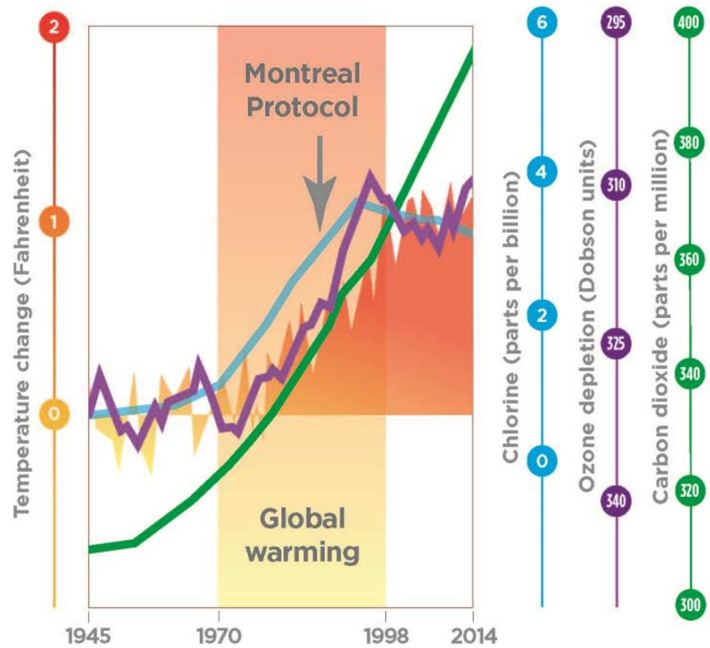
Why Did Global Warming Stop in 1998?

Because global warming is caused by ozone depletion, not by greenhouse gases

Global mean surface temperatures remained relatively constant from 1945 to 1970, rose sharply from 1970 to 1998, and have remained essentially constant since 1998 (red bars to the right). All major compilations of surface temperatures on land and at sea show this basic trend. Meanwhile, atmospheric concentrations of carbon dioxide (green line) have risen every year since 1945 at ever increasing rates. The sudden increase in temperature beginning around 1970 and ending in 1998 is a distinctly different trend from the continuous increase in carbon dioxide from 1945 to present. Dozens of scientific papers have been written trying to explain this stark difference in terms of natural variation of climate systems. Nevertheless, many scientists are beginning to agree that 16 years of relatively constant temperatures since 1998 is becoming harder and harder to explain based on greenhouse gas theory.

In 1984, climate scientists noticed that ozone in Earth's atmosphere above Antarctica was depleted (decreased) by as much as 50% in late winter and early spring compared to measurements prior to 1970. In 2011, depletion reached 45% above the Arctic. The zonal average amount of ultraviolet radiation reaching Earth increased from 1979 to 1998 by approximately 23% above southern Argentina (at a latitude of 50° South), 9% above Buenos Aires (35° S), 7% above Washington, DC (39° N), and 9% above London (50° N).

The ozone layer is a region in the lower stratosphere, 11 to 17 miles (18 to 27 kilometers) above Earth, where ozone is constantly formed and destroyed in an endless series of chemical reactions known as the Chapman Cycle. These chemical reactions are driven by the highest-energy ultraviolet solar radiation penetrating Earth's atmosphere to these altitudes. The heat given off by these reactions warms the stratosphere. When more ozone is destroyed or less ozone is formed, less of this high-energy ultraviolet radiation is absorbed in the stratosphere, and more of it penetrates to Earth. As a result, the stratosphere cools and Earth warms. This increase in solar ultraviolet energy reaching Earth is routinely measured by scientists concerned with increased risk of sunburn and skin cancer due to increases in the amounts of this high-energy erythemal radiation.



Trends in temperature (red bars), tropospheric chlorine (blue line) and ozone depletion (purple line) over the past 70 years are distinctly different from trends in concentrations of greenhouse gases such as carbon dioxide (green line).

