Draft 170407

Global temperatures are determined by the level of kinetic energy, not by the amount

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Greenhouse-warming theory assumes thermal energy is a macroscopic extensive physical property where changes in amounts of radiative forcing are added together to calculate changes in global temperature. Thermal energy, however, is the microscopic oscillation of all bonds holding matter together, an intensive physical property that is not additive. Amount of thermal energy determines rate of warming, but level of thermal energy, the temperature of the radiating body, determines temperature increase.

Ultraviolet-B, the highest level of solar energy reaching the lower stratosphere, is normally absorbed by the ozone layer. When ozone is depleted, more ultraviolet-B is observed to reach Earth, cooling the stratosphere, warming Earth. Ozone depletion, caused by manufactured chlorofluorocarbon gases and emissions of chlorine and bromine from effusive basaltic volcanic eruptions, explains in detail observed erratic periods of rapid global warming throughout Earth history.

Climate models calculate that terrestrial infrared radiation absorbed by greenhouse gases warms Earth more than solar ultraviolet-B radiation because greenhouse gases absorb a greater *amount* of infrared energy. Sun, however, warms Earth tens of degrees every day, something no amount of terrestrial infrared radiation can do over any period of time. Furthermore, solar ultraviolet-B radiation has a high-enough level of energy to burn your skin within hours, something no amount of terrestrial infrared radiation can do over any period of time.

Climate scientists think in terms of macroscopic amounts of energy in joules and fluxes of energy in watts per square meter that they assume add up to cause temperature change according to the wave theory of light, while atmospheric chemists think in terms of microscopic levels of energy in joules sufficient to cause chemical reactions such as sunburn or dissociation of oxygen, ozone, and other molecules according to the particle theory of light. Observations, however, suggest that the temperature of the radiating body has the primary effect on temperature of the absorbing body and on the chemical effects of absorbed radiation. To understand this difference in view, we need to ask what is thermal energy? What is radiation? How is thermal energy radiated and absorbed?

Thermal energy: Temperature is a measure of how fast the atoms and molecules in a material are moving (*3*). The lower the average velocity of the atoms and molecules, the lower the thermal energy, the lower the temperature of the material, approaching zero velocity as the temperature approaches absolute zero. In a gas, the atoms and molecules are free to move in any direction until they collide. Temperature of an ideal gas is proportional to the average kinetic energy of translation over all the atoms and molecules, each of which has a kinetic energy $E = \frac{1}{2} mv^2$ where m is the mass and v is its velocity. In matter, however, atoms and molecules are constrained by the bonds or pressures holding matter together. These bonds oscillate at higher and higher frequencies as their temperature increases until the bonds come apart. Temperature of matter, therefore, is primarily proportional to the kinetic energy of oscillation of all the degrees of freedom of all the bonds or pressures holding matter together.

The kinetic energy (E) of a single frictionless, anharmonic atomic oscillator is equal to the Planck constant (h) times the frequency of oscillation (ν, the Greek letter nu): $E=h\nu$, known as the Planck-Einstein relation. This equation says that frequency of oscillation (ν) times the Planck constant of proportionality (h) is the actual energy (E), the kinetic energy of oscillation. The higher the frequency of oscillation, the higher the level of energy of oscillation. Note that microscopic kinetic energy of oscillation is not a function of mass, which is distinctly different from macroscopic kinetic and potential energies that are functions of mass.

$E=h\nu$ is the equation for a straight line through the origin where h is the slope of the line in joules of energy per cycle per second. The unit "cycles" is often omitted from definitions of the Planck constant, leading to imprecise thinking. The unit "cycles" is needed to make it clear that the kinetic energy we are talking about is the kinetic energy of oscillation, which is intensive, not the kinetic energy of translation, which is extensive. The Planck constant can be estimated easily in a high school physics laboratory using four LEDs with four different colors, four different frequencies of oscillation, which by $E=h\nu$ are four different levels of energy (*4*).

Intensive energy: In 1917, Richard Tolman (*5*) defined two fundamentally different types of physical properties describing matter: *extensive* and *intensive*. Extensive physical properties depend on the extent or amount of mass and contain "a certain additive nature so that a given quantity can be regarded as being the sum of a number of smaller quantities of the same kind" (*5*). Intensive physical properties, on the other hand, are not affected by the extent or amount of matter and “have no such additive properties.” It is not physically meaningful to add together quantities of the same kinds of intensive physical properties. If the causes of a physical property can be placed together in some way, they may interact resulting, for example, in an average, but two quantities of an intensive physical property cannot be added together, they cannot physically interact in any way that results in a quantity that is the sum of their values.

Extensive physical properties of macroscopic matter, such as length, volume, mass, amount, and number of moles, generally describe the extent or amount, but they give little information about the physical nature of the matter. Intensive physical properties, such as temperature, freezing point, density, color, hardness, and malleability, however, generally describe the nature of microscopic entities related to the atomic granularity of matter—properties caused by how atoms and molecules interact. Intensive physical properties are essential to the nature of the substance, they are intrinsic, and they are often useful for identifying a substance primarily because they do not change with extent or amount.

Temperature is clearly an intensive physical property that is not additive. If you take a piece of mass at temperature T and divide it in half, you end up with two pieces of mass, each at temperature T. If you connect thermally two pieces of mass with temperature T_1 and T_2, you end up with one piece of mass with a temperature somewhere between T_1 and T_2—not the sum of T_1 plus T_2. If you mix two amounts of gas at different temperatures together, without changing pressure, there will be a new average translational kinetic energy corresponding to a new temperature somewhere in between—it will not be the sum of the temperatures. Temperature is not additive.

Microscopic thermal energy ($E=h\nu$), similarly, is an intensive physical property that describes the physical nature of thermal energy, saying it is simply frequency times a constant of proportionality and is not additive. If you connect together thermally two bodies of matter with the same thermal energy, you do not increase the frequency of oscillation and therefore you do not increase the energy. You just have a greater amount of the same energy. Macroscopic, extensive energy flux in watts per square meter, on the other hand, is thought to describe the amount of energy crossing an area of one square meter each second, but it gives no information about what that energy actually is.

The problem: Greenhouse-warming theory and associated computer models assume that the intensive physical properties of temperature, thermal energy, and the energy of photons are each additive, thereby calculating thermal energy incorrectly. Here are some examples.

First, greenhouse-warming theory is built on the assumption that temperature on Earth is determined by a radiative balance between the amount of solar thermal energy absorbed by the Earth-atmosphere system and the amount of thermal energy lost to space. This concept assumes that thermal energy is additive, that amounts of thermal energy can be added together, and that temperature on Earth is additive. Temperature and thermal energy are both intensive physical properties that are not additive.

