Ozone depletion, not greenhouse warming, caused recent warming

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Annual average global temperatures remained relatively constant from 1945 to 1970, rose from 1970 to 1998, remained relatively constant from 1998 through 2013, known as the global warming hiatus, and rose sharply since 2014 (Fig. 1). Meanwhile CO_2 concentrations have risen at ever increasing rates, so that they are unable to explain the inflection points in temperature trends in 1970, 1998, and 2014.

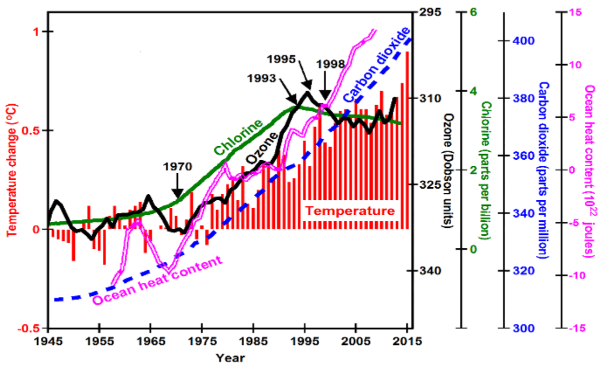


Fig. 1. Trends in temperature, tropospheric chlorine, ozone depletion, CO_2, and ocean heat content since 1945. Temperatures NOAA [2016a]. CO_2 NOAA [2016b]. Ocean heat content Levitus et al. [2012].

Chlorofluorocarbons (CFCs) became popular in the 1960s for use as spray-can propellants, refrigerants, solvents, etc. because they are so chemically inert. The green line shows the tropospheric chlorine available tied up in CFCs based on the amounts manufactured [*Solomon*, 1999]. By 1970, ozone depletion and temperatures began to rise. *Molina and Rowland* [1974] discovered that CFCs high in the stratosphere are broken down by ultraviolet-C solar radiation ultimately releasing chlorine atoms especially in the vicinity of polar stratospheric clouds (PSCs) in late winter. One atom of chlorine can destroy 100,000 molecules of ozone. With discovery of the ozone hole over Antarctica [*Farman et al.*, 1985], scientists worked closely with politicians to pass the Montreal Protocol on Substances that Deplete the Ozone Layer, limiting manufacturing of CFCs effective January 1989. By 1993 tropospheric chlorine stopped increasing. By 1995 ozone depletion stopped increasing. By 1998 temperatures stopped increasing. Humans had accidentally caused warming by manufacturing CFCs and accidentally stopped the warming by trying to reduce ozone depletion.

Ultraviolet-B is the highest energy solar radiation to reach the lower stratosphere where it is absorbed by ozone, causing dissociation in the Chapman cycle, warming the ozone layer. When ozone is depleted, less UV-B is absorbed by the ozone layer, causing it to cool, and more UV-B reaches Earth, causing it to warm. UV-B penetrates oceans tens of metres, directly and efficiently increasing ocean heat content, which continues to increase because ozone remains depleted relative to pre-1970 levels. A warmer ocean absorbs less CO_2, providing at least a partial explanation for continued rise in CO_2.

Chlorine and bromine from volcanic eruptions are also observed to deplete ozone (Fig. 2). The greatest depletion was in 1992 and 1993,

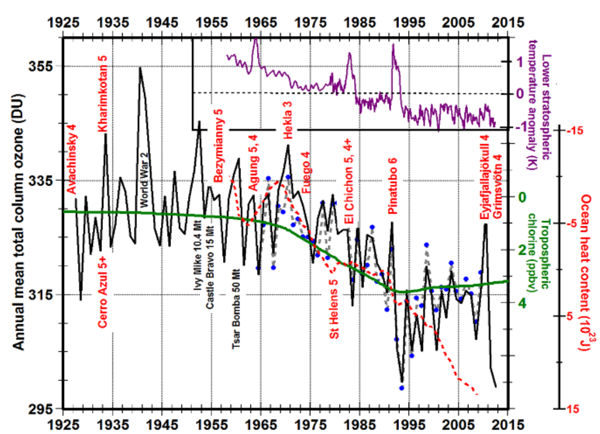


Fig. 2. Annual mean total column ozone measured at Arosa Switzerland (black line), chlorine (green) temperature lower stratosphere (purple), ocean heat content (dashed red). Volcanic eruptions (red lettering).