In the 1960s, human-made chlorofluorocarbons (CFCs) began to be used widely as refrigerants, solvents, and spray-can propellants. In 1974, atmospheric chemists discovered that CFCs are broken down by ultraviolet radiation in especially cold environments in the lower stratosphere to release chlorine. One atom of chlorine in the ozone layer can catalytically destroy over 100,000 molecules of ozone, disrupting the Chapman Cycle.

The concentration of chlorine-containing gases in the lower atmosphere began inceasing in the 1960s (blue line). Within a few years, the time it takes for CFCs in the lower troposphere to reach the ozone layer in the lower stratosphere, ozone depletion began increasing (purple line). Global concern over the growing Antarctic Ozone Hole and the potential for ultraviolet damage to biosystems led to the Montreal Protocol On Substances That Deplete the Ozone Layer, effective on January 1, 1989. By 1993, there was a substantial reduction in emissions of CFCs. By 1996, ozone depletion had stopped increasing and had begun to decline very slowly. CFCs are very stable gases. Atmospheric concentrations of CFCs are not expected to return to pre-1970 levels until at least 2050.

Thus increases in emissions of CFCs were followed within a few years by increases in ozone depletion and by increases in surface temperatures that were apparently caused by the observed ozone depletion. Once CFC emissions were substantially decreased as a result of the Montreal Protocol, ozone depletion and surface temperatures stopped increasing. The newly established higher level of ozone depletion, however, means that more high-energy ultraviolet sunlight is reaching Earth's surface than was the case before 1970. On land, much of the heat from this radiation can be re-emitted into the atmosphere at night. But in the ocean, which covers 71% of Earth, ultraviolet radiation penetrates tens of meters down into the water, warming the ocean. An increase in ocean heat content is well documented, especially since 1998. This ocean warming is not readily explained by greenhouse-gas theory.

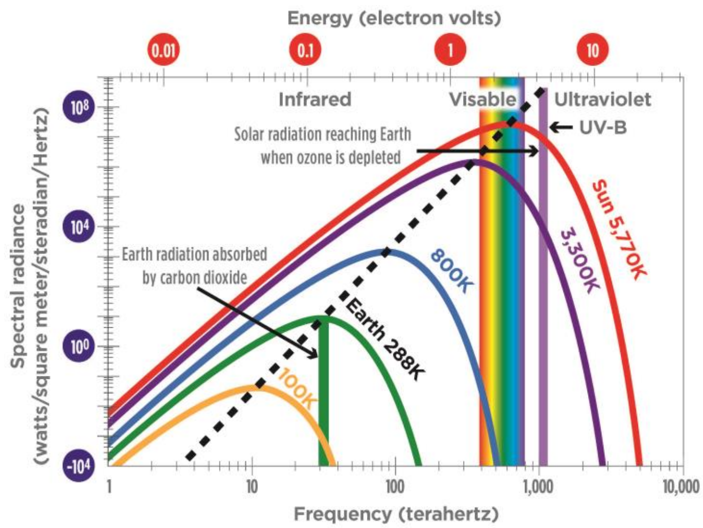
The observed decrease of temperatures in the lower stratosphere, increase of surface temperature on Earth, and warming of the ocean are all explained much more directly by the ozone depletion theory of global warming than by greenhouse-gas theory.

What is Wrong with Greenhouse-gas Theory?

Current computer models do not calculate correctly the thermal energy contained in radiation nor how this radiation is emitted and absorbed by matter.

Heat in matter, the temperature of matter, is the macroscopic evidence of the oscillations of all of the molecular and atomic bonds that hold matter together. Because these bonds are very small, they oscillate at very, very high frequencies, measured in terahertz: a trillion cycles per second. The higher the temperature, the higher the amplitude of oscillation at each frequency, the higher the peak amplitude of oscillation as shown by the dashed black line, and the larger the volume of the matter.

These microscopic oscillations on the surface of matter transmit their frequencies through air and space in the same manner as oscillations on the surface of a radio antenna transmit the frequency of the specific radio station. Electromagnetic radiation consists of nothing but frequency, and Max Planck showed in 1900 that the energy contained in radiation is simply equal to its frequency of oscillation times a constant. Thermal radiation is transmitted through air and space as frequency and is only absorbed by matter that is oscillating at lower temperatures.

