Policy Brief The Heartland Institute

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A Climate Science Tutorial Prepared for Hon. William Alsup

By Jay Lehr, Ph.D., Kenneth Haapala, Patrick Frank, Ph.D., and Patrick Moore, Ph.D.[1]

Introduction

On March 9, 2018, Federal District Court Judge William Alsup asked legal counsel for the parties in *The People of the State of California* v. *BP P.L.C, et al.* to present a tutorial on climate science during a five-hour hearing before the court, scheduled to take place on March 21.

> Although completed too late to submit to the judge, this document stands on its own as a good primer on climate change.

Judge Alsup asked each side's counsel to present an overview of current climate science and more specifically to answer eight questions posed by the judge. Judge Alsup also asked plaintiffs' counsel to produce documents related to plaintiffs' claim that ExxonMobil, BP, Chevron, and other oil companies conspired to hide evidence of an impending climate disaster.

Motivated by concern that neither party would present an objective overview of climate science, The Heartland Institute convened a team of scientists to write their own answers to the judge's

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questions. Unfortunately, that effort was completed too late to submit to the judge. However, the resulting document, presented here, stands on its own as a primer on climate change for anyone looking for a sound foundation in the basic science.

In this *Policy Brief*, we offer first an overview of the current state of scientific understanding of the human impact on Earth's climate, followed by some commentary providing context for the eight questions asked by Judge Alsup. Answers to the judge's questions follow, and then a comment regarding his request for documentation of the claim that the oil industry conspired to mislead the public.

The Heartland Institute helped an independent group of scientists submit their own *amicus brief*, which was received by the judge's deadline.[2] In response to that brief, plaintiffs filed a statement with Judge Alsup filled with inaccurate claims meant to discredit the *amici* and The Heartland Institute. The final section of this *Policy Brief* presents a reply by Jay Lehr to the charges made against The Heartland Institute. The qualifications of the authors appear on page 23.

1. Overview of the Current State of Science

An accurate overview of the current state of scientific understanding of the human impact on Earth's climate supports the following findings:

(1) Current climate change is indistinguishable from natural variations. Any human impact is invisible within the available science.[3] We know this in part because larger and more rapid past changes in climate preceded human use of fossil fuels by thousands of millennia.[4]

(2) Much recent climate modeling places "climate sensitivity" (the effect of a doubling of atmospheric CO_2 concentrations) at just 1 to 2 degrees Celsius, not the 1.5 to 4.5 degrees estimated by the Intergovernmental Panel on Climate Change.[5]

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[2] Monckton, Soon, Legates, Briggs, Limburg, Jeschke, Henney, Whitfield, and Morrison, Amici Curiae Brief: The people of the State of California vs. BP P.L.C. *et al.*, submitted to the U.S. District Court, Northern District of California, San Francisco District on March 19, 2018.

[3] G.G. Anagnostopoulos, D. Koutsoyiannis, A. Christofides, A. Efstratiadis, and N. Mamassis, "A Comparison of Local and Aggregated Climate Model Outputs with Observed Data," *Hydrological Sciences Journal* 55 (2010): 1094–110; P. Frank, "Negligence, Non-Science, and Consensus Climatology," *Energy & Environment* 26 (2015): 391–416.

[4] J. Adams, M. Maslin, and E. Thomas, "Sudden Climate Transitions During the Quaternary," *Progress in Physical Geography* 23 (1999): 1–36.

[5] "IPCC Revises Climate Sensitivity," *Scientific American*, September 2013. (The new range is 1.5° to 4.5°C.) See also C. Monckton, W. W-H. Soon, D. Legates, and W.M. Briggs, "Keeping It Simple: The Value of an Irreducibly Simple Climate Model," *Science Bulletin* 60, no. 15 (2015): 1378–90), where in footnotes 7 to 33, 27 peer-reviewed articles are identified placing climate sensitivity at 1 to 4 degrees Celsius. See also Roy W. Spencer and William D. Braswell, "The Role of ENSO in Global Ocean Temperature Changes during 1955–2011," *Asia-Pacific Journal of Atmospheric Science* 50, no. 2 (2014):

(3) Claims of extreme floods, hurricanes, droughts, and wildfires attributable to man-made global warming are not supported by science or data. Long-term records show no increases, and in some cases show decreases, in the frequency and intensity of such events.

(4) Science and the historical record both say weather in a warmer world is likely to be less extreme, not more extreme. This would produce more benefits than harms for humankind as well as the natural world.

(5) The United Nations' Intergovernmental Panel on Climate Change (IPCC), the source for most of the alarmist literature on the subject, is politicized and corrupted, and its reports are not peer-reviewed.[6]

(6) Former President Barack Obama enlisted the Environmental Protection Agency and other agencies of the federal government to support his campaign to extinguish coal use, and this campaign negatively affected the reliability of public statements of research findings and their implications for public policy.

An honest assessment of climate science concludes there is no general agreement on the causes or consequences of climate change. Such a finding should lead a fair and balanced adjudication that there is no man-made climate crisis on the horizon. Arguing to assign blame for a non-existent problem is unnecessary and irrelevant.

These findings are supported by the work of many independent scholars, and are perhaps best collected and presented in the work of the Nongovernmental International Panel on Climate Change (NIPCC), an international network of scientists assembled to critique the work of the UN's IPCC. The NIPCC reports cite more than 3,000 peer-reviewed studies that contradict the alarmist narrative of a man-made climate disaster. While the reports themselves run to more than 3,000 pages, accessible summaries for policymakers can be found online here:

Climate Change Reconsidered 2009 Summary for Policymakers
Climate Change Reconsidered 2011 Summary for Policymakers
Climate Change Reconsidered 2013 Summary for Policymakers
Climate Change Reconsidered 2014 Summary for Policymakers

229–37; Hermann Harde, "Radiation Transfer Calculations and Assessment of Global Warming by CO_2," *International Journal of Atmospheric Sciences* Volume 2017, Article ID 9251034, 30 pages; Willie Soon, Ronan Connolly, and Michael Connolly, "Re-evaluating the Role of Solar Variability on Northern Hemisphere Temperature Trends Since the 19th Century," *Earth-Science Reviews* 150 (2015): 409–52.