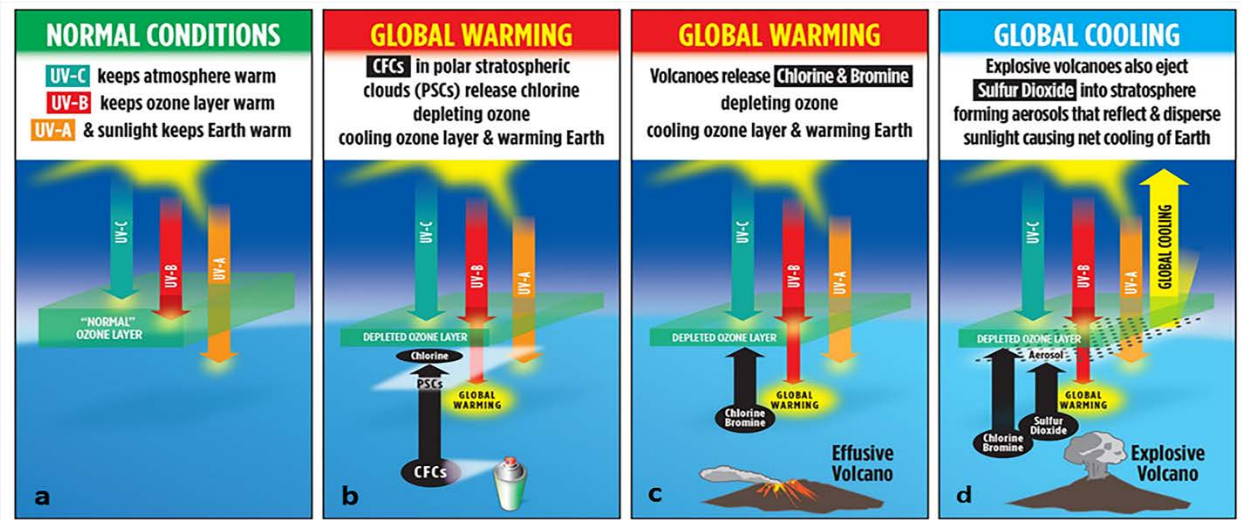


Fig. 3. CFCs and effusive basaltic eruptions deplete the ozone layer causing warming. Explosive volcanoes deplete the ozone layer but also form aerosols that reflect and scatter sunlight causing net cooling of 0.5ºC for three years.

following the 1991 eruption of Mt. Pinatubo, the most explosive volcanic eruption since 1912. A similar amount of depletion followed the much smaller eruption of Eyjafjallajökull in 2010 that included a lava flow and was followed by the 2010 eruption of Grímsvötn.

Sudden warming began again in 2014 with the effusive eruption of Bárðarbunga in Iceland, which extruded 85 km^2 of lava, the highest rate of basalt extrusion in the world since 1783.

Climate change throughout geologic time appears to be controlled by the balance of volcanism determined by plate motions. Effusive volcanoes (Fig. 3c), common along subaerial spreading plate margins, deplete ozone for years to hundreds of thousands of years, warming Earth. Sequences of more than a few large explosive eruptions per century (Fig. 3d), common along convergent plate margins, increment Earth into ice ages over periods of 100,000 years (Fig. 4). The greatest known warming was 252 million years ago when basaltic lavas covered an area in Siberia as large as Europe and 96% of all marine species and 70% of all terrestrial vertebrates vanished.

From 110,000 to 10,000 years ago, Earth warmed suddenly out of the last ice age 25 times, typically within a few years, but then drifted back into ice age conditions within centuries to millennia (Fig. 4). In most of these cases, effusive basaltic volcanism in Iceland caused the sudden warming that did not last long enough to warm the ocean, which then cooled the world back into the ice age. Intensive volcanism from 11,750 to 9,375 years ago lasted long enough to warm the ocean out of the ice age. This type of rapid cycling between low and high temperature periods as often as every 4000 years is well observed throughout Earth history and cannot be explained directly by greenhouse gases. Volcanoes rule climate.