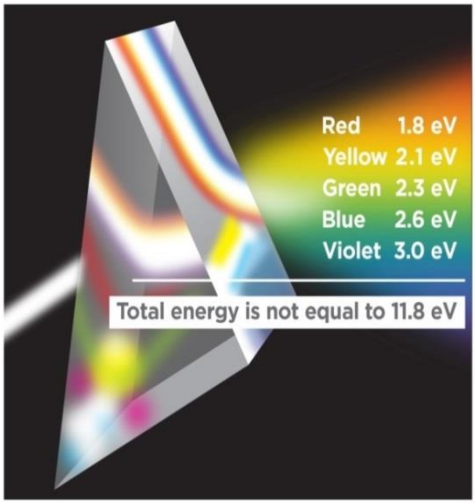


Spectral radiance, the amount of energy at each frequency, predicted by Planck's law for bodies of matter at different absolute temperatures in degrees Kelvin.

In 1900, Planck empirically derived an equation for the amplitude of oscillation at each frequency observed to be emitted (transmitted) from a body of matter with a particular surface temperature. The red line above shows a typical spectrum of emissions observed from the surface of the sun at a temperature around 5770 degrees Kelvin; the green line shows emission from Earth with a surface temperature around 288 degrees Kelvin. Note that the spectral radiance, which I will show below is actually the amplitudes of oscillation on the surface of the sun, are higher at all frequencies than the amplitudes of oscillation on the surface of Earth and that the frequency of the maximum amplitude of oscillation is also higher. According to the second law of thermodynamics, heat only flows from hot to cold, from higher amplitude of oscillation to lower amplitude of oscillation at each frequency. This means that only radiation from a warmer body containing higher amplitude and frequency of oscillation can warm a cooler body.

Greenhouse-gas theory assumes that radiation from Earth is absorbed by greenhouse gases and is then re-radiated back to Earth, causing global warming. This is physically impossible because radiation from Earth does not contain high-enough amplitudes of oscillation at each frequency to warm Earth. Heat is frequency; thermal energy is frequency. Heat flows only from higher temperature to lower temperature, from higher amplitude of oscillation to lower amplitude of oscillation at each frequency.

Secondly, most physicists and climate scientists think of light (electromagnetic radiation) as traveling



A prism divides white light into its components. The total energy of the white light is not equal to the sum of the energies of each color in this rainbow as currently assumed when calculating the thermal effects of greenhouse gases.

through the atmosphere and through space in the form of waves. But waves are a physical property of matter. They occur in matter when some form of energy deforms the bonds that hold matter together. Energy propagated as waves is typically proportional to the square of the amplitude of the waves and is attenuated with distance. When light interacts with matter, the bonds in matter cause wavelike phenomena such as reflection, refraction, diffraction and interference, but light does not travel as a wave outside of matter.

Waves do not propagate in space because there is no matter in space. And light waves do not propagate in the atmosphere because there are no bonds holding different molecules of gas together. Radiation travels through air and space simply as frequency. Since the energy of electromagnetic radiation is equal to the frequency times a constant, ultraviolet radiation reaching Earth when ozone is depleted contains nearly 50 times more energy than infrared radiation absorbed by greenhouse gases. There simply is not enough energy in infrared radiation to have a primary effect on global warming.