[6] Donna Laframboise, *The Delinquent Teenager Who Was Mistaken for the World's Top Climate Expert* (Toronto, Ontario: 2011); Bernie Lewin, *Searching for the Catastrophe Signal: The Origins of The Intergovernmental Panel on Climate Change* (London, England: GWPF Books, 2017).

2. Background and Context

The answers to Judge Alsup's eight questions about the science of climate change must be placed in a sensible context. Below is an effort to do so.

Energy Flows: Air temperature is governed by energy flow: what slows or intensifies energy flow from the sun to Earth and from Earth back into space. It is not straightforward. There are several sources of instability and/or uncertainty.

The principle source of energy is the sun, providing irradiance, solar wind (plasma), and solar magnetism. The changing intensity of the sun, the changing orbit of Earth, and the slowly changing tilt of Earth's rotation axis all affect the climate. Also, galactic cosmic rays may play a role. These are external sources of instability and uncertainty.

Thus, we have natural variation even without human influence, and some of the mechanisms (like clouds) are very poorly understood. Complicating the issue even further is that Earth's rotation produces gyres and flows in two dynamic fluids – the atmosphere and the oceans. Oceans cover more than 70 percent of Earth's surface. The fluid dynamics of these systems is not well understood. Coupled with rotation, the flows in these two dynamic fluids create internal variability in the climate system. The exchange of energy within or between the oceans and the atmosphere can cause one or the other to warm or cool even without any change in the heat provided by the sun.

Carbon dioxide (CO_2) is the atmospheric gas most readily absorbed by water, such as the oceans and rain. Cold water more readily absorbs gases than does warm water. When the oceans cool they absorb more atmospheric CO_2, when they warm they release CO_2, increasing its concentration in the atmosphere. Consequently, as Earth has alternately experienced cold glaciations over the last million years, atmospheric CO_2 levels have varied, with warm "interglacials" causing higher atmospheric CO_2 levels due to oceanic outgassing, and colder glacial periods causing lower atmospheric CO_2 levels due to oceanic absorption. This variation in the composition of the atmosphere over the last 800,000 years is evident in ice cores, such as those taken at Vostok and "Dome C" in Antarctica.

In the ice core records, CO_2 level changes (measured from air bubbles in the ice) generally *follow*, rather than precede, temperature changes (inferred from isotopic evidence), by hundreds of years. Thus, although CO_2 undoubtedly contributed to the "hysteresis" between glacial (cold) and interglacial (warm) periods, through positive feedback with ocean temperatures, CO_2 cannot have been the "control knob" which caused those glaciation/deglaciation cycles.

Based on geology, for more than 2.5 million years (the Pleistocene) the world has been in a cold period with long glaciations ("ice ages") interrupted by relatively brief warm periods of typically 10,000 to 15,000 years. We have been in the Holocene warm period for about 11,500 years. Earth's orbital changes, known as Milankovitch cycles, are the generally accepted explanation for these broad changes in temperatures. What occurred earlier than 2.5 million years ago is not presently germane.

Recent warming and cooling: Within the Holocene, there is strong physical evidence for global warming and cooling, though less extreme than the Milankovitch glaciation cycles. The current warm period was preceded by the Little Ice Age (1300-1850 AD), which was preceded by the Medieval Warm Period or Medieval Climate Optimum (800 to 1300 AD), which was preceded by the Dark Ages Cold Period (400 to 800 AD), which was preceded by the Roman Warm Period or Roman Climate Optimum (250 BC to 400 AD). Before that there is evidence of a Minoan Warm Period (~2500 BC) and a thousand-year Holocene Climate Optimum about 6,500 years ago. Most or all of those "warm periods" or "climate optimums" are thought to have been at least as warm as, and likely warmer than, Earth's current climate.

Greenhouse gases: The issue of greenhouse gas warming centers on how much of the energy flow passing through the atmosphere is obstructed by atmospheric gases. Many laboratories have repeated tests for more than a century, with handbooks published on the results since the 1920s. All gases absorb energy at various wavelengths, but the gases in Earth's atmosphere are transparent to the visible wavelengths, meaning that energy from visible light is not absorbed by these gases.

Absorption properties depend on the gas. Some gases, such as nitrogen and oxygen, absorb energy in the ultraviolet spectrum – with wavelengths shorter than visible light. However, greenhouse gases, such as water vapor, carbon dioxide, methane, etc., absorb energy in the far infrared spectrum (a/k/a longwave infrared or LWIR), with wavelengths much longer than visible light and so invisible to the human eye.

The Earth gives off much more LWIR than it receives, so gases which absorb LWIR have a warming effect, by preventing the escape of some of the LWIR radiation to space. If all the radiation of a particular wavelength is absorbed, the wavelength is said to be "saturated."

Without "greenhouse gases" absorbing infrared radiation, Earth's surface temperature would average about –18°C (0°F), thus much colder than current temperatures and largely uninhabitable. The day-night temperature range would be huge, similar to the moon. In the Holocene, the average temperature has been about 15°C (59°F), with periods of warming and cooling. The net effect of the greenhouse gases is to increase the content of thermal energy in the atmosphere, thereby warming the surface of the planet.

Laboratory tests show the effect of greenhouse gases varies by type of gas. The dominant greenhouse gas is water vapor. It absorbs radiation from a broad range of wavelengths in the far infrared range. Water vapor is also the most abundant greenhouse gas, consisting of about 1 percent to 2 percent of the atmosphere near the surface (less in the deserts, more in the tropics). With increasing altitude water vapor "condenses out" and falls as rain or snow, and the concentration of water vapor falls to a few parts per million. At about 10 km (33,000 feet), CO_2, which does not "condense out," becomes the most abundant greenhouse gas.