Second, radiative forcing is thought of as a measure of the influence a greenhouse gas or other factor has on altering the balance of incoming and outgoing energy in the Earth-atmosphere system (*6*). Climate scientists add up radiative forcings to calculate a net radiative forcing, something Tolman (*5*) calls "the sum of a number of smaller quantities of the same kind." This sum of approximately one watt per square meter (*7*) is thought to explain current global warming. Radiative forcing is an intensive physical property that is not additive.

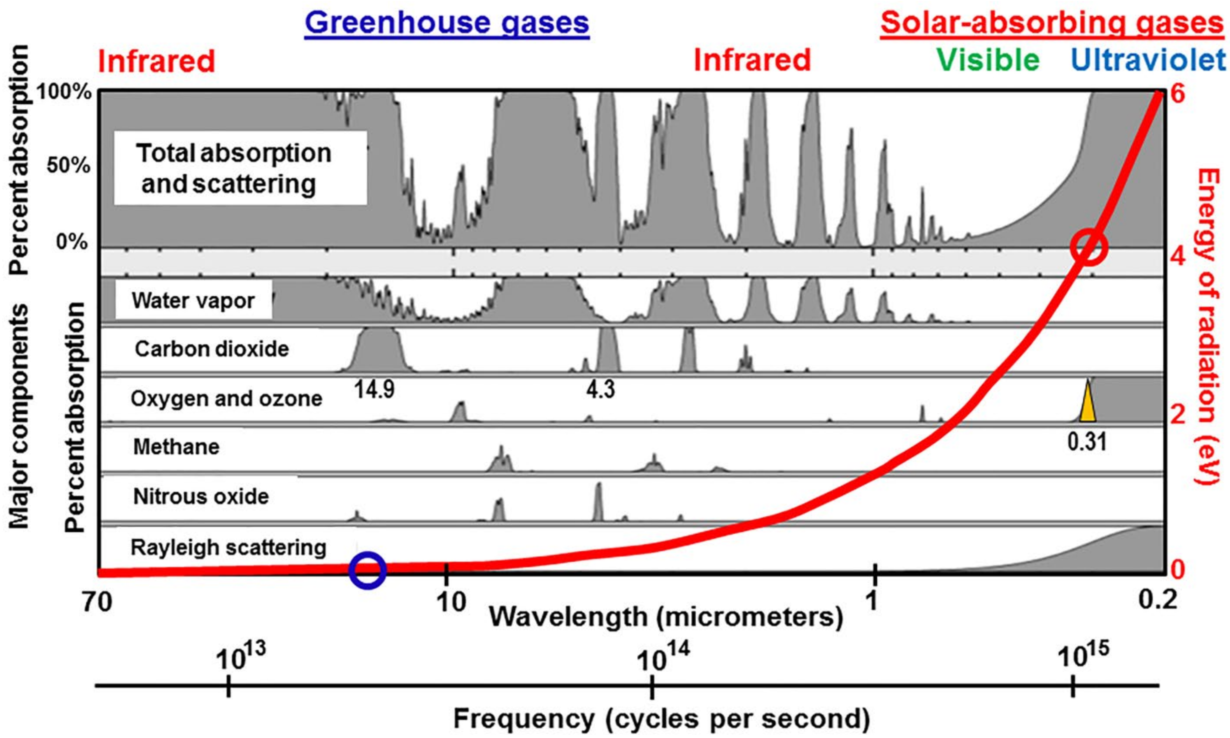

Figure 1. When ozone is depleted, a narrow sliver of solar ultraviolet-B radiation with wavelengths close to 0.31 µm (orange triangle) reaches Earth. The red circle shows that the energy of this ultraviolet radiation, based on E=h*v*, is around 4 electron volts, 48 times the infrared energy absorbed most strongly by carbon dioxide (blue circle, 0.083 eV at 14.9 micrometers wavelength. Shaded grey areas show the bandwidths of absorption by different greenhouse gases. Current computer models calculate radiative forcing by adding up the areas under the broadened spectral lines that make up these bandwidths. Thermal energy is not additive. Net radiative energy, is proportional to frequency only (red line), not to amplitude, bandwidth, or amount.

Third, the concept of climate sensitivity assumes that doubling the amount or extent of CO_2 in air will lead to an increase in the amount of infrared thermal energy absorbed, causing global temperatures to rise somewhere in the range of 2.2 to 4.8 K (*8*). The assumption is that the greater the amount of energy absorbed, the higher the resulting temperatures, but temperatures are the result of level of energy described below, not amount of energy.

Fourth, climate models integrate over (add up the area under) all spectral lines of absorption contained within the spectral bands of absorption shaded gray in Figure 1, concluding, for example, that carbon dioxide absorbs a much larger amount of infrared radiation than the narrow sliver of ultraviolet-B radiation reaching Earth when ozone is depleted (orange triangle). While most climate scientists are aware that a photon of ultraviolet-B radiation is 48 times more energetic than a photon of infrared radiation absorbed most strongly by carbon dioxide, they argue that there is a much larger number (amount) of photons of infrared energy than photons of ultraviolet-B. They conclude, therefore, that an increase in temperature is caused by a larger amount of radiation rather than a higher level of radiation. This conclusion is in direct conflict with our personal observations: sunlight feels much hotter, makes us feel much warmer, than infrared radiation welling up from Earth. Ultraviolet-B has a level of energy high enough to cause sunburn. No amount of infrared radiation can cause sunburn.

Levels of energy: In 1887, Heinrich Hertz (*9*) discovered the photoelectric effect where shining light on freshly cut surfaces of certain metals causes release of electrons. The peculiar thing about the photoelectric effect is that no electrons are observed to be released when the color of the light is below some minimum frequency in the blue to ultraviolet range, depending on the metal. No electrons are observed to be released no matter how great the amount of light, no matter how great the intensity of light, and no matter how long the light shines on the surface. Once the minimum frequency (level of energy) is reached, electrons are released and the intensity of the light determines the rate of electron release. This minimum frequency, this minimum level of energy, cannot be explained by Maxwell's wave equations for electromagnetic radiation, the most widely respected theory of radiation at the time that is still part of greenhouse-warming theory today.

In 1900, Max Planck discovered a "mathematical trick" useful in developing his empirical law (Figure 2), by introducing the concept of an "energy element" whose energy (ε) was the product of a constant (h) times frequency (ν): $\varepsilon = h\nu$ (*10*). In 1905, Albert Einstein, while trying to understand the photoelectric effect, thought this "energy element" might better be viewed as a "light quantum", a quantity of energy large enough to break an electron loose (*11*). By 1926, the "light quantum" had become known as the photon (*12*).

Today, most physicists think of the energy of a photon as $E=h\nu$ and are convinced that the higher the number (amount) of photons, the higher the amount of energy. Yet radiant energy is an intensive physical property. Atomic oscillators, the source of radiant energy, have intensive physical properties. Two atomic oscillators do not have twice the energy of one—they are simply two discrete oscillators that coexist, each with their own energy. Similarly, two photons coexist, but do not have twice the kinetic energy of oscillation or twice the frequency of oscillation. E_1+E_2 does not equal $h\nu_1+h\nu_2$. Frequencies are not additive and therefore the energies of atomic oscillators are not additive. If you add blue light to red light, you do not get ultraviolet light; the red and blue colors of light simply coexist until they interact with matter.

