Earth's atmosphere is clearly warmed daily by conduction and by dissociation but not by greenhouse gases

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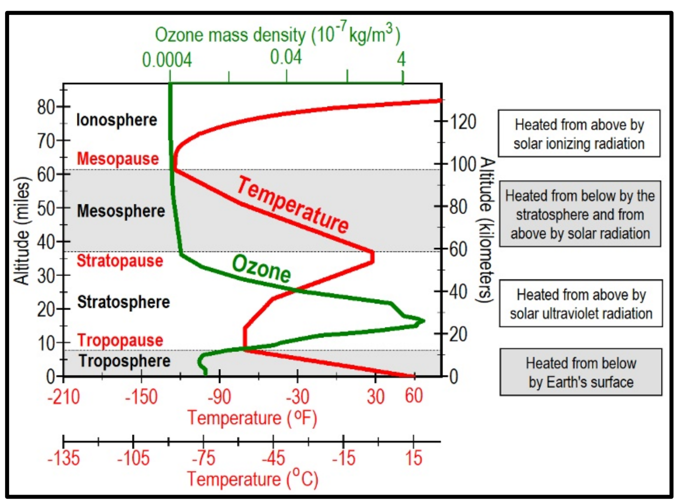
Global average surface temperatures have risen 0.9 degrees Celsius (1.6 degrees Fahrenheit) since 1950. What caused this warming? How much of this warming was caused by humans? Will Earth continue to warm? What actions should we take?

To answer these questions, we need to revisit a number of direct observations of what is physically happening in the world around us. After all, direct observations of Nature, that do not depend on some theory to understand, are the closest things to truth in science.

Warming by conduction in the troposphere is relatively constant at any location year after year: Every day, air touching Earth's sun-heated surface is warmed by conduction just like air above a hot frypan. Warmed air rises into cooler air above because it has lower density. In this way, temperature differences lead to convection of air from hot regions to cooler regions both vertically and from the tropics toward the poles. These convection cells drive weather systems throughout the troposphere, the lowermost layer of Earth's atmosphere. Warming by conduction varies by latitude, season, and by concentrations of clouds, aerosols, smoke, and other particles in the atmosphere, but on average, is relatively constant at any location year after year. Changes over time in solar radiation reaching the top of Earth's atmosphere appear to be less than one percent.

The top of the troposphere, known as the tropopause, is the most important boundary in the atmosphere. The tropopause is the surface between air in the troposphere warmed from below by Earth's sun-heated surface and air in the stratosphere warmed from above by absorbing solar ultraviolet radiation.

The tropopause forms at altitudes up to 18 kilometers (11 miles) in the tropics and mid-latitudes, but only 6 kilometers (4 miles) in polar regions during winter. Annual average global temperatures typically decrease linearly from around 15 ºC (59 ºF) near Earth's surface to minus 51 ºC (-60 ºF) at the tropopause.



Warming by dissociation of oxygen in the stratosphere is even more constant year after year: Above the tropopause, in the stratosphere, temperatures rise approximately 36 degrees to become close to -15 ºC (5 ºF) at the stratopause, the top of the stratosphere at an altitude of 50 to 55 kilometers (31 to 34 miles).

To understand this warming, we need to look at the atomic level, where the atmosphere consists of atoms and molecules of various gases moving at high velocities through space—frequently colliding with each other. Molecules consist of atoms held together by molecular bonds. Molecular bonds are thought to result from electrodynamic forces of attraction between opposite charges and electrodynamic forces of repulsion between same charges. Therefore, these bonds are not rigid. They are observed to oscillate back and forth at frequencies of oscillation measured in trillions of cycles per second (10^{12} cycles per second) and amplitudes of oscillation measured in picometers (10^{-12} meters). The bonds oscillate much like two masses connected by a spring, except at much higher frequencies of oscillation, at much shorter amplitudes of oscillation, and without any friction.

When a molecule of oxygen absorbs ultraviolet-C radiation from Sun in the frequency range of 1237 trillion cycles per second, the bond holding the two atoms of oxygen together breaks—comes apart—is dissociated. The two atoms fly apart at very high velocity, much like the ends of a rubber band when it breaks.

Temperature of a gas is well-known to be proportional to the average kinetic energy of motion through space of all atoms and molecules making up the gas. Kinetic energy of motion is simply defined as one-half the mass of an atom or molecule times its velocity of motion squared. Thus, dissociation converts bond energy holding a molecule together directly, completely, and efficiently into an increase in air temperature. Radiant energy of oscillation is equal to the Planck constant times frequency of oscillation according to the Planck-Einstein relation. Thus, the energy of a frequency of 1237 trillion cycles per second and the energy stored in an oxygen bond is around 5.1 electronvolts.