CO_2 constitutes about 4 parts per 10,000 (0.04 percent, or 400 parts per million) of the atmosphere. Although that doesn't sound like much, LWIR absorption by CO_2 is already largely saturated. Only at the fringes of CO_2's 13–17 μm absorption band does additional CO_2 have

much effect on LWIR absorption, so additional CO_2 has a logarithmically declining warming effect per unit of added gas.

Source of Controversy: The current controversy over man-made global warming would not exist if it were not for a 1979 report published by the National Academy of Sciences, called the Charney Report.[7] This report conceded the increase in temperatures from a doubling of atmospheric CO_2 would be modest, probably not measurable at that time. However, the Charney Report went on to speculate that the modest warming from CO_2 would be amplified through positive feedback, because the warming would cause an increase in atmospheric water vapor (which is also a greenhouse gas). The report speculated that, with water vapor feedback, a doubling of CO_2 would increase atmospheric temperatures sufficiently to result in an increase of surface temperatures by 3°C plus or minus 1.5°C (by 3° to 8°F). The Charney Report states:

> Our estimate is based primarily on our review of a series of calculations with three-dimensional models of the global atmospheric circulation, which is summarized in Chapter 4. We have also reviewed simpler models that appear to contain the main physical factors. These give qualitatively similar results.[8]

A first order approximation of the effect of water vapor feedback can be calculated by assuming constant relative humidity, but that assumption results in only a small amplification. The scale of the amplification of CO_2 warming by an increase in water vapor, and the effects of other feedback mechanisms, both positive and negative, often estimated on the basis of highly questionable models, are core disputes in the debate over anthropogenic climate change. Generally, the climate model tests have focused on consistency rather than on accuracy.

Interestingly, in its latest assessment report (AR5, 2014) the IPCC retains the estimate of 3°C plus or minus 1.5°C, but drops any reference to the previously diagnostic tropospheric water vapor amplification, the so-called tropospheric hot spot. These model calculations continue in IPCC reports and reports by the U.S. Global Change Research Program (USGCRP). However, the estimates are not based on hard evidence from laboratory testing, and now the theoretical reasoning for amplification has been quietly dropped for lack of real-world evidence. All that remains are questionable computer models.[9]

Use of Proper Data to Test: When the Charney Report was published, comprehensive measurements of global atmospheric temperatures did not exist. Thus, there were no data to

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[7] *Carbon Dioxide and Climate: A Scientific Assessment*, Report of an Ad Hoc Study Group on Carbon Dioxide and Climate, Woods Hole, Massachusetts, July 23–27, to the Climate Research Board, Assembly of Mathematical and Physical Sciences, National Research Council (Washington, DC: National Academy of Sciences, 1979).

[8] *Ibid.*, p. 2.

[9] On the inadequacy of climate models, see Richard S. Lindzen, "Can Increasing Carbon Dioxide Cause Climate Change?" *Proceedings of the National Academy of Sciences* 94 (August 5, 1997): 8335–42; Craig D. Idso, Robert M. Carter, and S. Fred Singer, *Climate Change Reconsidered II: Physical Science*, Chapter 1 (Chicago, IL: The Heartland Institute, 2013), pp. 7–122; and Christopher Essex and Anastasios A. Tsonis, "Model Falsifiability and Climate Slow Modes," *Physica A: Statistical Mechanics and its Applications* 502 (forthcoming July 15, 2018): 554–62.

support the speculated amplification or to test it. In 1990, Roy Spencer, Ph.D. and John Christy, Ph.D. published a method to use data collected by satellites to calculate comprehensively global atmospheric temperatures. The data begin in December 1978, and have been intensively quality controlled.[10]

We now have almost 40 years of comprehensive satellite temperature data of the atmosphere, where the greenhouse gas effect occurs. These data are published monthly for public review and are independently supported by direct temperature measurements from weather balloons from four sources. The greenhouse effect occurs in the atmosphere, thus atmospheric temperatures should be the data used to test the claim.

Christy has testified repeatedly before Congress that satellite data show climate models overestimate observed atmospheric warming by 2.5 to 3 times.[11] The U.S. government-funded models overestimate atmospheric warming by even more than 3 times. Only the model by the Institute of Numerical Mathematics, in Moscow, comes close to the observed data.

There is no justification for publicly funded entities to continue to use procedures and models that are known to be wrong. When government entities use wrong information to enact policy, they are acting against the public interest.

Atmospheric vs. Surface Data: The atmospheric data record shows volcanic activity creates a cooling (in the early part of the record) and El Niños create a warming (in the later part of the record). However, such influences can be eliminated from the published data using conventional statistical methods.

The surface temperature measurements are also influenced by volcanoes and El Niños. However, they have many other influences that are poorly recognized. These include changing ocean dynamics, human influences such as change in land use, urbanization, farming, and land clearing, and changing instrumentation and instrument location. Further, surface temperature data are far less complete than satellite data and have poor global coverage. There is no good reason for the continued use, by government entities concerned with global warming from anthropogenic greenhouse gases, of global temperature indices based on surface temperature measurements, except for dates before the advent of satellite measurements, because the satellite temperature data are superior.[12]

Government Spending: At various times the Government Accountability Office, Congressional Research Service, and the Obama White House have reported to Congress on their estimates of

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[10] See J. Christy, R. Spencer, W.D. Braswell, and R. Junod**, "**Examination of Space-based Bulk Atmospheric Temperatures Used in Climate Research," *International Journal of Remote Sensing* 39, no. 11 (March 8, 2018).

[11] See, for example, John Christy, Testimony before the U.S. House Committee on Science, Space & Technology, March 27, 2017.