There is an even more surprising logical deduction from the Planck-Einstein relation, $E=h\nu$. Frequency of electromagnetic radiation is a continuum—all frequencies coexist, most with very small amplitudes. A continuum times a constant of proportionality (h) must also be a continuum. Therefore, if $E=h\nu$, the energy of oscillation (E) must be a continuum. This means that electromagnetic energy of oscillation in air and space is not quantized into photons as assumed by most physicists. In the photoelectric effect, energy is a continuum, but there is a specific level of energy, a specific minimum frequency of oscillation, required to release electrons.

Electromagnetic field: Thermal energy is a broad continuum of frequencies of oscillation of all the bonds holding matter together. These oscillations on the surface of matter induce an electric field just above the surface by charge-acceleration and/or dipole oscillation. This electric field induces a magnetic field, which induces an electric field, etc. forming an electromagnetic field that is observed to contain a continuum of frequencies. Gas molecules in the presence of this electromagnetic field absorb specific spectral lines of energy that are the resonant frequencies of all the bonds holding the molecule together (*13*). Bodies of matter absorb almost all frequencies, increasing the thermal energy contained within the matter, making the matter warmer. Thermal energy in matter and in radiation is simply a broad continuum of frequencies of oscillation. There is no need to hypothesize photons or waves in the transfer of thermal energy through space as explained in more detail in the Supplementary Materials. Thinking of electromagnetic radiation as a continuum of frequencies makes many of the problems addressed by quantum electrodynamics both physically intuitive and deterministic, results that Einstein sought for nearly 50 years.

Electromagnetic radiation does exhibit wavelike properties such as reflection, diffraction, and interference when in the immediate vicinity of matter, but these effects appear to be caused by the bonds holding matter together. Electromagnetic

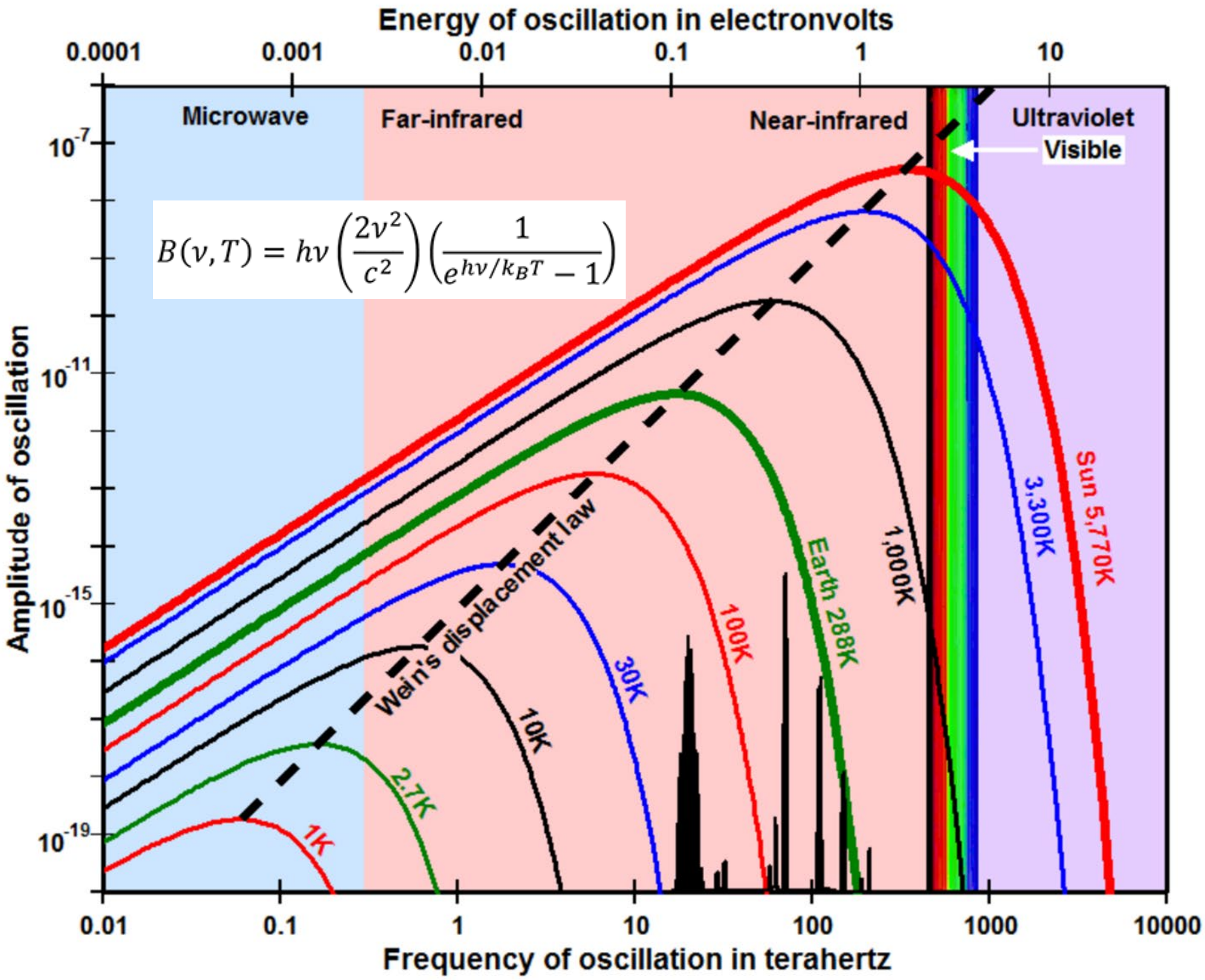

Figure 2. Planck's law shows that radiation from a warmer body has higher amplitudes of oscillation at all frequencies than does radiation from a cooler body and exhibits its greatest amplitude at a higher frequency, following Wien's displacement law (black dashed line). Each solid line shows the amplitude of oscillation radiated from a body at thermal equilibrium for the temperature shown. 3300K is the temperature of the filament of an incandescent light bulb. 2.7K is the temperature of the cosmic microwave background (*2*). The black vertical lines show frequencies absorbed by carbon dioxide.

radiation does exhibit particle-like properties in the photoelectric effect, in molecular dissociation, and in ionization, when the level of energy is high enough to break some bonds. What is observed to be traveling physically in air and space, however, is a continuum of frequencies of oscillation.