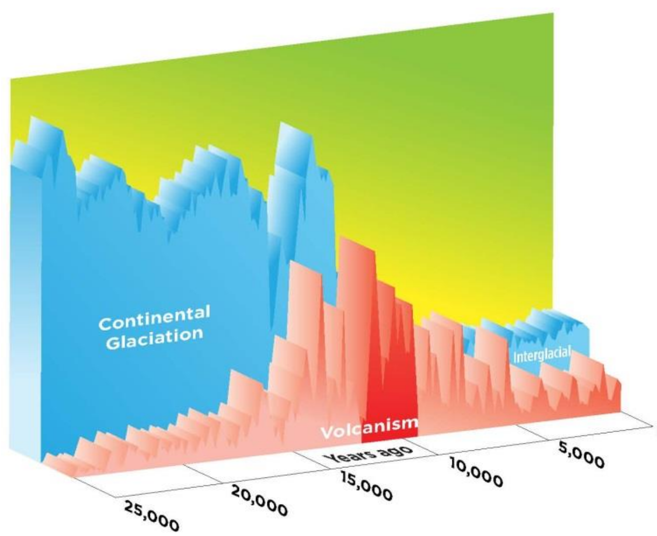
Radiant thermal energy is typically measured by the amount it warms a body of matter. Thus the y-axis in Planck's equation is traditionally shown containing units of watts (energy per second). But the x-axis is frequency, which if multiplied by Planck's constant is equal to energy (upper x-axis). Plotting energy as a function of energy does not make physical sense. The y-axis, spectral radiance, should simply be the amplitude of oscillation at a given frequency on the surface of the matter emitting the radiation. This amplitude is what is measured because, according to Planck's equation, the higher the amplitude, the higher the temperature of the body emitting the radiation and the higher the temperature becomes of the body that absorbs the radiation.

The amplitude of any specific wave in matter can be approximated by a Fourier series, which is essentially the sum, over a large range of frequencies, of the amplitude at each frequency. The bonds holding matter together cause these amplitudes to be summed. In space, there are no bonds and there is no summation. Each frequency exists on its own, does not interact with any other frequency, and is not attenuated with distance. Electromagnetic radiation in space is simply a Fourier series without the plus signs.

Similarly the energy of light cannot be added as assumed by greenhouse-gas theory. Radiation that contains red light with an energy of 1.8 electronvolts (eV), yellow light at 2.1 eV, green light at 2.3 eV, blue light at 2.6 eV, and violet light at 3.0 eV does not contain a total energy of 11.8 eV, the energy of extreme ultraviolet radiation only found in the uppermost parts of Earth's atmosphere. It just contains some energy at each color.

Effusive Basaltic Volcanoes Deplete Ozone and Warm Earth

Thousands of basaltic lava flows erupted in Iceland between 11,750 and 9,350 years ago, precisely when the world warmed out of the last ice



Volcanic sulfate (red), measured in ice below Summit Greenland, shows a peak in volcanism between 11,750 and 9,350 years ago, the ages of many basaltic lavas in Iceland. This is the same time when the world was warmed out of the last ice age according to an oxygen isotope proxy for local temperature (blue) measured in the same ice. (Data source: GISP2)

Lava fountains on the volcano Bárðarbunga that began erupting in Iceland in August, 2014. This type of effusive, basaltic volcanic eruption may continue to erupt for years, depleting ozone, but rarely ejects much material into the lower stratosphere. (Source: Wikimedia)

The large, explosive eruption of Mt. Pinatubo in the Philippines in June, 1991, ejected ash and gases 25 miles (40 kilometers) into the atmosphere. (Source David Harlow, USGS)

age. Such eruptions typically emit megatons of chlorine and bromine gases into the atmosphere. These gases are observed today to deplete the ozone layer. Even small basaltic eruptions deplete ozone approximately 6% over northern mid-latitudes with ozone levels returning to pre-eruption conditions within a decade.

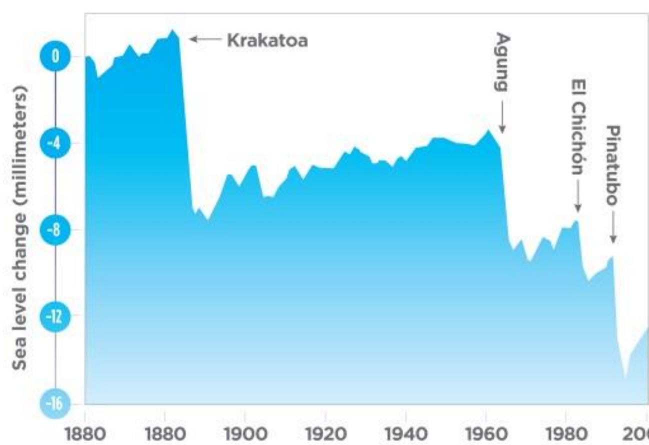
Explosive Volcanoes Also Deplete Ozone But Cool Earth

