We have already solved the climate crisis

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Average global surface temperatures (red line in Figure 1) increased 1.1°F from 1975 to 1998 and an additional 0.5°F from 2014 through 2016. Otherwise temperatures have remained remarkably constant since 1945. Meanwhile emissions of carbon dioxide (purple dashed line) increased steadily at ever increasing rates, showing no correlation with the clear sudden changes in warming trends around 1975, 1998, 2014, and after 2016, which is the hottest year on record.

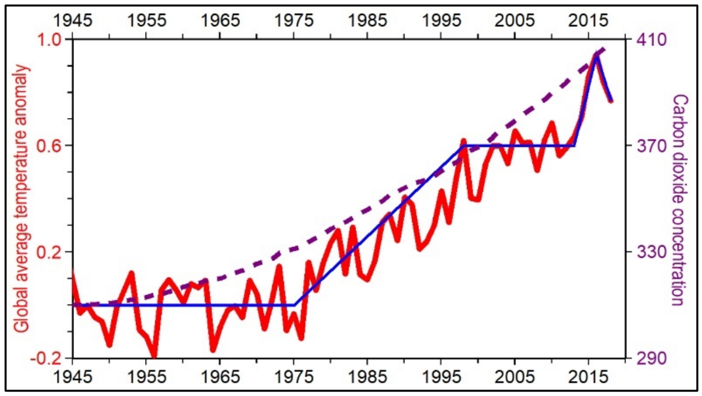

Figure 1. Global annual average temperatures (red line) changed very little except from around 1975 to 1998 and from 2014 to 2016. Concentrations of carbon dioxide (dashed purple line), on the other hand, rose steadily at ever increasing rates.

Warming since 1945 has caused environmental problems, but what worries climate scientists most is that their computer models of future climate predict several more degrees of warming by the end of this century. It is this predicted warming that world leaders hope to limit under the Paris Agreement. These climate models are all based on the assumption that global warming is caused primarily by increasing emissions of greenhouse gases.

Greenhouse-warming theory, however, is based on several assumptions that are turning out to be mistaken. The most significant mistake involves how we currently think about and calculate heat. Heat is what a body of solid matter must absorb to become hotter or lose to become cooler. More than two centuries ago, physicists started thinking of heat as an amount of thermal energy flowing each second through some surface in units of joules of energy per second per square meter. But an amount of what? What physically is heat? What physically is flowing? This definition of heat, which is still used today, is purely mathematical. It never addresses the physical issues of what heat is or how heat physically flows. Yet the purpose of physics is to determine what is physically happening in the world around us.

Thermal energy is kinetic energy of oscillation: Today, we observe that thermal energy in solid matter is the kinetic energy of oscillation of all the bonds holding matter together. These tiny, frictionless, molecular-scale oscillators are oscillating at room temperature at frequencies of trillions of cycles per second with amplitudes of oscillation measured in picometers (10^{-12} meters). There are more than one trillion, trillion (10^{24}) bonds in a mere gram of matter. Each of these oscillators on the surface of matter is thought to broadcast its frequency of oscillation through motion of charge, much like a radio station. Thermal radiation, then, physically, is the co-existence of all these frequencies of oscillation, forming what we call the electromagnetic spectrum with frequencies of oscillation ranging over twenty orders of magnitude from extremely low frequency radio signals, to infrared radiation, to visible light, to ultraviolet radiation, to X-rays, and finally to extremely high frequency gamma rays.

According to the widely-accepted Planck-Einstein relation, the kinetic energy of oscillation of each oscillator is equal to its frequency of oscillation times the Planck constant (top x-axis in Figure 2). Thus, thermal energy, physically, is the co-existence of all of these individual kinetic energies of oscillation—an extremely broad distribution of energies. It makes no physical sense to add these individual kinetic energies together to calculate a total energy because each energy simply applies to one specific molecular-bond-scale oscillator. Temperature is the single number that summarizes this broad distribution of kinetic energies of oscillation.

Planck's empirical law: In 1900, Max Planck, one of the fathers of modern physics, devised an equation by trial and error that calculates for thermal radiation the observed amplitude of oscillation at each frequency of oscillation as a function of the absolute temperature of the body of solid matter. This equation, now known as Planck's empirical law, shows the higher the temperature of solid matter, the greater the amplitude of oscillation at each and every frequency of oscillation and the higher the frequency of oscillation that has the greatest amplitude of oscillation.