Radiation temperature: The relationship between thermal energy and temperature in matter and in electromagnetic radiation is shown by Planck's Law (Figures 2 and S3 in the Supplementary Materials), an empirically derived equation found to describe radiation emitted by a black body at thermal equilibrium as a function of temperature. Electromagnetic radiation has two observable physical properties: frequency of oscillation, which, in the visible spectrum, is a shade of color, and amplitude of oscillation, commonly thought of as intensity or brightness. Electromagnetic radiation is thought to be produced by charge-acceleration and/or dipole oscillation on the surface of matter caused by oscillation of all the bonds holding matter together. Therefore, Planck's law should specify, for a body of matter at a given absolute temperature, the amplitude of oscillation on the surface of the radiating body at each frequency of oscillation. The units on the y-axis are discussed in the Supplementary Materials.

Radiation comes in many forms, emitted by many different types of devices. The term *thermal radiation* is used in this paper to specify the very broad continuum of frequencies of oscillation resulting from the temperature of a radiating body as described by Planck's law. The family of Planck curves plotted in Figures 2 and S3 describe the physical properties of thermal radiation in detail.

Each frequency of oscillation (ν) has a level of energy ($E=h\nu$) shown on the x-axis at the top of Figure 2 and an amplitude of oscillation shown on the y-axis. Thermal oscillatory energy is intensive because it is the result of microscopic oscillations permeating matter. Therefore, the level of thermal oscillatory energy and the amplitude of thermal oscillatory energy are each not additive.

The single most important observation from Figure 2 is that both the level and the amplitude of thermal oscillatory energy are determined by the temperature of the radiating body and can only be increased at the source by increasing this temperature. A body, therefore, can only be warmed via radiation by absorbing radiation from a hotter body. Heat flows only from hot to cold, the second law of thermodynamics.

Note that the lines do not intersect, although all the amplitudes of oscillation approach zero as the temperature approaches absolute zero. As the temperature of the radiating body increases, hotter bodies

1. emit radiation with higher amplitudes of oscillation at every frequency of oscillation,
2. contain considerably more high frequencies of radiation with significant amplitudes of oscillation (Figures 2 and S3), and
3. have the peak amplitude of oscillation at a higher frequency approximated by Wien's displacement law shown by the dashed black line where $T=9.67*10^{-12}*\nu_{max}$.

Temperature, therefore, is equal to the frequency of oscillation with the highest amplitude of oscillation times a constant of proportionality.

To warm a body from 100 K (red line) to 288 K (green line), for example, the body must appear to have absorbed, after reaching thermal equilibrium, the difference in amplitude of oscillation between the red line and the green line for every frequency. Since neither the amplitudes nor frequencies of oscillation are additive, this radiation must come from a body that is at least as hot as 288 K. Thus, terrestrial radiation can be thought of as having the temperature of Earth, 288 K. Let's define *radiation temperature* as the temperature of the black body from whence the radiation came and also the minimum level of thermal energy, the minimum radiation temperature that must be absorbed to warm another black body to that same temperature.

Heat is the amount of energy flowing from one body to another spontaneously due to their temperature difference. The area between the red and green lines in Figure 2 describes the heat that must be absorbed to raise the temperature from 100 K to 288 K. Note that heat not only involves frequency of oscillation, which is thermal energy, but also involves amplitude of oscillation.

Sharing amplitudes via resonance: Atomic oscillators have essentially no friction, no damping. The Planck curves in Figure 2 show clearly that both the dominant frequencies and amplitudes of oscillation increase with temperature. Without friction, the only way to share this energy of oscillation among oscillators, the only way thermal energy (heat) can flow spontaneously, is via resonance where, for two oscillators at nearly the same frequency, the same energy, amplitude of oscillation will appear to flow from the oscillator with the higher amplitude to the oscillator with the lower amplitude until they both have the same amplitude of oscillation. Thus, while the level of energy is directly proportional to the frequency of oscillation ($E=h\nu$), the amplitude of the energy, is shared through resonance at each frequency. Resonance does not add or difference amplitudes of oscillation, it averages them. When thermally connecting two bodies that are identical except for different temperatures, the resulting temperature, once thermal equilibrium is reached, is the average of the two original temperatures. This averaging of amplitudes has several important effects.

First, heat can only flow by resonance from higher amplitude to lower amplitude, which from Figure 2 means from higher temperature to lower temperature, an observation so widespread that it is enshrined as the second law of thermodynamics.

Second, the greater the difference in amplitude of oscillation, which means the greater the difference in temperature, the faster heat will flow. This is especially true at the higher frequencies, which have higher energies, where the differences in amplitude are typically very large (Figure 2).

Third, as the temperature difference goes to zero, the amount of heat that flows, due to this averaging process, will approach zero in an exponential manner, as is well observed. For this reason, the concept in greenhouse-warming theory that radiation from Earth warms Earth fails—only minuscule amounts of heat can flow across small differences in temperature. Furthermore, heat cannot flow from warm to warmer.

Resonance is the physical process by which temperatures equilibrate, by which heat flows. In matter, resonance is made possible by physical contact. In radiation, resonance is made possible by optical contact, by line of sight. It is the physical properties of the electromagnetic field that facilitate the occurrence of resonance over distances ranging from close at hand to galactic.

Resonance is the physical basis for what Einstein called "spooky action at a distance" (*14, p. 155*), where something over there influences something over here, but there is no visible connection between them. Resonance is also the physical phenomenon that the mathematical theory of quantum entanglement seeks to explain.

Because heat only flows across the surface of a body of matter by resonance, heat can only flow from warmer matter into colder space or from warmer radiation, radiation with a higher radiation temperature, into a cooler body of matter. Radiation from a colder body, therefore, cannot physically be absorbed by a warmer body via resonance—it appears to be reflected (*15*). Similarly, heat cannot flow in both directions across a surface at the same time, something often invoked by people explaining greenhouse-warming theory.

Resonance plays the major role not only in temperature and the flow of heat, but also in sight and sound. Visible light is visible precisely because the cone cells in our eyes have sizes that resonate at visible frequencies. The cilia in our ears resonate with frequencies of sounds. A radio receiver tuned to resonate at the frequency of a specific radio transmitter, extracts that small signal from the frequency continuum. The resonant frequencies of the bonds holding a gas molecule together extract, via resonance, energy for those specific frequencies from the frequency continuum of an electromagnetic field.

Dosage: For all radiation with frequencies greater than visible light (>789 terahertz, >3.26 electronvolts), the concept of dosage becomes very important because these are frequencies of oscillation that have enough energy to cause damage to living tissue and many other materials. How much damage depends on the frequencies and energies involved ($E=h\nu$), the amplitudes of oscillation (intensity) at these frequencies of oscillation, the length of time exposed to this radiation, and the sensitivity of the living tissue and other matter to this radiation often quantified as the Radiation Amplification Factor (*16, 17*). Plus, higher frequencies penetrate matter further, putting deeper tissue at risk.

