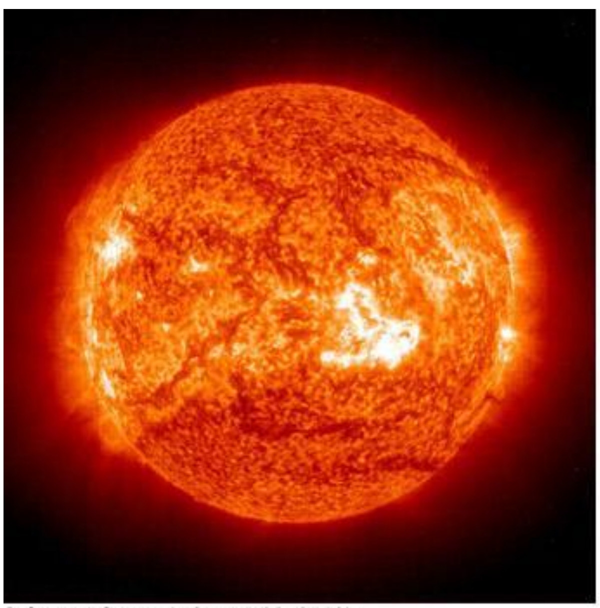
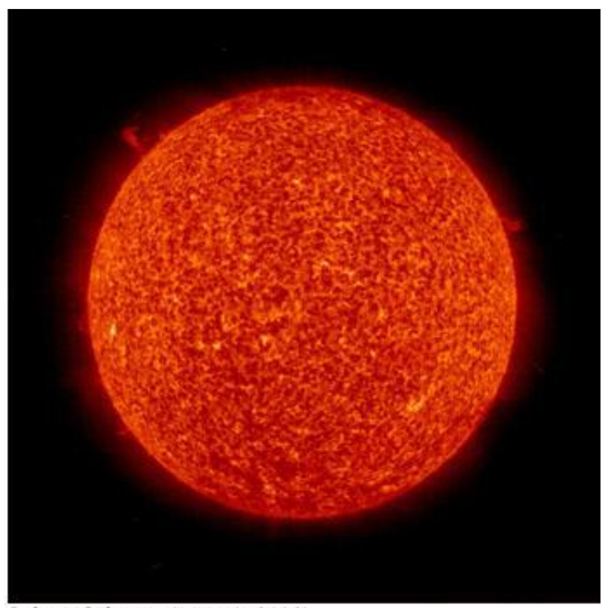
Although volcanoes are active around the world, and continue to emit carbon dioxide as they did in the past, the amount of carbon dioxide they release is extremely small compared to human emissions. On average, volcanoes emit between 130 and 230 million tonnes of carbon dioxide per year. By burning fossil fuels, people release in excess of 100 times more, about 26 billion tonnes of carbon dioxide, into the atmosphere every year (as of 2005). As a result, human activity overshadows any contribution volcanoes may have made to recent global warming.

Changes in the brightness of the Sun can influence the climate from decade to decade, but an increase in solar output falls short as an explanation for recent warming. NASA satellites have been measuring the Sun's output since 1978. The total energy the Sun radiates varies over an 11-year cycle. During solar maxima, solar energy is approximately 0.1 percent higher on average than it is during solar minima.



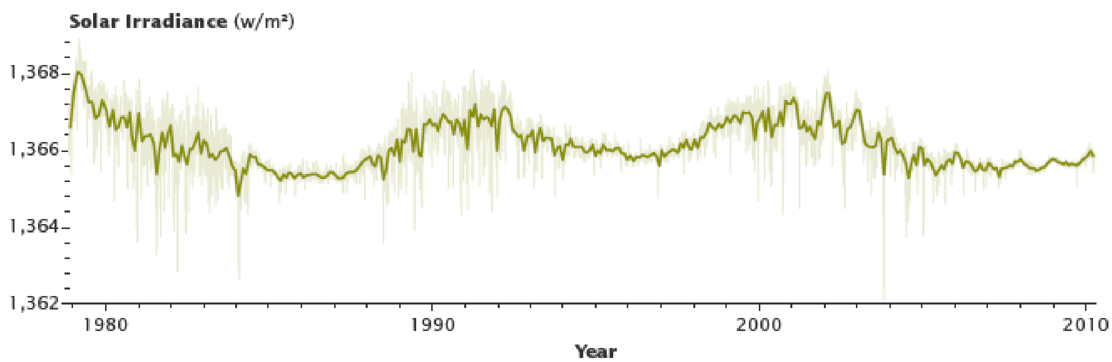
Solar Maximum (February 22, 2002)