[12] Benjamin D. Santer, *et al.,* "Volcanic Contribution to Decadal Changes in Tropospheric Temperature," *Nature Geoscience* 7, no. 3 (February 23, 2014): 185–189. "Satellite TLT data have near-global, time-invariant spatial coverage; in contrast, global-mean trends estimated from surface thermometer records can be biased by spatially and temporally non-random coverage changes."

government-funded research into what they define as climate science. Eliminating double counting, the total is more than $40 billion from 1993 to 2016. There have been no recent spending reports. Despite this enormous investment, government-funded climate science has been unable to find physical evidence justifying the claim that a doubling of CO_2 will cause a warming greater than that reported by laboratories for 100 years.

Summary: The key issues to the controversy are: 1) whether direct atmospheric measurements or indirect surface measurements are the proper data to measure the greenhouse effect, and 2) whether there is any strong physical evidence that carbon dioxide is causing dire greenhouse gas warming.

3. Answers to Judge Alsup's Eight Questions

Answers to the eight questions posed by Judge Alsup are presented below. Emphasis is placed on data, not speculation. Data come from repeated laboratory tests or repeated observations that include all information, including that which refutes a hypothesis. Computer models that are not rigorously tested or fail basic tests are not data, no matter how often repeated. Global climate models have not been rigorously tested for reliability.

1. What caused the various ice ages (including "the Little Ice Age" and prolonged cool periods) and what caused the ice to melt? When they melted by how much did sea level rise?

Major ice ages are caused by orbital characteristics of Earth such as its elliptical orbit and tilt, which increase and decrease solar energy hitting the atmosphere and surface. Surface irradiance has varied dramatically through Earth's history, with extensive periods of ice and glaciation lasting millions of years. Minor warming and cooling periods are likely caused by changes in solar activity and changes in cloudiness, altering the amount of radiation reaching the surface.

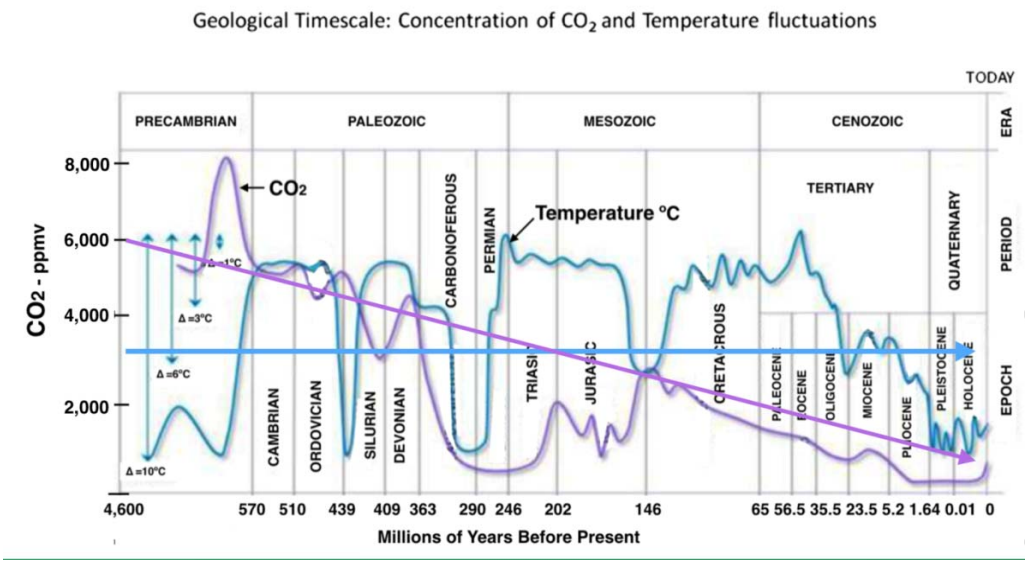
It is important to differentiate between "Ice Ages" such as the Pleistocene Ice Age, which began 2.6 million years ago, and "major glaciations" within an Ice Age. There have been many of the latter during the past 2.6 million years. There also have been more modest warming and cooling periods during interglacial periods such as the present Holocene. For example, the "Little Ice Age" began about 600 years ago and ended around 1850.

The Ice Age before the present Pleistocene Ice Age occurred 250 million years ago. During the 250 million years between then and now, Earth was always much warmer than it is today. During this Pleistocene Ice Age, which began "only" 2.6 million years ago, there have been many major glaciations. The last one began winding down 20,000 years ago and ended about 10,000 years ago. Since then we have been in the interglacial period known as the Holocene. During this age global temperatures began to decline 5,000 years ago at the onset of the Neoglacial Period.

If the history of the past few million years repeats itself, it appears we are already beginning the slow descent over the next 80,000 years into the next major glaciation, when all of Canada, Scandinavia, and northern Russia could again be buried under 1 to 3 kilometers of ice.

The figures below help get the geological time perspective. Figure 1 shows the past 500 million years, showing that, on that time scale, temperature (blue) and CO_2 (purple) are completely without correlation.