Frequencies of oscillation are clearly observed not to change with distance travelled, while amplitudes of oscillation decrease with the square of the distance traveled. Thus, ultraviolet-B radiation near Sun and ultraviolet-B radiation at Earth's surface both have energies of 4 electronvolts, radiation temperatures of 9350 K, the minimum level of energy required to cause sunburn, but the amplitude of oscillation at the top of Earth's atmosphere is 4.47 X 10^{-23} times smaller than the amplitude of oscillation near Sun. In bright sunlight on Earth, ultraviolet-B can penetrate a few cellular layers of skin within hours of exposure, killing the cells. Ultraviolet radiation also damages lawn furniture, but it takes many years of exposure to bright sunlight for the effects to become noticeable. Very low amplitude, short duration X-rays have enough energy to pass through bodies and expose film without causing damage, while very high amplitude X-rays can be focussed on a specific area to burn cancer cells. Nuclear radiation with energies of hundreds of thousands of electrovolts can pentrate our bodies instantly, causing substantial damage if the amplitudes are large enough.

Modulating the level of solar energy reaching Earth: Amplitudes of oscillation also decrease when interacting with gases in Earth's atmosphere. The red line in Figure 3 shows the amplitude of oscillation of solar radiation reaching the top of Earth's atmosphere. The highest frequency, highest energy, hottest, most chemically active radiation from Sun is absorbed in the atmosphere, never reaching Earth (*18*). Extreme ultraviolet radiation (Table S1) contains a level of energy sufficient to ionize nitrogen, oxygen, and other chemical species, forming and warming the ionosphere and thermosphere 75 to 1000 km above Earth's surface. As shown in Figure 3, most frequencies greater than 1650 terahertz are absorbed above 50 km in the ionosphere.

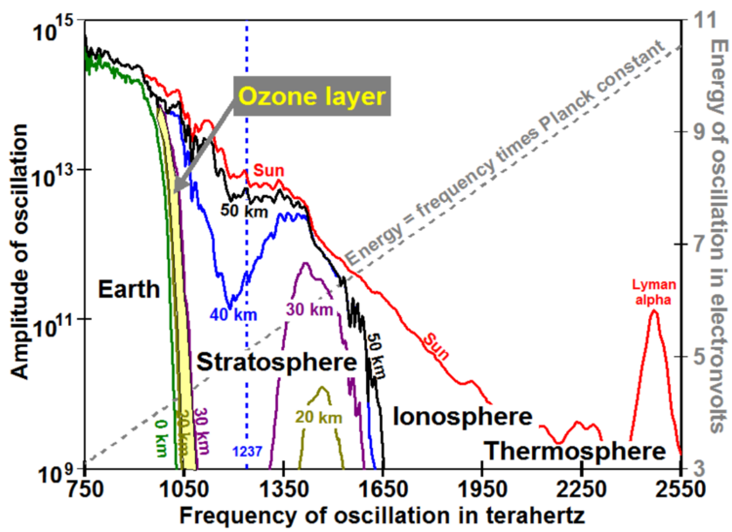

Figure 3. The highest frequency, highest energy, solar radiation is absorbed high up in the atmosphere. The red line shows the amplitude of solar radiant energy received at the top of Earth's atmosphere. Almost all radiation with frequencies greater than 1650 terahertz is absorbed above 50 km (31 mi) (black line). Much radiation with frequencies above 1090 THz is absorbed above the ozone layer (yellow).

Ultraviolet-C radiation dissociates oxygen and other species, especially at frequencies around 1237 terahertz (dashed blue line), forming and warming the stratosphere 10 to 50 km above earth. There is more than enough nitrogen and oxygen in Earth's atmosphere to absorb all the extreme ultraviolet and ultraviolet-C energy available.

Most frequencies greater than 1050 terahertz are absorbed above 20 km where they dissociate O_2 and many other chemical species, warming the stratosphere.

Ozone depletion: Most frequencies greater than 950 terahertz, with energies sufficient to dissociate ozone, are absorbed by the ozone layer. When the ozone layer is depleted, less of this ultraviolet-B energy is absorbed in the ozone layer, observed to cool the lower stratosphere (*19, 20*), and more of this ultraviolet-B energy is observed to reach earth's surface, warming Earth (*16, 21-23*) (Figure 4). At ground level, ultraviolet-B is absorbed most efficiently by ground-level ozone pollution in populated industrial areas and by oceans that it penetrates to depths of tens of meters. Since 1970, average temperatures in the northern hemisphere, containing 90% of world population and the highest concentrations of ground-level ozone pollution (*24*), warmed twice as much as those in the southern hemisphere (*25*). The greatest warming, however, was on the Antarctic Peninsula, beneath the Antarctic ozone hole, the greatest observed ozone depletion (*26*).

Global temperatures, in this way, are determined by the level of ultraviolet-B solar energy reaching Earth's surface, not by the amount of energy. Changes in global and regional temperatures are determined primarily by changes in the amount of total column ozone contained in the atmosphere not only throughout the year, but throughout geologic time.

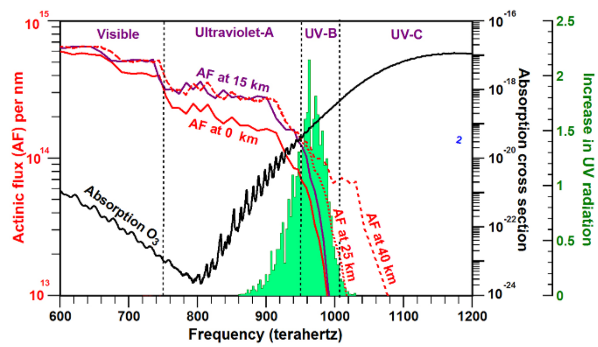

Figure 4. The green shaded area shows the frequency distribution of the increase in ultraviolet radiation reaching Earth when the ozone layer is depleted by 1% (*1*).

Ozone depletion caused by manufactured chlorofluorocarbon gases caused increasing global warming beginning around 1970 (Figure S4) (*27-29*). The Montreal Protocol, mandating reduction of the manufacturing of these gases beginning in 1989, stopped the increase in global warming by 1998 as explained in the Supplementary Materials. The eruption of Bárðarbunga volcano in 2014 in Iceland extruded basaltic lava over an area of 84 km^2 in 6 months, the highest rate of basaltic lava production since 1783. Flows of basaltic lava covering tens to millions of square kilometers have been contemporaneous with major, rapid global warming and mass extinctions throughout the history of man and throughout the history of Earth.

The atmosphere absorbs the highest energy solar radiation (Figure 3). If there were no atmosphere, major amounts of ultraviolet-C radiation would reach Earth's surface, boiling off the water, destroying life, and making the surface temperature much hotter. The moon and Mercury have essentially no atmosphere. Daytime temperatures on the moon range up to 397 K, while daytime temperatures on Mercury, which is 39% closer to Sun, range up to 700 K.