Solar Minimum (May 10, 2008)

The transparent halo known as the solar corona changes between solar maximum (left) and solar minimum (right). (NASA Extreme Ultraviolet Telescope images from the SOHO Data Archive.)

Each cycle exhibits subtle differences in intensity and duration. As of early 2010, the solar brightness since 2005 has been slightly lower, not higher, than it was during the previous 11-year minimum in solar activity, which occurred in the late 1990s. This implies that the Sun's impact between 2005 and 2010 might have been to slightly decrease the warming that greenhouse emissions alone would have caused.



Satellite measurements of daily (light line) and monthly average (dark line) total solar irradiance since 1979 have not detected a clear long-term trend. (NASA graph by Robert Simmon, based on data from the ACRIM Science Team.)

Scientists theorize that there may be a multi-decadal trend in solar output, though if one exists, it has not been observed as yet. Even if the Sun were getting brighter, however, the pattern of warming observed on Earth since 1950 does not match the type of warming the Sun alone would cause. When the Sun's energy is at its peak (solar maxima), temperatures in both the lower atmosphere (troposphere) *and* the upper atmosphere (stratosphere) become warmer. Instead, observations show the pattern expected from greenhouse gas effects: Earth's surface and troposphere have warmed, but the stratosphere has cooled.

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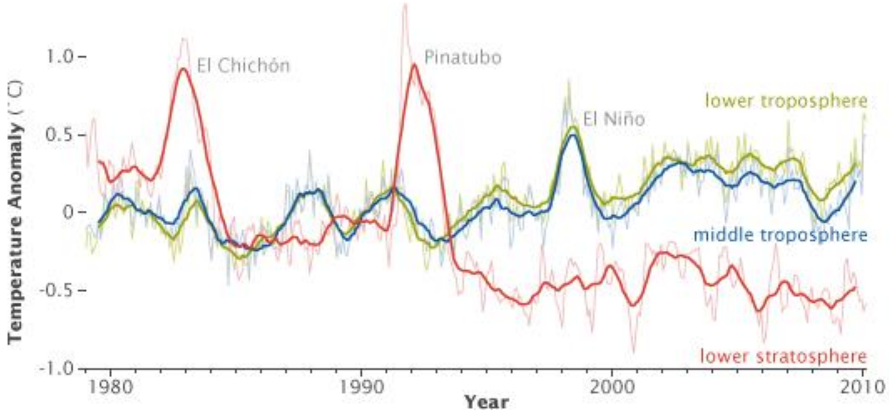

Satellite measurements show warming in the troposphere (lower atmosphere, green line) but cooling in the stratosphere (upper atmosphere, red line). This vertical pattern is consistent with global warming due to increasing greenhouse gases, but inconsistent with warming from natural causes. (Graph by Robert Simmon, based on data from Remote Sensing Systems, sponsored by the NOAA Climate and Global Change Program.)

The stratosphere gets warmer during solar maxima because the ozone layer absorbs ultraviolet light; more ultraviolet light during solar maxima means warmer temperatures. Ozone depletion explains the biggest part of the cooling of the stratosphere over recent decades, but it can't account for all of it. Increased concentrations of carbon dioxide in the troposphere and stratosphere together contribute to cooling in the stratosphere.

Clouds emit thermal infrared (heat) radiation in proportion to their temperature, which is related to altitude. This image shows the Western Hemisphere in the thermal infrared. Warm ocean and land surface areas are white and light gray; cool, low-level clouds are medium gray; and cold, high-altitude clouds are dark gray and black. (NASA image courtesy GOES Project Science.)