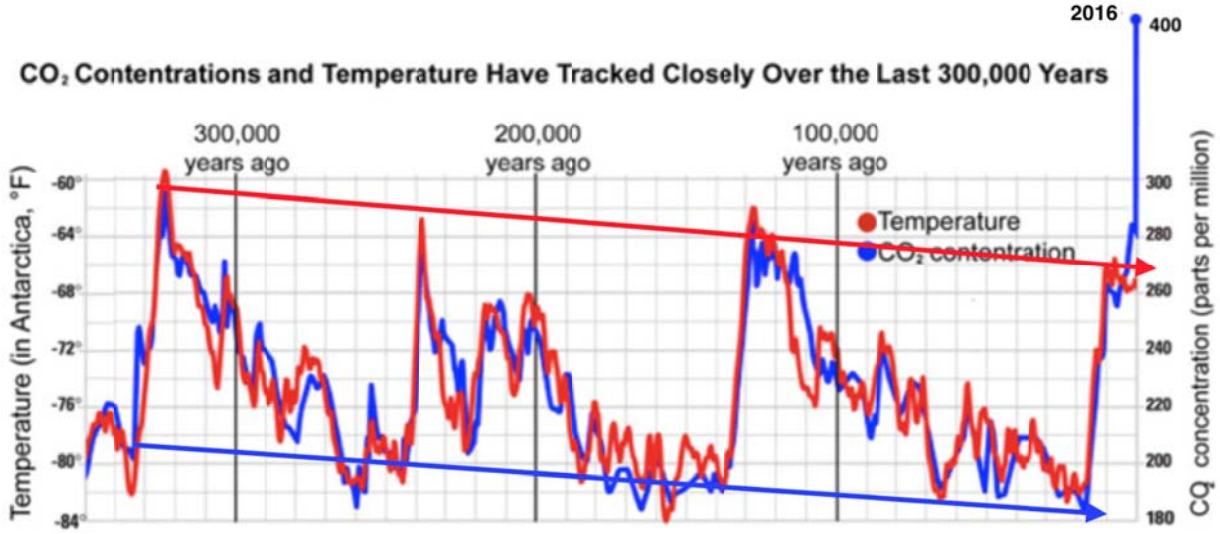
Figure 1



Global temperature and atmospheric CO_2 concentration over the past 600 million years. Note both temperature and CO_2 are lower today than they have been during most of the era of modern life on Earth since the Cambrian Period. Also, note that this does not indicate a lock-step cause-effect relationship between the two parameters. *Source*: Nasif Nahle, "Cycles of Global Climate Change," *Biology Cabinet Journal Online*, July 2009. Referencing C.R. Scotese, "Analysis of the Temperature Oscillations in Geological Eras," 2002; W.F. Ruddiman, *Earth's Climate: Past and Future* (New York, NY: W.H. Freeman and Co., 2001); Mark Pagani, *et al*., "Marked Decline in Atmospheric Carbon Dioxide Concentrations during the Paleocene." *Science* 309, no. 5734 (2005): 600–603.

Figure 2 shows the last four major glaciations. Note the close correlation between CO_2 and temperature during this period, until the twentieth century. A close look shows that CO_2 changed an average of about 600 years *after* the temperature changed. This does not mean CO_2 has no effect on temperature, but it does mean that CO2 is not the "control knob" for glaciation / deglaciation cycles.

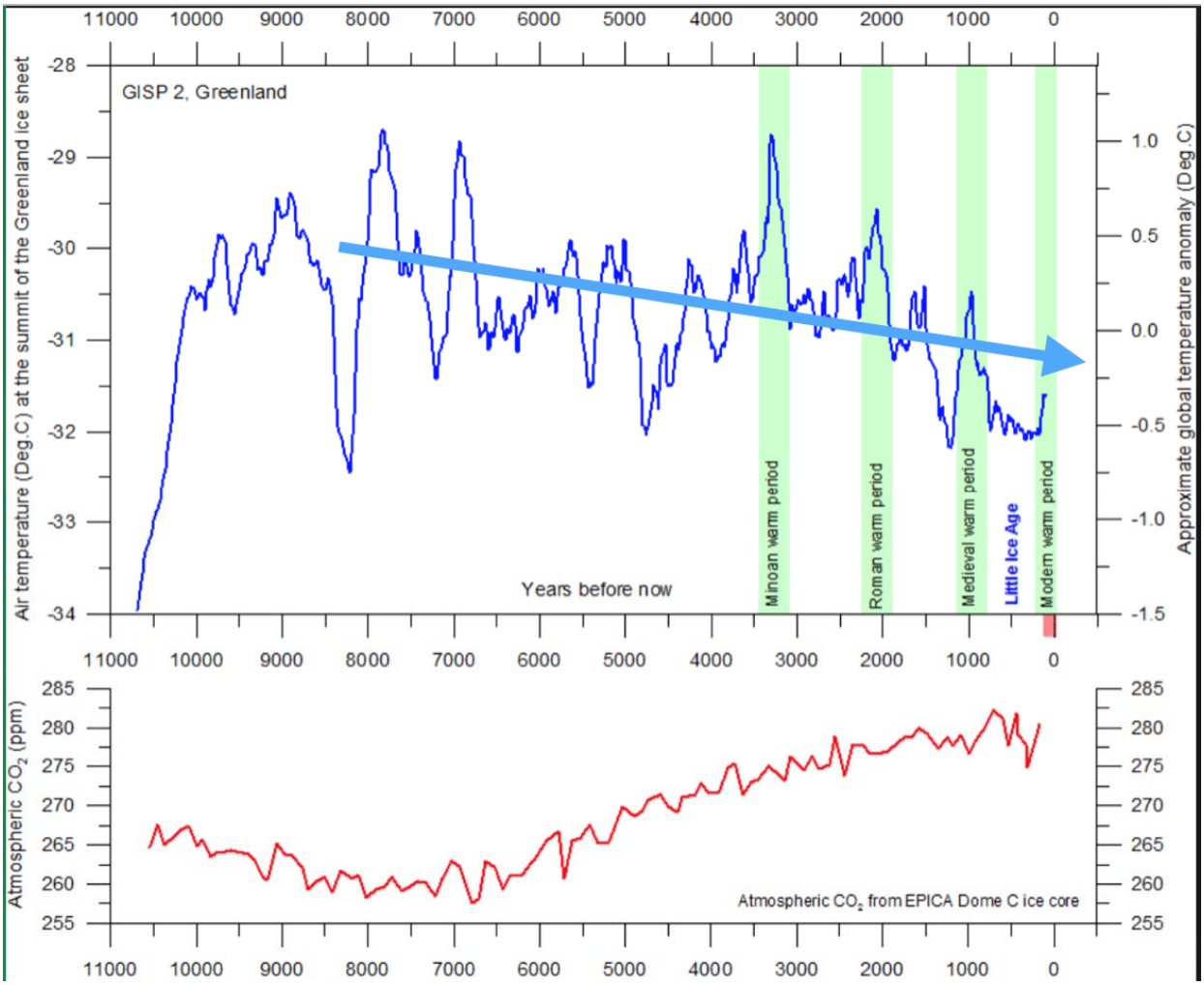
Figure 2



Atmospheric CO_2 concentration and temperature from Antarctica for the most recent four interglacial periods, closely tied to the Milankovitch cycles of 100,000 years. This graph is based on data from the 420,000 year record obtained from the Vostok ice cores drilled by Russian scientists. Note the gradual nature of the onset of colder temperatures and the rapid warming at the end of the cycle. Note that the peak warming during the most recent interglacial period (the Holocene) is lower than during the previous three interglacial periods. *Sources*: J.R. Petit, J. Jouzel, D. Raynaud, N.I. Barkov, J.M. Barnola, *et al*., "Climate and Atmospheric History of the Past 420,000 years from the Vostok Ice Core Antarctica," *Nature* 399 (1999): 429–436; and Patrick Moore, *The Positive Impact of Human CO2 Emissions on the Survival of Life on Earth*, Frontier Centre for Public Policy, June 2016, p. 13.