In 1991, the major eruption of Mt. Pinatubo, in the Philippines, depleted ozone 6% but exploded megatons of sulfur dioxide and water vapor high into the lower stratosphere, where they formed a fine, sulfuric acid mist or aerosol approximately 12 miles (19 kilometers) above Earth that spread throughout the world over several months. The aerosol particles grew large enough to reflect and scatter the highest-frequency components of sunlight (primarily ultraviolet-B), cooling Earth up to one degree Fahrenheit (0.6 degree Centigrade) for approximately three years. The ozone layer was most depleted during late winter in early 1992, causing warming over northern continents, but the globally distributed aerosols caused net cooling.

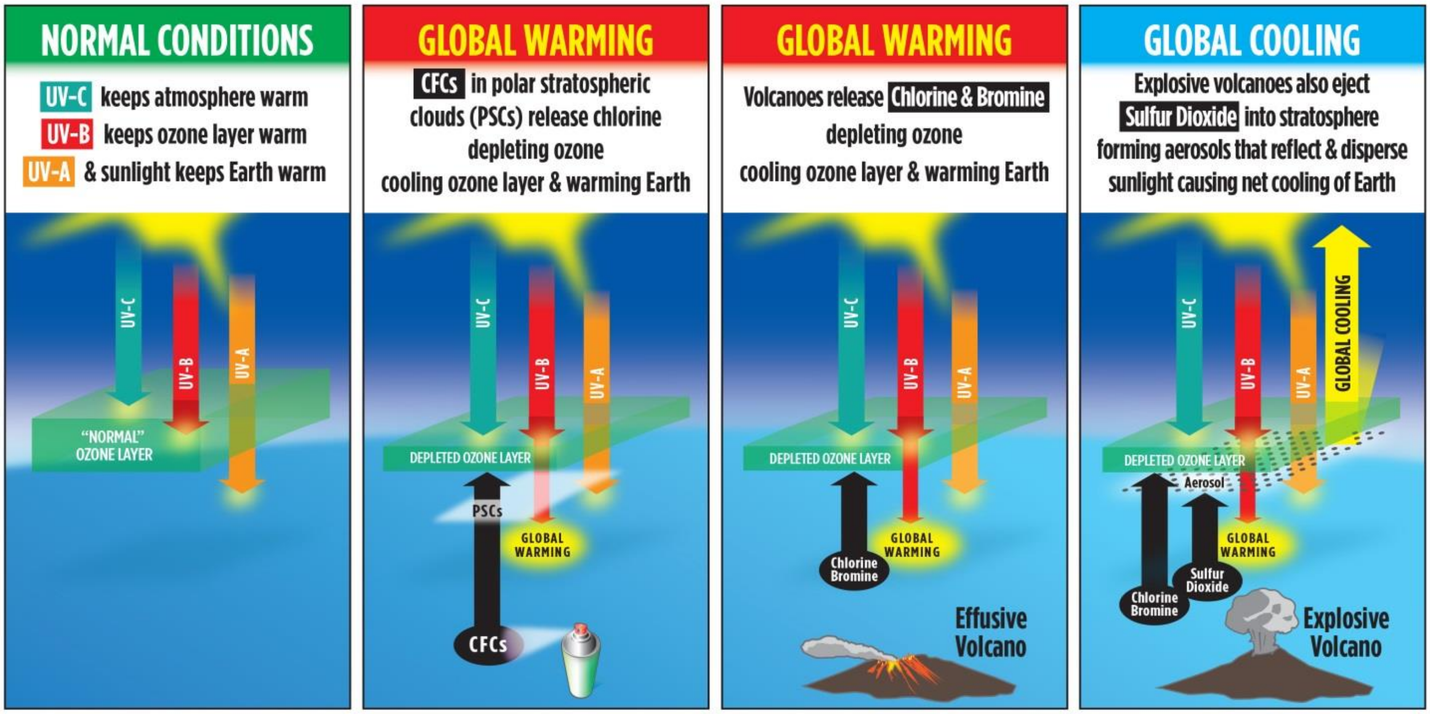
Such cooling has been observed after all major explosive volcanic eruptions throughout human history. When explosive eruptions happen frequently – every decade or so – their cumulative effects can decrease ocean temperatures substantially, ultimately ushering in an ice age.