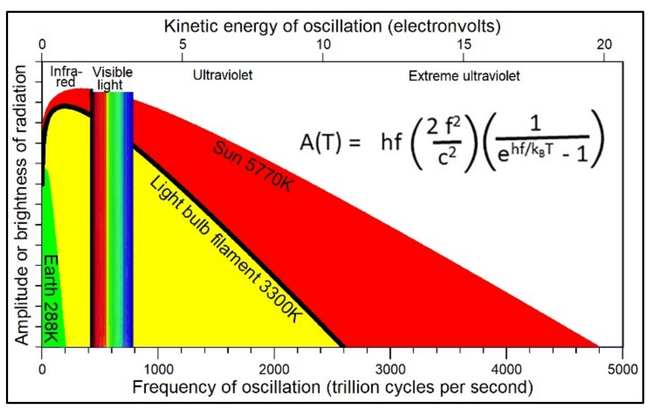

Figure 2. Planck's empirical law calculates for thermal radiation the observed amplitude of oscillation (A(T)) at each frequency of oscillation (f) as a function of the absolute temperature (T) of the radiating body. h is the Planck constant, k_B is the Boltzmann constant, and c is the velocity of light.

Planck's empirical law, as properly formatted, calculates the distribution of amplitudes of oscillation throughout the electromagnetic spectrum that must exist in a body of matter for that body to possess a specific temperature. Planck's law also shows unambiguously that when heat is absorbed by solid matter, it is the amplitude of oscillation that increases simultaneously at each and every frequency of oscillation throughout the whole electromagnetic spectrum. Therefore, when heat flows, it is the amplitude of oscillation at each frequency of oscillation that is physically flowing.

Amplitude of oscillation results in what we perceive as intensity or brightness of visible light. As we sit in front of a campfire, it is the amplitudes of oscillation at higher and higher frequencies of oscillation that increase most as a fire turns from warm to red hot to white hot.

Flow of heat is proportional to the difference in temperature: All plots of warming or cooling of solid matter approach their final temperature asymptotically. This universal observation shows that the rate of flow of heat decreases proportional to the decreasing difference in temperature. In other words, the change in temperature is greatest at first but decreases more and more slowly as the difference in temperature gets closer and closer to zero. You can plot a similar asymptotic curve if you plot the distance to a wall as you move half the remaining distance between you and the wall during each unit of time. You will approach the wall quickly, but you will never, in theory, reach the wall, although you will get extremely close.

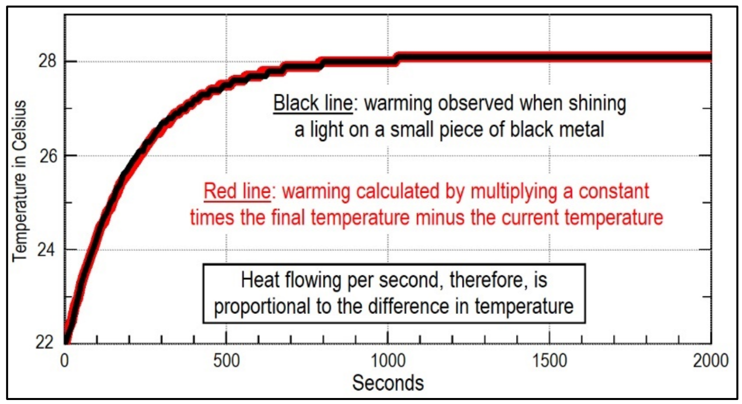

Figure 3. All plots of warming or cooling of solid matter approach their final temperature asymptotically showing that heat flows proportional to the difference in temperature.

When two bodies of matter that are identical in every way except for temperature are placed so that heat can flow between them, the resulting temperature is the average of the two initial temperatures, not the sum.

Averaging is done by resonance: This averaging is done in nature by resonance, one frequency at a time. Amplitude of oscillation is observed to flow by resonance. Resonance is a fundamental physical property of all oscillating systems. When two oscillators are oscillating at nearly the same frequency of oscillation, amplitude of oscillation is observed to decrease in the hotter body and increase in the cooler body often by the same amount. If the oscillators are physically touching in some way, we describe resonance as conduction. If the oscillators are separated by air or space, but are within line-of-sight, resonance is observed to occur in a very short length of time that we currently think of as being related to the velocity of light. But no physical substance is travelling at some velocity through space from emitter to absorber.