Figure 3 offers a closer look at the Holocene interglacial period reveals the conundrum that temperature fell while CO_2 levels rose.

Figure 3



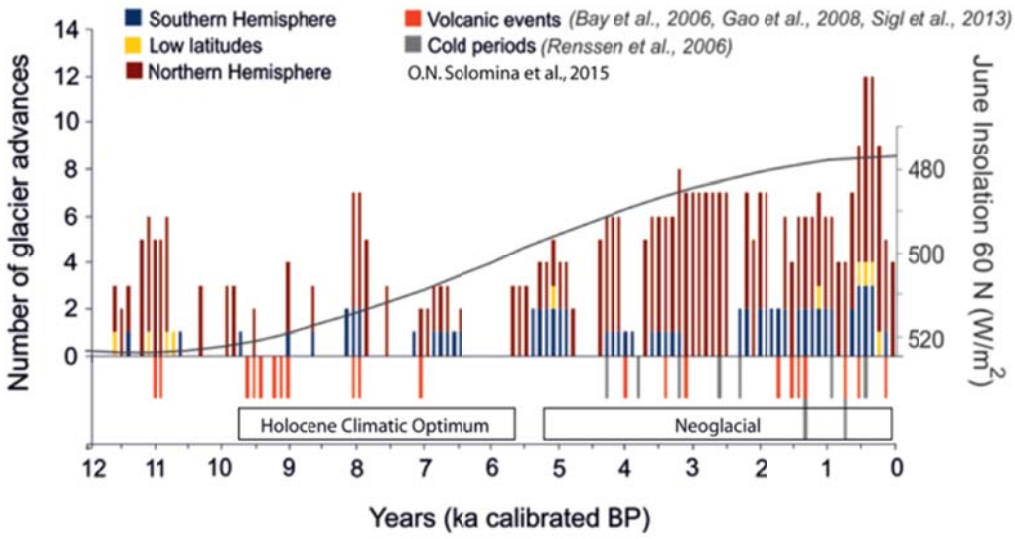
Reconstructed Greenland mean temperature anomalies (top) and Antarctic CO_2 concentration (bottom). Halving the temperature anomalies to allow for polar amplification gives a reasonable approximation of global temperature change in the Holocene. Since the Holocene Optimum began about 9,000 years before present (ka BP), global temperature has fallen by ~1°C, though CO_2 concentration rose over the last 7,000 years. *Source*: Michael Pacnik, "Does CO_2 correlate with temperature history? – A look at multiple timescales in the context of the Shakun *et al*. paper," *Watts Up With That?* (website), crediting *Climate4You* (website).

There are different answers to Judge Alsup's question for three distinct time frames: hundreds of millions, hundreds of thousands, and thousands of years.

Another excellent depiction of the Holocene is provided by Figure 4, a graph of glacial advances, showing both the Holocene Climate Optimum as warmer than today (fewer glacial advances)

and the cooling that began 5,000 years ago leading to the Neoglacial phase. The depths of the Little Ice Age around 1700 were the coldest years since the last major glaciation came to an end. Judging from the history of past interglacial periods, it is likely that Earth's climate will gradually cool over the next 80,000 years as it descends into the next glacial period.

Figure 4



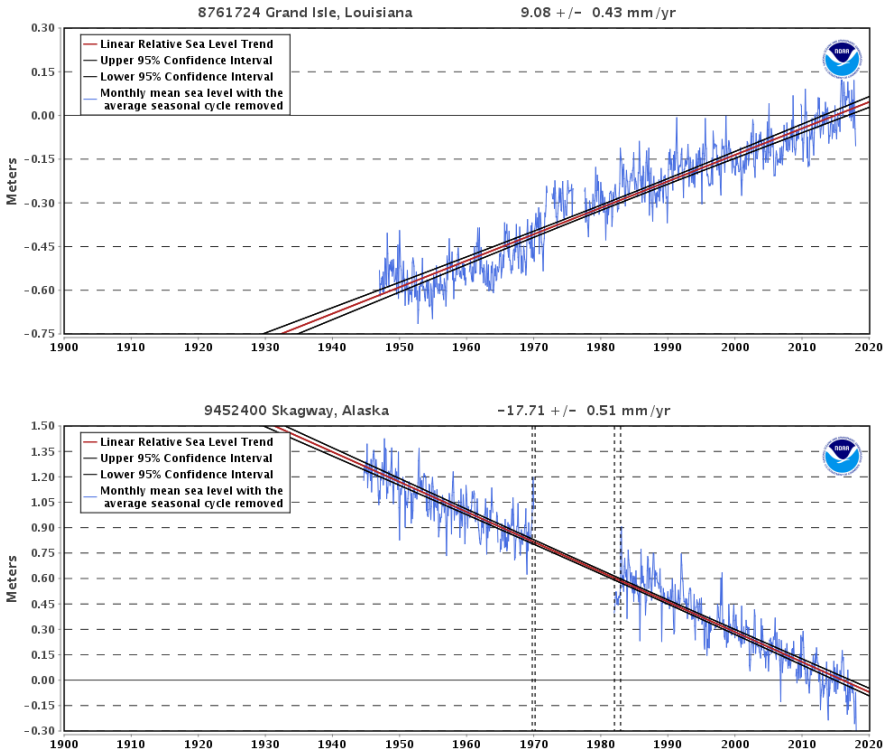
Global glacier advances during the Holocene. Number of areas that display glacier advances for every century during the Holocene. World glaciers were distributed between 17 geographical areas. 12 belonging to the Northern Hemisphere are represented in brown, 4 from the Southern Hemisphere in blue, and one for the Low Latitudes in yellow. For a geographical representation of the glaciers included in each area see Solomina *et al*., 2015, figure 1. Orange and grey downward bars represent significant volcanic and cold events respectively according to the references indicated. Grey curve is the June insolation at 60°N (inverted scale). The Neoglacial period is characterized by generalized glacier advances that take place coinciding with the decrease in Northern Hemisphere solar forcing. Source: Courtesy of Olga Solomina. *Source*: Javier, "Nature Unbound III – Holocene climate variability (Part B)," *Climate Etc*. (website), May 28, 2017.