Every 22 million years, on average, massive effusive eruptions of basaltic lava have covered areas as large as 70% of the contiguous United States. During some of these events, it took hundreds of thousands of years to extrude up to one million cubic miles (4 million cubic kilometers) of basaltic lava contemporaneously with lethally hot temperatures, acidic oceans, substantial ozone depletion, increased rates of mutation, and major mass extinctions.

Climate throughout Earth's history appears to have been controlled primarily by the frequency of major explosive volcanic eruptions forming aerosols that cause net cooling and the duration of effusive basaltic volcanic eruptions that deplete ozone, causing warming.



Cumulative cooling of the ocean following several explosive volcanic eruptions modelled as a change in sea level. Sea-level change is often taken as a proxy for global temperature change. (Data source: Gregory and others, 2006).



Global warming occurs when more ultraviolet-B sunlight than normal reaches the ocean because the ozone layer is depleted either by human-manufactured CFCs or by chlorine and bromine emitted by volcanic eruptions. Global cooling occurs when sulfuric-acid aerosols in the lower stratosphere reflect and disperse sunlight, decreasing the thermal energy reaching Earth. These aerosols are formed when sulfur dioxide gas and water vapor are injected high into the stratosphere by large, explosive volcanoes.

The relative proportion of these two types of volcanism is determined by plate tectonics processes that control how large slabs ("plates"), which make up the uppermost layer of Earth, move relative to each other. For example, 56.1 million years ago, global temperatures rose 11 degrees Fahrenheit (6 degrees Centigrade) in less than 20,000 years, and were associated with voluminous basaltic eruptions during the initial opening of the Greenland-Norwegian Sea.

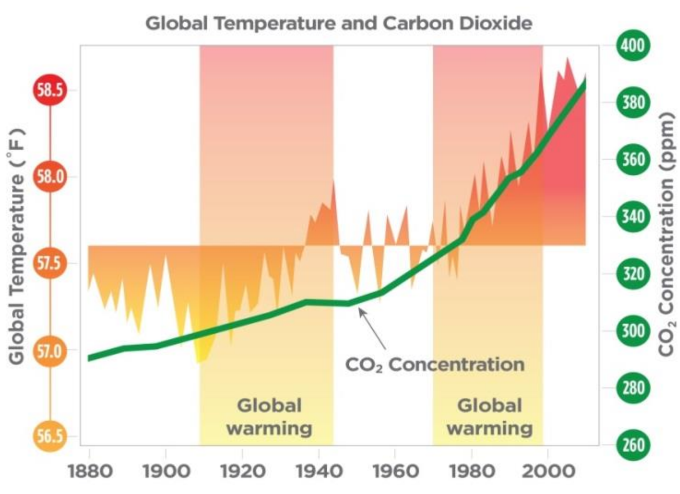
20th Century Climate Change

Average global surface temperatures cooled following the major explosive eruptions of Tambora (1815), Krakatoa (1883), Santa Maria (1902), and Novarupta/Katmai (1912). Then temperatures increased as smaller, more moderate, and more effusive eruptions occurred once or twice per year through 1943.

A highly unusual sequence of seven small volcanic eruptions around the Pacific Ocean from 1931 through 1933 preceded the great "Dust Bowl" drought and warming, which was worst in 1934 and 1936, suggesting the effects of ozone depletion.

Average global temperatures were relatively constant from 1945 until 1970. But temperatures rose sharply from 1970 through 1998, contemporaneously with a substantial increase in CFCs, as discussed in more detail above.

Discovery in 1974 that CFCs deplete ozone, and discovery in 1984 of the Antarctic ozone hole, led to negotiation of the Montreal Protocol on Substances that Deplete the Ozone Layer. Kofi Annan, former Secretary General of the United Nations said in 2005 that the Montreal Protocol was "perhaps the single most successful international agreement to date."