Moving forward: Global warming is a serious problem, but the possibility that greenhouse-warming theory may not be correct is quite unsettling to climate scientists who have been working very hard for decades to convince government leaders to act now to mitigate a problem many scientists are convinced is extremely serious. Yet, one of the major benefits of science is that, over time, science is self-correcting. Maxwell (*30*) assumed in 1865 that electromagnetic radiation travels as waves and Arrhenius (*31*) assumed in 1896 that radiative forcing is additive. Both assumptions seemed reasonable at the time and most scientists still think they are reasonable today. A great deal of science has been built on these assumptions, especially since 1988 when the Intergovernmental Panel on Climate Change was formed under the United Nations to convince political leaders of the need to mitigate global warming. These assumptions turn out not to be correct, as explained in this paper. It is extremely important scientifically, economically, and politically that we straighten this out right away.

Supplementary Materials

The nature of an atomic oscillator: The microscopic atomic and molecular bonds that hold matter together are not rigid. Each atom in a molecule oscillates in a number of characteristic ways including vibrational degrees of freedom. Each vibration oscillates around a potential-energy minimum. Electrodynamic forces attract atoms when they are close and other electrodynamic forces repel atoms when they are too close typically modeled as a Morse potential energy function (Figure S1). As temperature increases, amplitude of oscillation increases, increasing level of thermal energy of oscillation. When the level of thermal energy of oscillation reaches a certain level of energy (E_{max}), the bond comes apart, leading to the photoelectric effect and ionization by freeing electrons, and leading to dissociation for molecules. Because the force of repulsion increases much more rapidly than the force of attraction decreases, the length of each bond increases with temperature, meaning the volume of material increases with temperature.

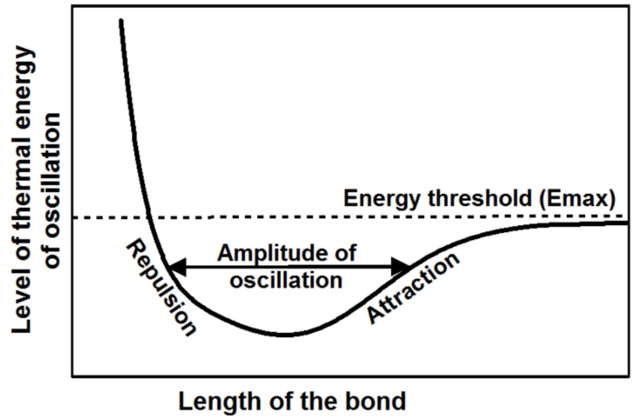

Figure S1. Each degree of freedom of each bond oscillates around a potential-energy minimum between electrodynamic forces that attract atoms when they are close and other electrodynamic forces that repel atoms when they are too close. When the level of thermal energy is increased, the amplitude of oscillation is increased.

The atomic dimensions of these oscillators are very small, so their natural frequencies of oscillation are very high, around 30.6 terahertz (30.6 x 10^{12} cycles per second) at room temperature.

A continuum of frequencies: Electromagnetic radiation is a continuum of frequencies of oscillation induced by oscillations on the surface of radiating matter. Table S1 summarizes the frequency bands and energy bands of this radiation, the absolute temperature of the radiating body, and the chemical effects.

Table 1. Higher frequency radiation contains more energy and is able to warm matter to higher temperatures than lower frequency radiation. Values shown, except for room temperature, are for the top of the radiation band so that, for example, frequencies for extreme ultraviolet radiation range from 30,000 to 2,998 THz.

Radiation Band	Maximum Frequency Terahertz	Maximum Level of Energy Electronvolts E=hv	Temperature Kelvin of Radiating Body	Chemical Effects of this Radiation
Gamma rays	$3x10^8$	$1.24x10^6$	$2.9x10^9$	Lethal even in small amounts
Extreme ultraviolet	30,000	124	289,978	Ionizes N_2, O_2, etc. Forms and heats ionosphere
Ultraviolet-C	2,998	12.4	28,978	Dissociates O_2, SO_2, etc. Heats stratosphere
Ultraviolet-B	1,071	4.43	10,352	Dissociates O_3, sunburn, vitamin D, skin cancer
Ultraviolet-A	952	3.94	9,202	Skin cancer, fading of materials
Visible light	789	3.26	7,626	Photosynthesis, dissociates NO_2, NO_3, HONO
Near infrared	400	1.65	3,866	Begin absorption by water vapor
Short wavelength infrared	214	0.886	2,069	Absorption by water vapor
Mid-wavelength infrared	99.9	0.413	966	Main absorption by greenhouse gases
Long-wavelength infrared	37.5	0.155	362	Main absorption by greenhouse gases
	30.6	0.127	296	Room temperature, 23 ^{o}C, 73 ^{o}F
Far-infrared	20	0.0827	193	
Microwave	3	0.0124	29	
Longwave AM radio	$2.79x10^{-7}$	$1.15x10^{-6}$	$2.7x10^{-3}$	

Units on the y-axis for Planck's law:
Planck's law was formulated to explain measurements in the laboratory collected by many different physicists (*32-35*) who separated the radiation of interest into a rainbow spectrum, using a glass prism (Figure S2) for visible and ultraviolet frequencies or a halite prism for infrared frequencies not energetic enough to penetrate glass. They then placed a temperature sensor within each narrow spectral band, measuring the increase in temperature of a small piece of mass within the sensor. They were, therefore, measuring the thermal effect of this narrow band of radiation on the small piece of mass. Based on Maxwell's wave theory for radiation, they thought they were measuring the amount of energy required to cause this thermal effect in units including watts per square meter on the y-axis as a function of frequency of oscillation in cycles per second on the x-axis.

Since both thermal energy in matter and radiant energy in air and space are equal to the Planck constant (h) times frequency of oscillation (v) so that E=hv, and temperature is defined by a broad continuum of frequencies, then Planck's law actually calculates, for a body at a given absolute temperature, the amplitude of oscillation at each frequency of oscillation. What they were measuring as volts was a proxy for amplitude of oscillation. Amplitude of oscillation needs to be calibrated experimentally in the laboratory. That is why no units for amplitude of oscillation are shown on the logarithmic y-axes in Figures 2, 3, 4, and S3.

Planck's law shows that the natural, normal amplitude of bond oscillation at a particular temperature has a particular value at a particular frequency. This normal amplitude of oscillation can be increased by adding more energy, for example by creating a laser, by creating high-energy fields such as in a microwave oven, by moving closer to the emitting surface, or by using a magnifying lens to cause diverging rays to converge.