Resonance is observed to occur by line-of-sight even over galactic distances. Frequencies of oscillation do not change with distance, but amplitudes of oscillation are observed to decrease with the distance squared. We do not fully understand how resonance of molecular-bond-scale oscillators works over such distances, but constructive interference plays the key role. A simple example of resonance caused by constructive interference is when you push a child on a swing. If you push at the same frequency that the swing is swinging, the two frequencies constructively interfere, causing the amplitude of oscillation of the swing to increase. If you push at any other frequency, the amplitude of oscillation of the swing will decrease as the two frequencies destructively interfere with each other.

Resonance is what Albert Einstein referred to as "spooky action at a distance" where something over there interacts with something over here, but there is no observed physical connection between them. Resonance is all around us. We see by resonance as frequencies of oscillation of visible colors cause three slightly different cells in the cones of our eyes to resonate in slightly different ways so that our brains can distinguish more than a million different shades of color. We hear by resonance as different sizes of hair-like cilia in our inner ears resonate to audible frequencies of sound. Resonance as heat flows is one of the most common physical actions taking place throughout the universe.

Heat physically is the flow of amplitude of oscillation: Thus, thermal energy within solid matter is physically the result of oscillation of all the bonds holding matter together. Planck's empirical law calculates the observed amplitude of oscillation for each frequency of oscillation as a function of the absolute temperature of a body of solid matter. Heat physically is the spontaneous and simultaneous flow of amplitude of oscillation at each and every frequency of oscillation throughout the electromagnetic spectrum via resonance. This flow at each frequency is only from greater amplitude to lesser amplitude, which from Planck's law is from higher temperature to lower temperature.

Heat is an intensive physical property: In 1917, Richard Tolman proposed that the physical properties of matter should be grouped as extensive properties describing the observable, measurable extent of matter and intensive properties resulting from the physical nature or motion of matter at the atomic and molecular level. Extensive physical properties include length, area, mass, volume, weight, and quantity or amount. Intensive physical properties include temperature, heat, thermal energy, frequency of oscillation, amplitude of oscillation, density, color, hardness, and pressure.

The fundamental difference between these two types of physical properties when combining or subdividing different macroscopic bodies of matter is that extensive physical properties occur as physical quantities or amounts that can be added together or subtracted from each other while intensive physical properties occur as levels on arbitrary scales. It makes no physical sense to add or subtract these levels.

Temperature, for example, is measured as a level on an arbitrary scale such as Celsius or Fahrenheit. If you subdivide a body of matter, all pieces of any size will have the same initial temperature. If you add these pieces back together, the restored body will still have the same temperature. Similarly, if you add red light to blue light, you do not get ultraviolet light. You simply get some red light coexisting with some blue light.

Thermal energy and heat are clearly intensive physical properties. Greenhouse-warming theory, however, assumes that they are extensive physical properties measurable in amounts of joules per second flowing through a surface area, that these amounts are additive, and that that you can integrate or add up thermal energy as a function of frequency. Greenhouse-warming theory assumes that Earth will get warmer if Earth absorbs a greater amount of heat from Sun than it loses to space. But intensive physical properties do not occur as physical amounts that are additive. In reality, if Earth gets warmer, the difference in temperature between Earth and space increases, which means the flow of heat to space will increase.

Greenhouse-warming theory also assumes that heats quantified as radiative forcings are additive and that the longer heat flows, the hotter the body is expected to become. In reality, heat does not physically exist in amounts, heat is not additive, and a body cannot become warmer than the source of heat because heat only flows from higher temperature to lower temperature at a rate proportional to the difference in temperature. Thermal energy, heat, and temperature are all clearly intensive physical properties that are each not additive. Greenhouse-warming theory is not only mistaken—it is not even physically possible.