When two atoms of oxygen collide, they can recombine to form a molecule of oxygen that can then be dissociated again. These cycles make air hotter and hotter as long as sufficient solar ultraviolet-C radiation exists. We observe that essentially all ultraviolet-C radiation has been absorbed by the time sunlight reaches the lower stratosphere. The primary absorption is by molecules of oxygen, making up nearly 21% of all gases in Earth's atmosphere, but trace gases such as water, carbon dioxide, nitrogen oxides, and methane are also dissociated at different energy levels. The higher the frequency causing dissociation, the higher the energy stored in the bond, the higher the velocity of the dissociated pieces, the higher in the atmosphere dissociation typically takes place, and the greater the resulting increase in temperature.

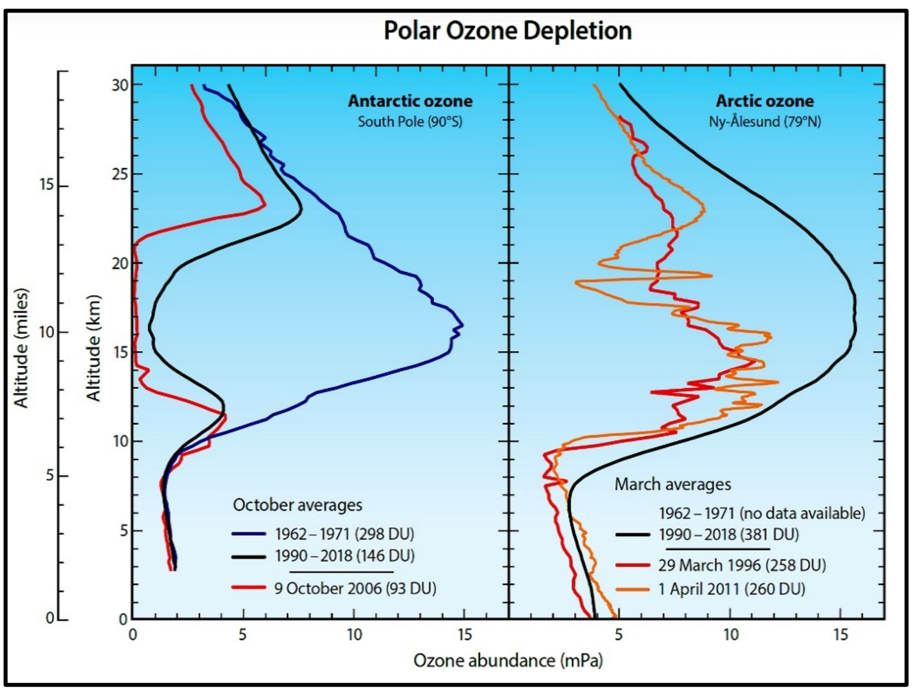
Warming by dissociation of ozone, however, is changing continuously: A molecule of oxygen (O_2) and an atom of oxygen (O) can combine to create a molecule of ozone (O_3). Most ozone forms in the lower stratosphere, creating the ozone layer extending primarily from 15 to 35 kilometers (9.3 to 21.7 miles) above Earth's surface. When ozone absorbs solar ultraviolet-B radiation primarily at frequencies around 967 trillion cycles per second, it is dissociated back into a molecule of oxygen and an atom of oxygen. This dissociation warms the ozone layer.

Repeated formation and dissociation of ozone is observed to occur in the well-known ozone-oxygen cycle as long as solar ultraviolet-B radiation is available. Sun produces about 12% of the ozone layer each day, implying that the average lifetime of a single molecule of ozone is only about 8.3 days. Because of the ozone-oxygen cycle, very small concentrations of ozone, measured in parts per million, maintain higher than normal temperatures in the ozone layer. The thermal energy comes from solar ultraviolet-B radiation with energies around 4 electronvolts.

Ozone concentrations are changing substantially worldwide all the time and especially in winter. Because of dissociation, higher regional concentrations of ozone imply higher regional air temperatures compared to similar latitudes.

Warming by ozone depletion has changed radically since 1970: Life as we know it on Earth is only possible because all frequencies of solar radiation greater than ultraviolet-B and most ultraviolet-B are absorbed by gases in the atmosphere above the tropopause, warming the stratosphere, which includes the ozone layer. Ultraviolet-B is the highest frequency, highest energy, hottest, solar radiation normally reaching Earth's surface, where, with sufficient duration of exposure, it causes sunburn, skin cancer, cataracts, and mutations. If the concentration of ozone in the ozone layer is reduced—depleted—more solar ultraviolet-B radiation than usual is observed to reach the troposphere, cooling the ozone layer and warming Earth.