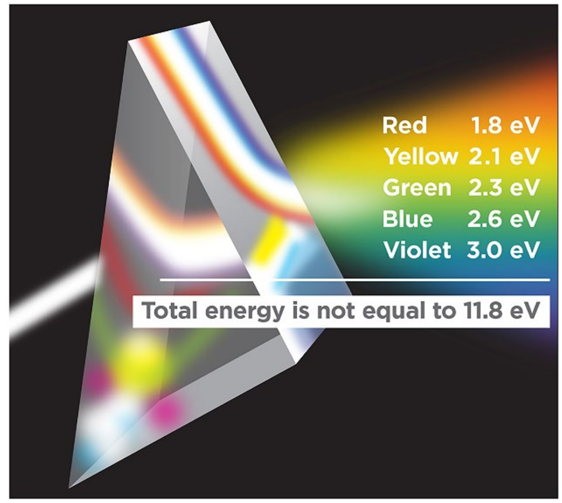

Figure S2. White light entering from the left is spatially separated by a prism into its component colors. The total energy contained in white light is not the sum of the energies of the colors (frequencies) that it contains.

Why electromagnetic radiation does not appear to propagate as waves or photons: For 2500 years, leading natural philosophers and scientists have debated whether light, something we cannot see until it interacts with matter, travels through air and space as waves or as particles, things we can visualize. Doesn't it seem illogical to describe something we cannot see in terms of things we can see?

Light is observed to contain a broad spectrum of frequencies (Figures 2 and S3) that we cannot see until light interacts with matter such as in a rainbow or prism (Figure S2). Today we are familiar with radio stations transmitting radiation at specific frequencies of oscillation, and a radio receiver that can be tuned to receive just the frequency of the desired station. These devices, however, became widespread only in the past century after physicists thought they understood what light is. While many physicists have concluded that frequencies and amplitudes of oscillations on the surface of the radiating matter generate the electromagnetic field, I have been unable to find in the literature any suggestion that light might simply travel as a continuum of frequencies in air and space, by line of sight, via the electromagnetic field that they generated and continue to generate as long as they are oscillating. Yet that is what appears to be happening.

In 1818, Fresnel (*36*) noticed that light (electromagnetic radiation) could be polarized, concluding that light must therefore travel as transverse waves. He understood, however, that transverse waves can only propagate in solid matter, where the bonds holding the matter together provide the restoring forces that allow the waves to propagate. He therefore proposed that there must be some form of "luminiferous aether" in space that somehow provides those restoring forces.

In 1849, Faraday (*37*) introduced the concept of an electromagnetic field in air and space consisting of coupled transverse electric and magnetic waves vibrating in mutually perpendicular planes.

By 1865, Maxwell (*30*) formulated a set of partial differential equations showing that electric and magnetic fields in space can satisfy wave equations when you think of EMR as transverse waves traveling at some velocity. He showed that this velocity was equal to one divided by the square root of the product of two constants: the vacuum permittivity (the resistance to forming an electric field) times the magnetic permeability (the ability to form a magnetic field) (*38*). Thus, velocity of light appears to be proportional to the maximum rate at which an electric field can induce a magnetic field, which in turn can induce an electric field, ad infinitum. This very short increment in time would affect how fast frequency of oscillation would appear to travel in an electromagnetic field.

For decades, many physicists sought to discover what Fresnel's luminiferous aether was or to prove that it could not exist. In 1887, Michelson and Morley (*39*) convinced most physicists that an aether does not exist and therefore waves cannot propagate through space. To this day, many physicists think there must be something different about electromagnetic waves that allows them to travel in space, but no one can explain the physical process in detail.

We observe that the physical properties of electromagnetic radiation (light) are distinctly different from the physical properties of mechanical waves in matter. Mechanical waves have frequencies defined as their velocity divided by their wavelength. The higher the frequencies, the more rapidly they are attenuated with distance. Frequencies of oscillation in light are a trillion times higher than frequencies for mechanical waves. They do not interact in any way and they are not attenuated with distance, even over galactic distances. The only argument for light traveling as waves is the wavelike behavior of light in the immediate presence of matter as described in the main paper.

In 1905, Einstein (*11*) introduced the concept of " light quanta", a quantum of energy that ultimately became known as a photon (*12*). Today, most physicists think of electromagnetic radiation as wave-particle duality, meaning sometimes it is more convenient to use wave equations and sometimes it is more convenient to use particle equations. As a basic point of logic, if something behaves sort of like waves and sort of like particles, then it is equal to neither. As discussed in the main paper, if $E=h\nu$, if frequency (ν) is a continuum, and if h is a constant, then energy of oscillation (E) must be a continuum, not made up of discrete photons. There are many logical problems trying to describe a continuum as discrete photons. Is there a different photon for every decimal place of every frequency? How does a photon interact with a gas molecule? Does it collide with the gas molecule? If so, what happens if it glances off the molecule? How do you explain, using photons, the numerous spectral lines observed when a greenhouse gas absorbs energy from the electromagnetic field, given that these are the resonant frequencies of the gas molecule? The photon is a very handy mathematical concept for calculating electromagnetic energy, but there are many reasons to wonder whether it can be a physical reality.

High-frequency energy: Hotter bodies radiate substantially higher amplitudes of higher frequencies of oscillation, as shown by Figure S3, a plot of Planck's law similar to Figure 2, but with a linear x-axis. Radiation from Earth at 288K (green) contains frequencies from 0 to more than 200 terahertz. Radiation from the filament of an incandescent light bulb contains frequencies to more than 2600 terahertz. Radiation from Sun at 5770K (red) contains frequencies to more than 4800 terahertz.