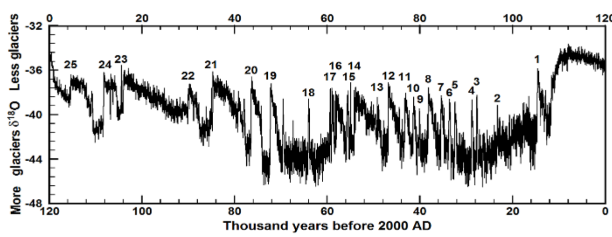


Fig. 4. Oxygen isotope proxy for temperature measured in drill holes near Summit Greenland

Temperature in matter results from oscillation of all the microscopic bonds that hold matter together. Each normal mode of each degree of freedom, of each bond oscillates at some high frequency measured in trillions of cycles per second. Temperature is defined when these oscillations occur over a very broad range of frequencies described by Planck's law (Fig. 5). Planck's law defines a curve for each specific temperature that shows the natural amplitude of oscillation at that temperature for each frequency of oscillation. When you heat matter, the amplitude of oscillation at each frequency of oscillation increases, and the greatest increases in amplitude are at the highest frequencies of oscillation. The higher the temperature, the higher the amplitude of oscillation at every frequency. The capacity of matter to store heat increases with the number of degrees of freedom of motion within the bonds.

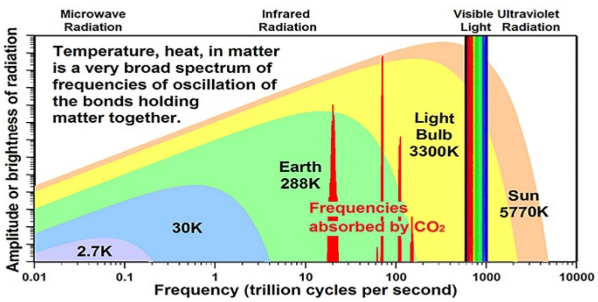


Fig. 5. Planck's law plots, for a body of matter at some absolute temperature, essentially the amplitude of oscillation at each frequency of oscillation.

These oscillations on the surface of matter induce the same oscillations in an electromagnetic field whose frequencies do not interact and do not change with distance, while amplitudes decrease inversely with the square of distance traveled. Energy (E) of each of these atomic anharmonic oscillations equals the Planck constant (h) times frequency (v): $E=hv$, the Planck-Einstein relation.

The frequency content of solar radiation reaching the top of Earth's atmosphere is shown by the red line in Fig. 6. The highest energy radiation, with frequencies above 1650 THz, is absorbed above 50 km, ionizing nitrogen and oxygen, forming the ionosphere and thermosphere. Frequencies around 1237 THz (dashed blue line) are absorbed by oxygen, causing dissociation and the formation of ozone. There is more than enough oxygen to absorb all of these frequencies of radiation. The highest energy radiation reaching the bottom of the ozone layer is typically small amounts of UV-B, with frequencies greater than 952 THz. When the ozone layer is depleted by 1%, more UV-B reaches Earth as calculated in Fig. 7 by *Madronich* [1987] (green shaded area).

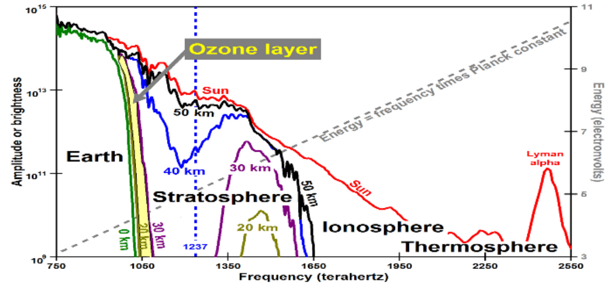


Fig. 6. Frequencies of radiation absorbed in the upper atmosphere before reaching the ozone layer (yellow) from Fig. 7 in *DeMore et al.* [1997].

The greatest ozone depletion is located above Antarctica in late winter, as is the greatest warming anywhere in the world in the past 1800 years. Minimum monthly temperatures rose 6.7°C from 1951 to 2003 [*Hughes et al.*, 2007]. Winter sea ice decreased 10% per decade [*Clarke et al.*, 2007]. Summer surface temperatures of the Bellingshausen Sea rose 1°C [*Meredith and King*, 2005]. Ozone depletion also provides a direct explanation for widely observed Arctic amplification of warming.