How air is heated: There are only three ways observed every day that air can be heated naturally as shown in Figure 4: first by conduction as air touches Earth's sun-warmed surface and convects upward, second by photodissociation in the stratosphere where solar ultraviolet radiation dissociates primarily oxygen and ozone, and third by photoionization in the ionosphere where high-energy solar radiation ionizes available gases. Photodissociation and photoionization convert molecular bond kinetic energy of oscillation efficiently and completely into kinetic energy of linear motion, which is directly proportional to air temperature according to the kinetic theory of gases. Infrared radiation emitted by Earth and absorbed by greenhouse gases does not have enough energy to dissociate anything. There is no known physical way that increases in emissions of greenhouse gases absorbing low-energy infrared radiation can warm Earth's surface. In fact, no body of matter can be warmed in any way by its own radiation because its own radiation does not contain the greater amplitudes of oscillation at all frequencies of oscillation required according to Planck's empirical law to increase temperature. Heat simply cannot flow physically from warm to warmer.

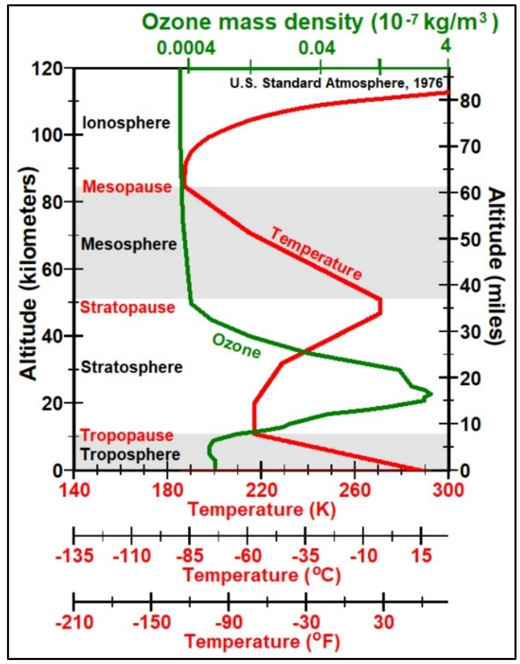

Figure 4. Air is heated in the stratosphere by continual dissociation primarily of oxygen and ozone. Air is heated in the ionosphere by ionization of available gases.

A depleted ozone layer is observed to heat air near Earth's surface: The ozone layer in Earth's lower stratosphere, 10 to 40 kilometers above Earth, is formed by photodissociation of oxygen initially by solar ultraviolet-C radiation, formation of ozone, and photodissociation of ozone back into molecular and atomic oxygen by ultraviolet-B radiation in an endless cycle as long as ultraviolet-B radiation is available. The ozone layer normally absorbs nearly all available solar ultraviolet-B radiation. When the ozone layer is depleted by some chemical process, more ultraviolet-B is observed to reach Earth's surface where it dissociates ground-level ozone pollution, causing the greatest warming in populated areas where pollution is most concentrated. Ultraviolet-B radiation also has enough energy to cause sunburn, skin cancer, cataracts, and mutations.

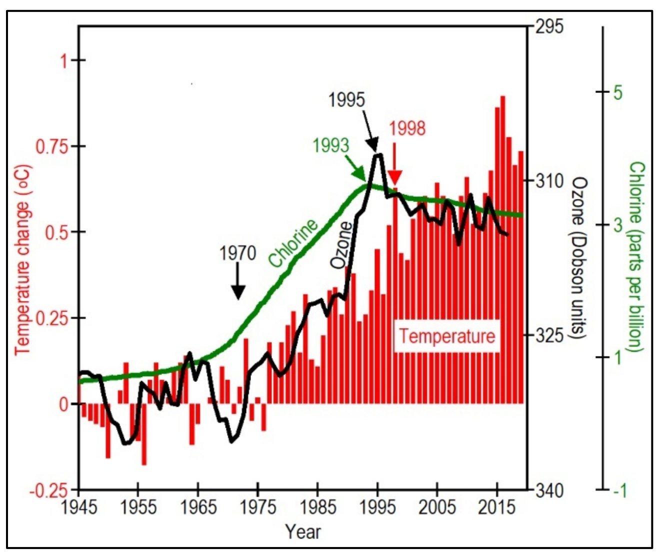

Figure 5. As concentrations of CFC gases increased in the troposphere (green line), ozone depletion (black line) and temperatures (red bars) increased.

Ozone depletion clearly heated Earth from 1975 to 1998: In the 1960s, manufactured chlorofluorocarbon gases (CFCs) became widely used as spray-can propellants, refrigerants, solvents, and foam blowing agents (green line in Figure 5). Around 1975, ozone depletion (black line) and average global surface temperatures (red bars) began increasing. In 1974, scientists discovered that CFCs are broken down by ultraviolet radiation in the stratosphere, freeing atoms of chlorine and that one atom of chlorine, under the right conditions, can destroy 100,000 molecules of ozone. This work earned the Nobel Prize in Chemistry in 1995.