Solar ultraviolet-B radiation penetrates oceans tens of meters so that very little of this energy absorbed during the day can be lost back into space at night. Oceans cover 71% of Earth. Ocean heat content has been rising constantly since the ozone layer began to be depleted around 1970. That depletion, shown in this figure, was caused by humans manufacturing large volumes of chlorofluorocarbon gases used as spray-can propellants, refrigerants, solvents, and foam-blowing agents. It turns out that these very inert gases are broken down in the stratosphere by ultraviolet radiation, releasing atoms of chlorine. One



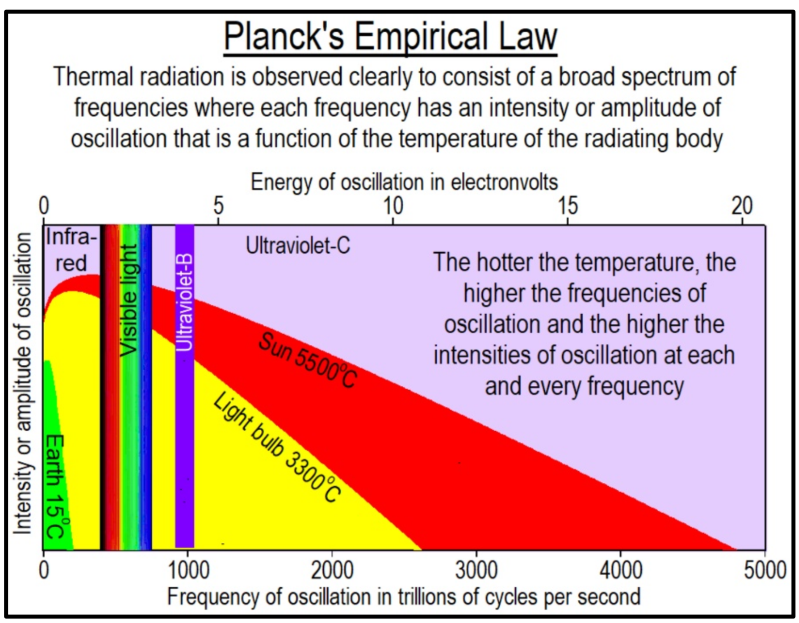
atom of chlorine, under very cold, relatively moist conditions in the lower stratosphere, can destroy up to 100,000 molecules of ozone.

When the United Nations passed the Montreal Protocol in 1987, limiting production of chlorofluorocarbon gases, both ozone depletion and global temperatures stopped increasing by 1998. Humans had caused global warming by manufacturing large volumes of chlorofluorocarbon gases and humans took action that stopped the increase in emissions of chlorofluorocarbon gases, stopping the increase in global warming, completing the most definitive experiment ever done relating changes in atmospheric temperatures to changes in concentrations of atmospheric gases.

Global warming from 2014 to 2016 can be explained by ozone depletion caused by Bárðarbunga volcano in central Iceland, extruding the largest basaltic lava flow since 1783. Basaltic lavas contain ten times more chlorine and bromine than explosive magmas and are much hotter, providing a way to convect these gases rapidly into the lower stratosphere. Throughout Earth history, basaltic lava flows covering hundreds to even millions of square kilometers of land have been contemporaneous with major warming and widespread mass extinctions—the more extensive the lava flows, the greater the warming. The second warmest year on record was 2019 because of the 2018 Lower Puna eruption in Hawaii, which was 41% of the size of the Bárðarbunga eruption.

On land, so called “bad” ozone is a major toxic component of air pollution, formed near Earth’s surface by nitrogen oxides and volatile organic compounds in the presence of heat and sunlight. These oxides and compounds are released in emissions from motor vehicles, industrial facilities, electric power plants, gasoline vapors, and chemical solvents. Any solar ultraviolet-B radiation reaching Earth’s surface would dissociate this ground level ozone, causing local warming of air—a direct explanation for the urban heat island effect. This helps explain why average global warming since 1950 was twice as great in the northern hemisphere as in the southern hemisphere, which contains less than 12% of world population and industry.

Ozone depletion caused by humans and by large basaltic lava flows explains with considerable accuracy most observations of temperature increases and observations of changes of rates of temperature increase throughout Earth history.



In 1900, Max Planck developed empirically an equation that calculates as a function of temperature the observed amplitude of oscillation at each frequency of oscillation existing within a body of matter and within its radiation. What has become known as Planck's empirical law shows that for a body to become warmer, it must absorb radiation from a hotter body that contains greater amplitudes of oscillation at every frequency of oscillation and especially at the highest frequencies. For this reason, Earth is warmed most effectively by absorbing ultraviolet-B radiation, the hottest, most energetic solar radiation reaching Earth's surface.