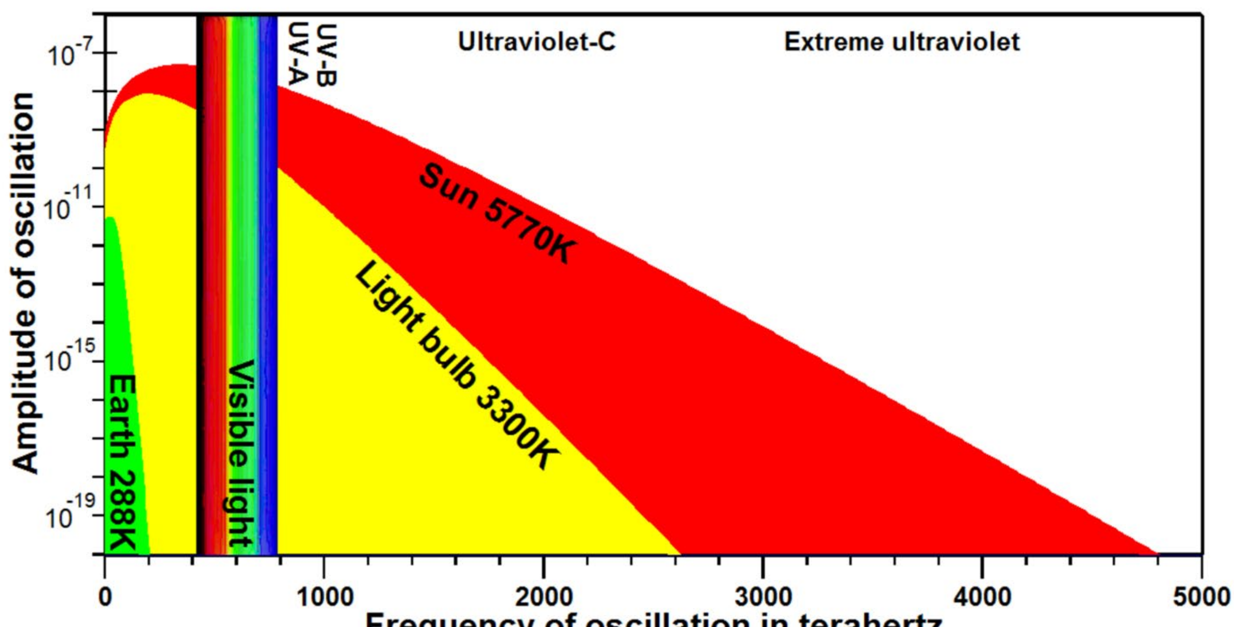

Figure S3. This plot of Planck's law with a linear x-axis for frequency, shows how radiation from warmer bodies contains considerably more high frequencies of oscillation than radiation from smaller bodies.

Human caused ozone depletion: From 1945 to 1970, average global temperatures increased very little (red bars, Figure S4) (*25*). In the 1960s, chlorofluorocarbon gases (CFCs) became popular for use as refrigerants, spray-can propellants, solvents, and foam blowing agents because they are so inert that they do not interact with most other chemicals. By 1970, a wide variety of products in spray cans had become available with CFCs as propellants. Emissions of these human-manufactured, chlorine-bearing gases into the troposphere began increasing around 1965 (green line) (*40*). By 1970, depletion of total column ozone measured at Arosa Switzerland (black line) (*41*) began increasing, soon followed by increases in average global temperatures (red bars). In 1974, Molina and Rowland (*42*)

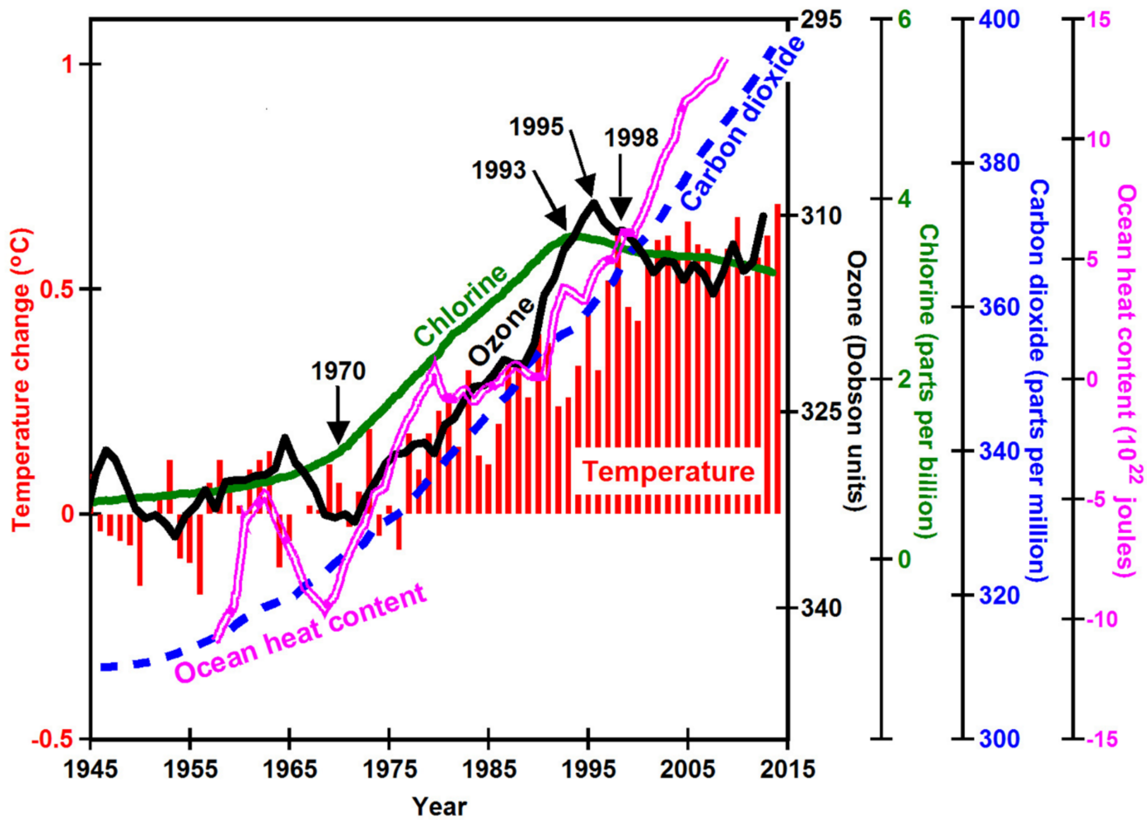

Figure S4. The increase in tropospheric chlorine (green line), caused by manufacturing of chlorofluorocarbon gases, led to increased ozone depletion (black line), which led to increased temperature (red bars).

discovered that CFCs reaching high into the stratosphere can be broken down by ultraviolet solar radiation, ultimately releasing atoms of chlorine, and that only one atom of chlorine can destroy 100,000 molecules of ozone in a catalytic process. After discovery of the Antarctic ozone hole in 1985 (*43*), scientists and politicians worked efficiently together under the Vienna Convention for the Protection of the Ozone Layer to develop the Montreal Protocol on Substances that Deplete the Ozone Layer mandating reduced production of CFCs, which became effective

January 1, 1989. By 1993, increases in chlorine stopped. By 1995, increases in ozone depletion stopped. By 1998, increases in temperature stopped, followed by the global warming hiatus from 1998 through 2013 (*44*). Humans appear to have caused the global warming beginning around 1970 by manufacturing CFC gases and to have stopped the increase in global warming in 1998 by reducing the manufacture of CFC gases.

Annual average ozone concentrations have remained depleted since 1998 by approximately 4% in northern mid-latitudes compared to pre-1970 concentrations. The resulting increased influx of ultraviolet-B radiation continues to increase ocean heat content (fuchsia double line) (*45*) because ultraviolet-B penetrates tens of meters into the ocean (*46*), from which depth the energy cannot be radiated back into the atmosphere at night.

Concentrations of carbon dioxide in the atmosphere (dashed blue line) (*47*) continue to rise with ocean heat content, which could be explained by reduced solubility of carbon dioxide in a warming ocean.

Major warming since 2014, appears to have been caused by the eruption of Bárðarbunga volcano in Iceland, the highest rate of basalt extrusion since 1783. Details are explained by Ward (*27-29*).

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