The United Nations ultimately passed the Montreal Protocol on Substances that Deplete the Ozone Layer, severely restricting production of CFCs, that took effect in 1989. By 1993 the increase in atmospheric concentrations of CFCs stopped. By 1995, the increase in ozone depletion stopped. By 1998, the increase in global temperatures stopped. The world warmed 0.6°C from 1975 to 1998. Humans caused the warming by producing CFCs and humans stopped the increase in warming by passing the Montreal Protocol. Without the Montreal Protocol (dashed green line), Earth would probably be at least 0.5°C warmer today.

Basaltic volcanic eruptions heated air from 2014 to 2016: The only other period of warming since 1950 followed the 2014 eruption of Bárðarbunga volcano in central Iceland, the largest eruption of basaltic lavas in 230 years. Global temperatures rose 0.3°C from 2014 to 2016, nearly five times faster than the warming caused by CFCs. 2016 is still the hottest year on record. Temperatures remained high following the 2018 eruption of lavas from Kilauea volcano in Hawaii, which covered less than half the area as those extruded from Bárðarbunga. Depletion of the ozone layer increased for two years following the end of each eruption apparently due to megatons of chlorine and bromine gases emitted from the 1200°C basaltic lavas.

Figure 6. Basaltic lavas flowed from Bárðarbunga volcano in central Iceland, covering 85 square kilometers in six months.

Throughout Earth history, essentially all periods when well-dated major basaltic eruptions occurred were contemporaneous with global warming—the more extensive the eruption, the greater the warming. At least twice in Earth history, basaltic lavas covered areas of land almost as large as the United States and oceans became as hot as hot tubs. Ozone depletion explains observed global warming in considerable detail.

In the future, global temperatures will most likely decrease slowly: Numerous climate models summarized by the Intergovernmental Panel on Climate Change (IPCC) predict global average annual temperatures will increase several degrees by 2100. These models also suggest that if we take major action to reduce greenhouse-gas emissions, future warming might be limited (blue line). But as discussed above, greenhouse-warming theory is based on several assumptions about heat that turn out to be mistaken. There is no known physical way that increases in concentrations of greenhouse gases could cause observed or predicted global warming.

Ozone-depletion theory, on the other hand, predicts that global temperatures will generally decrease in future decades as the ozone layer slowly recovers (green line). There are actions we can take to speed this recovery. By passing the Montreal Protocol, humans have already solved the major part of the climate crisis caused by humans.

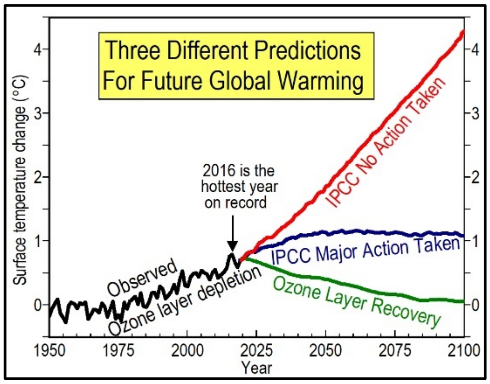

Figure 7. Average global temperatures are expected to decrease slowly over future decades as the ozone layer recovers.

Large basaltic lava eruptions could cause short-term warming, but for the sizes of eruptions likely to occur, the ozone layer typically recovers within a few years after these eruptions stop. Thus, unless there is some unusually large depletion of the ozone layer, global temperatures over the next few decades will most likely decrease slowly back towards pre-1975 levels.

Average surface temperatures may not quite reach pre-1975 levels because the oceans have been warming and will continue to warm as long as ozone remains depleted. But when the warmed surface waters are mixed with the cold ocean bottom waters at an average depth of 12,100 feet, the net increase in ocean temperature will be small.