Warming by greenhouse gases has never been verified by experiment: For 125 years, scientists have assumed that because greenhouse gases are observed to absorb some infrared energy radiated by Earth, they must either warm air or at least slow the rate by which Earth loses heat to space. We now measure in considerable detail that the limited number of frequencies absorbed by greenhouse gases are simply the resonant frequencies of the bonds that hold the gas molecule together. This shows that the energy is absorbed into the bonds.

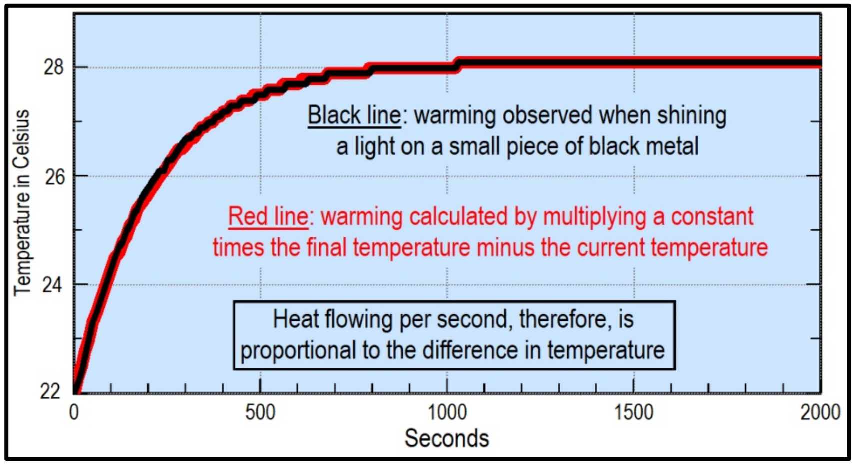
For carbon dioxide, these absorbed frequencies make up less than 16% of the infrared frequencies radiated by Earth—less than 16% of the heat radiated by Earth. The dominant frequency absorbed by carbon dioxide is around 20 trillion cycles per second, which has an energy of only 0.08 electronvolts, nearly 50 times less than the energy required to dissociate ozone. Molecules of carbon dioxide absorbing infrared radiation are not dissociated. Increasing the amplitudes of oscillation of the bonds holding a molecule together has no direct effect on increasing air temperature. Some scientists assume that bond energy can be converted to kinetic energy of motion during myriads of collisions, but the efficiency of this conversion has never been measured and cannot be great. Furthermore, since carbon dioxide only makes up 0.04% of the gases in air, any increase in velocity of one molecule of carbon dioxide must be shared equally with 2500 other atoms and molecules.

It has never been shown by experiment, a cornerstone of the scientific method, that an increase in concentration of greenhouse gases can cause the degrees of global warming observed. Greenhouse-warming theory does not even appear to be physically possible as explained in detail at Physically-Impossible.com.

Several scientists have proposed that a blanket of greenhouse gases keeps Earth 33 ºC (59 ºF) warmer than expected for a planet at Earth's distance from Sun. The stratosphere is clearly observed to be Earth's blanket, where the temperature at the top of the stratosphere is approximately 36 ºC (65 ºF) warmer than the temperature at the base of the stratosphere. The stratosphere is warmed primarily by dissociation of oxygen by solar ultraviolet-C radiation.

The atmosphere of Venus contains 96% carbon dioxide. Many scientists propose that greenhouse warming must be the reason why surface temperatures on Venus are around 462 ºC (864 ºF). But carbon dioxide is dissociated by solar ultraviolet-C radiation at frequencies above 1795 trillion cycles per second, energies above 7.4 electronvolts, more than enough energy to make the atmosphere of Venus much hotter than Earth's stratosphere.

Most atmospheric scientists today assume that greenhouse gases trap heat, slowing the rate of heat lost to space, so that sun makes Earth warmer. While this assumption seems quite logical, it is based on a mistaken understanding of what heat is physically made in 1798 that still prevails today. All curves of warming or cooling of matter are asymptotic to the final temperature as shown by the black line in this figure for warming. The asymptotic shape shows that the rate heat flows per second is proportional to the difference in temperature between the radiating body and the absorbing body as shown by the red curve. A warmer Earth will simply radiate more heat into space.