Sea Level Rise

The recent Pleistocene Ice Age slowly ended 20,000 years ago, with an initially slow warming and a concomitant melting of ice sheets. As a result sea level rose nearly 400 feet to approximately the present level. For the past thousand years it is generally believed that globally averaged sea level change has been less than seven inches per century, a rate which is functionally negligible, because it is frequently exceeded by coastal processes like erosion and sedimentation.

Local sea level trends vary considerably, because they depend not only on the average global trend, but also on tectonic movements of adjacent land. In many places vertical land motion, either up or down, exceeds the very slow global sea level trend. Consequently, at some locations sea level is rising much faster than the global rate, and at other locations sea level is falling. Figure 5 shows sea level from 1930, for Grand Isle, Louisiana and Skagway, Alaska.

Figure 5



Source: NOAA, David Burton, www.sealevel.info.

Many people have attempted to "find" evidence of accelerated sea-level rise. Most use very short measurement records. Some have used short, low-quality, satellite altimetry measurements, in preference to long, high-quality, coastal measurements. Others have spliced together measurements from different locations at different times. Perhaps the most famous attempt was Church and White 2006, "*A 20th Century Acceleration in Global Sea-Level Rise*."[13] The title led

[13] J.A. Church and N.J. White, "A 20th Century Acceleration in Global Sea-Level Rise," *Geophysical Research Letters* 33 (2006): L01602.

many people to believe that sea level rise is accelerating. In fact, all of the (very slight) acceleration they measured had occurred prior to 1930 – when CO_2 levels were under 310 ppm.[14]

The poster child for man-made catastrophic sea level rise has been the Pacific island of Tuvalu, from which it was predicted there would be climate change refugees pushed into the sea. We know in fact that the reverse is true. That island nation's land area has been increasing rather than declining due to inundation (flooding).[15]

Projections of sea level rise in the San Francisco Bay area may be of particular interest to plaintiffs in this suit. David Burton at www.sealevel.info produced the graph shown as Figure 6 below. The red line in the graph is the linear trend; the solid orange line is the quadratic trend; and the dotted orange lines are the 95% confidence interval for the quadratic trend. The trend since the 1906 earthquake is −0.00296 ±0.01385 mm/yr². In other words, there has been no acceleration at all in the rate of sea-level rise at San Francisco since the 1906 earthquake.

According to Burton,

> At the best tectonically stable locations, sea level has been rising at about 1½ mm/year (6 inches per century) since the 1920s or before, with no sign of significant acceleration due to rising CO_2 levels. At San Francisco, sea level rise is just slightly more rapid, at 2.0 mm/year (8 inches per century), but, again, with no sign of acceleration. So the best estimate of sea level rise at San Francisco by 2100 is simply a linear extrapolation of the current linear sea-level trend: 2.00 mm/yr × 82 years / 25.4 mm/inch = 6.5 inches.[16]

Burton goes on to say, "For planning purposes, it might be wise to use the upper end of the 95% confidence interval. Using the linear trend, that would be (2.00 + 0.20) mm/yr × 82 years / 25.4 mm/inch = 7.1 inches. Using the quadratic regression confidence intervals, it's 0.276 meters = 10.9 inches. None of those numbers is frightening, and none of them can be blamed on the oil companies."[17]

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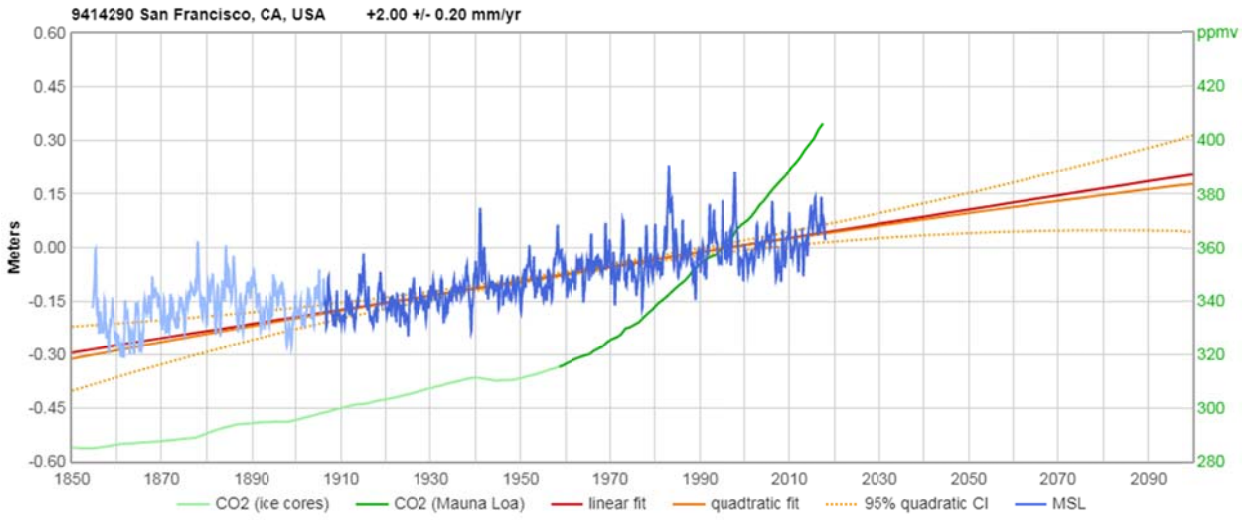
[14] David A. Burton, "Comments on 'Assessing Future Risk: Quantifying the Effects of Sea Level Rise on Storm Surge Risk for the Southern Shores of Long Island, New York,'" *Natural Hazards* 63 (2012): 1219.