High cold clouds, however, form in a part of the atmosphere where energy-absorbing water vapor is scarce. These clouds trap (absorb) energy coming from the lower atmosphere, and emit little energy to space because of their frigid temperatures. In a world with high clouds, a significant amount of energy that would otherwise escape to space is captured in the atmosphere. As a result, global temperatures are higher than in a world without high clouds.

If warmer temperatures result in a greater amount of high clouds, then less infrared energy will be emitted to space. In other words, more high clouds would enhance the greenhouse effect, reducing the Earth's capability to cool and causing temperatures to warm.

Scientists aren't entirely sure where and to what degree clouds will end up amplifying or moderating warming, but **most climate models predict a slight overall positive feedback or amplification of warming due to a reduction in low cloud cover.** A recent observational study found that fewer low, dense clouds formed over a region in the Pacific Ocean when temperatures warmed, suggesting a positive cloud feedback in this region as the models predicted. Such direct observational evidence is limited, however, and clouds remain the biggest source of uncertainty--apart from human choices to control greenhouse gases—in predicting how much the climate will change.

Scientists predict the range of likely temperature increase by running many possible future scenarios through climate models. Although some of the uncertainty in climate forecasts comes from imperfect knowledge of climate feedbacks, the most significant source of uncertainty in these predictions is that scientists don't know what choices people will make to control greenhouse gas emissions.

The higher estimates are made on the assumption that the entire world will continue using more and more fossil fuel per capita, a scenario scientists call "business-as-usual." More modest estimates come from scenarios in which environmentally friendly technologies such as fuel cells, solar panels, and wind energy replace much of today's fossil fuel combustion.

It takes decades to centuries for Earth to fully react to increases in greenhouse gases. Carbon dioxide, among other greenhouse gases, will remain in the atmosphere long after emissions are reduced, contributing to continuing warming. In addition, as Earth has warmed, much of the excess energy has gone into heating the upper layers of the ocean. Like a hot water bottle on a cold night, the heated ocean will continue warming the lower atmosphere well after greenhouse gases have stopped increasing.

These considerations mean that people won't immediately see the impact of reduced greenhouse gas emissions. **Even if greenhouse gas concentrations stabilized today, the planet would continue to warm by about 0.6°C over the next century** because of greenhouses gases already in the atmosphere.

More importantly, perhaps, global warming is already putting pressure on ecosystems, the plants and animals that co-exist in a particular climate zone, both on land and in the ocean. Warmer temperatures have already shifted the growing season in many parts of the globe. The growing season in parts of the Northern Hemisphere became two weeks longer in the second half of the 20th century. Spring is coming earlier in both hemispheres.

This change in the growing season affects the broader ecosystem. Migrating animals have to start seeking food sources earlier. The shift in seasons may already be causing the lifecycles of pollinators, like bees, to be out of synch with flowering plants and trees. This mismatch can limit the ability of both pollinators and plants to survive and reproduce, which would reduce food availability throughout the food chain.

Warmer temperatures also extend the growing season. This means that plants need more water to keep growing throughout the season or they will dry out, increasing the risk of failed crops and wildfires. Once the growing season ends, shorter, milder winters fail to kill dormant insects, increasing the risk of large, damaging infestations in subsequent seasons.

In some ecosystems, maximum daily temperatures might climb beyond the tolerance of indigenous plant or animal. To survive the extreme temperatures, both marine and land-based plants and animals have started to migrate towards the poles. Those species, and in some cases, entire ecosystems, that cannot quickly migrate or adapt, face extinction. The IPCC estimates

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that 20-30 percent of plant and animal species will be at risk of extinction if temperatures climb more than 1.5° to 2.5°C.

CONCLUSION

The same small change in temperature, however, would reduce food production at lower latitudes, where many countries already face food shortages. On balance, most research suggests that the negative impacts of a changing climate far outweigh the positive impacts. Current civilization—agriculture and population distribution—has developed based on the current climate. The more the climate changes, and the more rapidly it changes, the greater the cost of adaptation.

Ultimately, global warming will impact life on Earth in many ways, but the extent of the change is largely up to us. Scientists have shown that human emissions of greenhouse gases are pushing global temperatures up, and many aspects of climate are responding to the warming in the way that scientists predicted they would. This offers hope. Since people are causing global warming, people can mitigate global warming, if they act in time.

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