Volcanoes cause both cooling and warming in erratic sequences: When major explosive volcanic eruptions eject megatons of gases and debris into the stratosphere, molecules of water and sulfur dioxide are observed to form a sulfuric-acid aerosol or mist in the lower stratosphere that spreads worldwide, reflecting and scattering sunlight, causing air temperature on land to decrease approximately 0.5 ºC (0.9 ºF) for two to four years. Modelling of ocean temperatures show that the effects of this worldwide cooling are still seen in ocean temperatures at depth a century later. Thus, when many large, explosive volcanic eruptions occur each century, continuing for millennia, the ocean is observed to be cooled incrementally down into ice-age conditions.

Ice cores under Summit Greenland, where snowfall levels are much higher than in Antarctica, provide an exceptionally detailed record of air temperatures and volcanism over the past 120,000 years. Twenty-five times, air temperatures rose rapidly as much as 16 ºC (29 ºF) within years to decades and then cooled slowly, incrementally, over millennia. These sequences averaged every few thousand years but were clearly not cyclic. These detailed observations show that no cyclic process can be the primary cause of global warming.

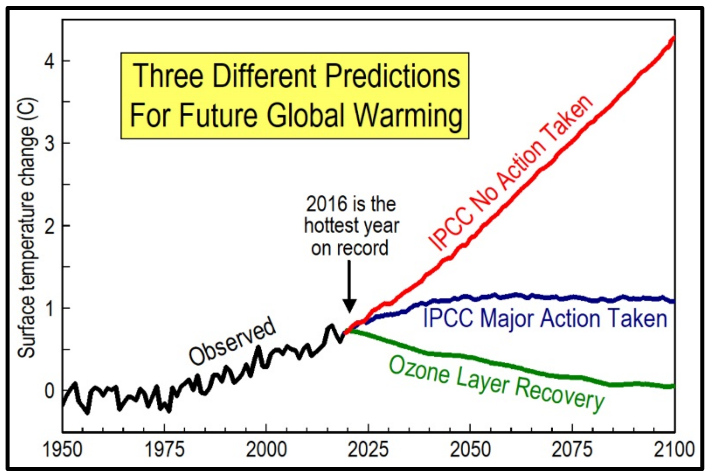
These sequences are highly erratic. They appear to coincide with sudden warming caused by basaltic lava flows most common in continental rift zones. Slow, incremental cooling, on the other hand, appears driven by sequences of major explosive volcanic eruptions most common above subduction zones where oceanic plates are moving down under continental plates. Motions of these tectonic plates, which make up Earth's surface, determine when rift-related basaltic volcanism causing global warming is more common than explosive, subduction-related volcanism causing cooling into ice-age conditions.

Ozone depletion provides a clear and direct explanation for observed global warming: The troposphere is warmed every day by conduction when air touches Earth's sun-heated surface and convects upward and toward the poles. The stratosphere is warmed every day when oxygen, ozone, and other gas molecules absorb solar ultraviolet-C and ultraviolet-B radiation energetic enough to cause dissociation of the molecules. Greenhouse gases absorbing infrared radiation from Earth are not dissociated and, therefore, it is not clear how they could physically cause significant warming of air. Nor can they slow the radiation of heat back into space because the rate heat flows per second is clearly observed to be proportional to the difference in temperature. A warmer Earth simply radiates more thermal energy into space.

Global warming of 0.6 ºC (0.9 ºF) from 1970 to 1998, at a rate of 0.2 degrees per decade, was caused by humans manufacturing chlorofluorocarbons and is expected to last for many more decades, the lifetime of chlorofluorocarbons in the atmosphere. Warming of 0.3 ºC (0.5 ºF) from 2014 to 2016, at a rate of 0.9 degrees per decade, was caused by the eruption of Bárðarbunga and was fully recovered within a few years.

Average global temperatures are, to first order, determined by how much ultraviolet-B radiation reaches Earth's surface. Depletion of total column ozone at 47 ºN by 30 Dobson Units can cause warming of around 0.9 ºC (1.6 ºF).

Will global warming continue? The Intergovernmental Panel on Climate Change (IPCC) predicts, based on greenhouse warming theory, that global average temperatures will continue rising rapidly as shown by the red line assuming we take no action to reduce greenhouse-gas emissions. If we take major action costing tens of trillions of dollars, the IPCC predicts that warming could be limited as shown by the blue line.



If ozone depletion is responsible for warming since 1950, there should be no warming in the future unless there is an increase in ozone depletion. Instead, temperatures should cool as the ozone layer recovers as shown by the green line. Spending tens of trillions of dollars to reduce greenhouse-gas emissions would be a waste of money. We can burn fossil fuels safely, provided we minimize pollution. There are relatively inexpensive actions we should take to speed up recovery of the ozone layer.

Considerably more detail is provided in print and video at
WhyClimateChanges.com