Global temperatures rose primarily from 1910 to 1945 and from 1970 to 1998. Meanwhile carbon dioxide concentrations in the atmosphere have risen nearly continuously. (Data source: National Climatic Data Center)

Under this protocol, emissions of CFCs began to decline by 1993, halting the increase in ozone depletion by 1996. Some of these very stable gases are expected to remain in the atmosphere at least until 2050, so the warming they have caused will continue for some time. As long as ozone remains depleted, compared to average amounts before 1970, increased ultraviolet-B radiation will continue to warm the ocean as has been clearly observed since 2000.

Global surface temperatures have remained relatively constant since 1998. But record warm temperatures and drought in central and northeastern North America during 2012 and 2013 appear directly related in time and location to 15% depletion of ozone measured over Toronto, Canada, compared to the average level in the 1960s. The observed depletion included 3% from CFCs, 6% from the eruption of Eyjafjallajökull volcano in Iceland in 2010, and 6% from the eruption of Grímsvötn volcano in Iceland in 2011.

Ozone depletion is most noticeable in the Antarctic Ozone Hole, where nearly half the ozone is depleted in late Antarctic winter and early spring each year relative to levels prior to 1970. The greatest observed warming on Earth since 1970 has been in the regions with the greatest observed ozone depletion and has occurred during late-winter-early-spring when this depletion is greatest.

Ozone depletion caused by volcanoes appears to explain global warming throughout geologic time. The rapid increase in emissions of CFCs manufactured by humans after 1965 and the decrease in emissions of CFCs after 1992 appears to explain increasing ozone depletion and global temperatures from 1970 to 1998 as well as the fact that both have remained relatively constant during the past 16 years. Concentrations of carbon dioxide in the atmosphere, meanwhile, have been rising steadily, and the rate of increase has been greatest since 1998.

What Actions Should We Take?

Human activities have caused the world to warm approximately one degree Fahrenheit (0.6°C) between 1970 and 1998. Earth's thermostat has been reset. Even when ozone levels return to values typical before 1970, the ocean will remain warmer, and therefore Earth will remain warmer. The only natural way to lower the thermostat is through increased numbers of major explosive volcanic eruptions.

We have halted human-caused global warming by reducing emissions of CFCs via the Montreal Protocol. We need to continue to strengthen the prohibition against manufacturing gases that deplete ozone and to seek ways to remove these gases from the atmosphere.

We also need to understand better exactly how volcanoes deplete ozone and what our options will be if the rates and types of global volcanism should suddenly change.

Reducing emissions of carbon dioxide will not reduce global warming but may slow ocean acidification.

Rapid increases of such pollutants as black carbon formed by incomplete combustion, sulfur dioxide from burning fossil fuels, and ground-level ozone formed as a result of nitrogen oxides, volatile organic compounds, and other pollutants, occurred 30 years prior to major warming, suggesting that they do not have much effect on global warming. Since many absorb ultraviolet-B radiation, they can increase warming of the air in polluted areas when stratospheric ozone is depleted.

These pollutants do have major deleterious effects on public health, however, and many cause acid rain. Most developed countries have reduced pollution to relatively healthy levels, but improvements are still possible and of value. Developing countries with rapidly increasing energy use, such as China and India, need to put major emphasis on reducing pollution for the health of their citizens and others living downwind. Concentrations of corrosive sulfate in acid-rains reaching the western United States from Asia and from ships at sea, approach or exceed maximum levels allowed by U.S. regulations.

Our modern life styles depend heavily and increasingly on the availability of inexpensive energy. Sources of fossil fuels are limited. Currently, we waste more than half the energy we produce for consumption. While much of this waste is inevitable, much can be conserved. Conserving energy not only makes good economic sense, but it also extends the long-term availability of fossil fuels.

More Information

The document is meant to be a brief introduction for non-specialists. The science behind these conclusions is described in detail on a major website found at **ozonedepletiontheory.info**.

The science is described in a YouTube video found at **tinyurl.com/ozone-depletion-theory.**

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