The crisis in climate science: Thousands of scientists are convinced, based on climate science as they currently understand it, that observed global warming is caused by increasing emissions of greenhouse gases. Many genuinely fear that if we do not reduce emissions immediately, the climate system could pass tipping points, threatening our very existence. They point to detailed analyses of extensive data sets, described in tens of thousands of peer-reviewed papers that document the correlation between increasing greenhouse-gas emissions and increasing temperature. They point to numerous, very sophisticated climate models, all of which give similar results. They point to the largest consensus ever reached among scientists and scientific organizations developed for the purpose of convincing world leaders to take action to reduce greenhouse gas emissions immediately. They fear that any questioning of greenhouse-warming theory could delay action. They simply cannot conceive of the possibility that there could be the slightest problem with greenhouse-warming theory.

Many scientists think that their job is to show how new observations fit and improve well-accepted theories. It is much easier to get funding and to publish papers that build on well-established ideas than it is to propose a new idea. If inconsistencies show up, it is only human to seek ways to rationalize them. It takes a scientific revolution to change well-accepted theories.

Unfortunately, none of the participants in the climate consensus and none of their peer-reviewed papers seriously question the physics of heat or how heat physically flows. Most climate scientists and most physicists think that thermodynamics as developed long ago is beyond reproach. Thermodynamics has worked adequately for small differences in temperature but fails catastrophically for differences as large as 15°C for Earth and 5500°C for Sun. Current approaches to thermodynamics do not take into account the fundamental differences in the physical properties of heat as a function of temperature shown clearly by Planck's empirical law (Figure 2).

Greenhouse-warming theory was first quantified in 1896 by Svante Arrhenius, a physical chemist. Just four years later, Knut Ångström, a radiation physicist and friend of Arrhenius, showed by experiments that this theory did not seem to be correct. In 1938, Guy Callendar, a steam engineer, resurrected greenhouse-warming theory from the trash bin of history, summarily dismissing Ångström's work in one short sentence. In 1965, a national report primarily by geochemists raised this theory to national attention. By 1981, climate scientists were stressing the effect of greenhouse gases on future health and safety, raising the emotional intensity of the research. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was formed under the United Nations for the purpose of demonstrating consensus behind greenhouse-warming theory. It is notable that no physicist since Ångström has questioned the veracity of the physics of greenhouse-warming theory. It is the physics of what heat is and how heat flows that determines by how much temperature increases.

As described above, the problem gets down to how we visualize things happening physically at the molecular and atomic level. This is a problem that has preoccupied physicists studying quantum mechanics and particle physics for more than a century. What I propose leads to a major revolution in physics. Normally it would take years to decades for such a revolution in science to take hold. But in this case, we do not have the time because world leaders are being urged to spend tens of trillions of dollars immediately to reduce greenhouse-gas emissions. Climate scientists need to reevaluate their recommendations immediately before greenhouse-warming theory becomes the most expensive mistake ever made in science. My fellow scientists burying their heads in the sands of consensus is not a viable option.

More detailed information is available as follows:

Article: [Fundamental errors regarding the physics of heat]

Article: We have already solved the global warming crisis
Article: The crisis in climate science
Book: What Really Causes Global Warming? Greenhouse Gases of Ozone Depletion?
Paper: The photochemistry of gas molecules in Earth's atmosphere determines the structure of the atmosphere and the average temperature at Earth's surface
Paper: Ozone depletion explains global warming
Paper: On the Planck-Einstein relation
Paper: Heat does not physically flow in the ways assumed by greenhouse-warming theory
Video: Listen up about climate change if you can bear it. I have some good news (1 minute)
Video: A most unexpected revolution in the physics of heat (13 minutes)
Video: TEDx talk: Volcanoes : A forge for climate change (18 minutes)
Video: The most expensive mistake ever made in the history of science (16 videos each 5 to 12 minutes)
Videos of talks at scientific meetings
Website: WhyClimateChanges.com
Website: OzoneDepletionTheory.info
Website: JustProveCO2.com
Website: Physically-Impossible.com

Dr. Peter Langdon Ward earned a BA at Dartmouth College and a PhD at Columbia University in geophysics. He worked 27 years at the United States Geological Survey, leading a group of more than 140 scientists and staff and playing a lead role in establishing and initially leading a major national research program. He chaired a committee at the White House, worked on a committee for Vice President Gore, and testified before Congress in 2004 and in 1978. He earned two national awards for explaining science to the public. He and his work were featured on Good Morning America. More details about Ward can be found at WhyClimateChanges.com/About. Ward has worked full time in retirement, at his own expense, since 2006, carefully reexamining all the evidence and theories for why climate has changed throughout Earth history.