Ozone depletion theory provides a clear, direct, and complete explanation for global warming since 1945 (Fig. 1) and throughout geologic time. When ozone is depleted, we measure more UV-B reaching Earth where it heats air primarily by dissociating ground-level ozone pollution, which occurs primarily in populated regions of the northern hemisphere, causing twice the warming as observed in the southern hemisphere. We observe the stratosphere getting cooler (Fig. 2) and oceans warming (Fig. 1) as expected.

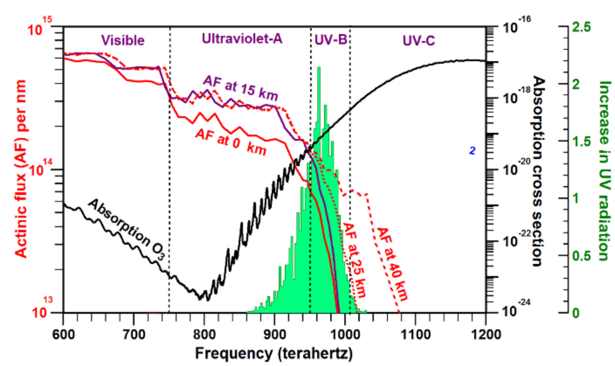


Fig. 7. Frequencies of ultraviolet radiation reaching Earth when ozone is depleted by 1%.

Greenhouse warming theory, on the other hand, appears mistaken. Energy in radiation is clearly observed to be a function of frequency (E=h*v*). Climate models calculate radiative forcing assuming the energy is the same at all frequencies and that energy is additive. Frequency of an atomic oscillation is an intensive physical property of matter that is not additive. If E=h*v*, energy is not additive because it makes no physical sense to add red light to blue light to get ultraviolet light. Red and blue light coexist, do not interact, and are therefore non-additive. Temperatures similarly are not additive. When you put one body at 30°C in thermal contact with another body at 40°C, the temperature will become between 30 °C and 40 °C, not 70°C.

It is physically impossible for radiation from Earth, no matter how efficiently it is reflected back, to warm Earth. Earth can only be warmed by radiation from a hotter body. It takes higher amplitudes at higher frequencies than exist in terrestrial radiation (Fig. 8).

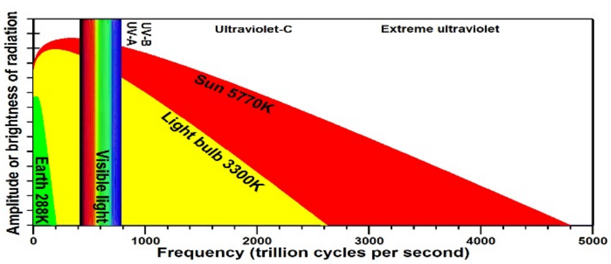


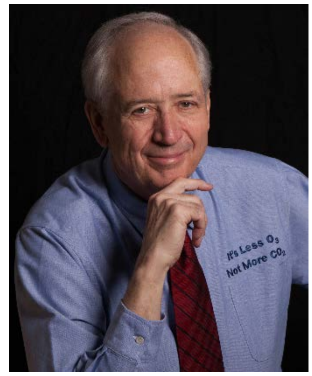
Fig. 8 It takes radiation with higher amplitudes of frequencies to warm a body of matter. Planck's law plotted with a linear frequency scale.

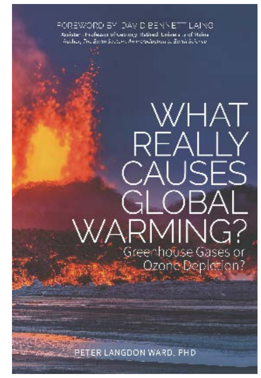
CO_2 does not absorb enough heat to play a major role in global warming. Temperature is defined by a very broad range of frequencies (Fig.5). The red vertical bars show the frequencies absorbing terrestrial infrared radiation, less than 10% of the frequencies required to define Earth temperature. The energy absorbed goes into the bonds holding the molecule together and does not warm the air. To warm air, you must increase the average translational velocity of all the molecules making up the gas. CO_2 makes up only 0.04% of the molecules. It has never been shown experimentally that increasing CO_2 concentration leads to warming air in any significant way.

The details are explained in my book *What Really Causes Global Warming? Greenhouse Gases or Ozone Depletion.* Extensive web-pages, numerous scientific papers, and many videos explaining the details are found at

WhyClimateChanges.com

Also check out ScienceIsNeverSettled.com.





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