[15] Paul S. Kench, *et al*., "Patterns of Island Change and Persistence Offer Alternate Adaptation Pathways for Atoll Nations," *Nature Communications* 9, no. 605 (February 2018).

[16] David Burton, www.sealevel.info, email correspondence shared with the authors, April 5, 2018.

[17] *Ibid*.

Figure 6



The quadratic regression is calculated starting the month after the 1906 earthquake, to avoid questionable data (it ends with January 2018). Confidence intervals are plotted for the quadratic trend. The red line is the linear trend; the solid orange line is the quadratic trend; and the dotted orange lines are the 95% confidence interval for the quadratic trend. *Source*: David Burton, https://tinyurl.com/sanfran-acceleration (www.sealevel.info), email correspondence shared with the authors, April 5, 2018.

2. What is the molecular difference by which CO_2 absorbs infrared radiation but oxygen and nitrogen do not?

It is at once simple and complicated to understand the difference.[18] In a nutshell, two atoms can spin and oscillate, while three can also bend, which adds to the possibilities for interactions with radiation. Water vapor is more effective at warming the atmosphere because it absorbs much more IR radiation than CO_2 absorbs. These vibration-rotation spectra fall into infrared and not the visible because the energetic transitions are below the energy of visible light.

Oxygen (O_2) and nitrogen (N_2) are symmetrical molecules, meaning not only are they linear but they include only a single element. The molecular stretches of two identical elements do not involve moving charges.

In CO_2 the chemical elements are different. The C-O stretches of CO_2 include moving charges because the molecular electrons are not symmetrically distributed. These moving atomic charges

[18] For a more academic discussion of the CO_2 radiative effect, see J.N. Howard, D.E. Burch, and D. Williams, "Infrared Transmission of Synthetic Atmospheres. II. Absorption by Carbon Dioxide," *Journal of the Optical Society of America* 46 (1956): 237–41; and D.J. Wilson and J. Gea-Banacloche, "Simple Model to Estimate the Contribution of Atmospheric CO_2 to the Earth's Greenhouse Effect," *American Journal of Physics* 80 (2012): 306–15.

induce an oscillating electromagnetic (EM) field around the CO_2 molecule. That field can now couple with the EM field of infrared (IR) radiation.

The energy quanta associated with CO_2's bending mode transition corresponds to a photon of 15 μm longwave infrared radiation, which enables LWIR to be absorbed by CO_2.

3. What is the mechanism by which infrared radiation trapped by CO_2 in the atmosphere is turned into heat and finds its way back to sea level?

Radiative transfer is understood through the equation of transfer, which was discovered by Karl Schwartzschild in 1911 and developed by Milne, Hopf, and others.

When CO_2 absorbs IR radiation, it becomes vibrationally excited. This means the C-O atoms oscillate back-and-forth more quickly and with greater amplitude than they did before the IR was absorbed.

The vibrationally excited CO_2 molecule, call it CO_2*, bumps into an oxygen (O_2) or nitrogen (N_2) molecule in the air and transfers that vibrational energy to the O_2 or N_2. That energy transfer causes the N_2 or O_2 velocity to increase. It's like slamming a car with a backhoe, causing the car to speed up. That greater velocity is called "translational energy" and is identical to heat energy.

In a nutshell, CO_2 transforms IR radiation into vibrational energy, and then offloads that vibrational energy into air molecules as thermal energy, which is injected into the atmosphere. The real question is what the climate does with that energy. How much of it remains as sensible heat (the heat measured by thermometers), and how much of it is lost through negative feedbacks such as increased convection, evaporation, cloud formation, and precipitation?

4. Does CO_2 in the atmosphere reflect any sunlight back into space such that the reflected sunlight never penetrates the atmosphere in the first place?

No. "Reflects" is a technical term, different from absorption and emission. Carbon dioxide does not reflect sunlight or solar energy. There is nothing special about CO_2 in this regard. Absorption and re-emission can happen in all directions, so incoming radiation can be absorbed and re-emitted in part back out into space.

Reflection of sunlight is the province of clouds (or suspended particles). About 23 percent of incoming solar radiation is absorbed in the atmosphere by water vapor, dust, and ozone, and 48 percent passes through the atmosphere and is absorbed by Earth's surface.

Like other atmospheric gases, CO_2 does participate in "Rayleigh scattering" of short wavelength light, but changing levels of CO_2 in the atmosphere do not affect that.

5. Apart from CO_2, what happens to the collective heat from tailpipe exhausts, engine radiators, and all other heat from combustion of fossil fuels? How, if at all, does this collective heat contribute to warming of the atmosphere?

The heat energy of fossil fuel combustion is very small compared to the natural heat flux from the sun. It is estimated that the total man-made combustion energy, which releases about 38 gigatonnes of CO_2, amounts to about 0.031 Watts of energy per square meter, averaged over the surface of the Earth. The sun provides 342 Watts per square meter, which is nearly 11 thousand times more energy.

Cities tend to record higher ambient temperatures than suburban and rural areas due to the combination of heat generated largely by the combustion of fossil fuels and its capture, for a while, by buildings and other parts of the built environment. Likewise, urban pavement surfaces, especially black asphalt, are warmed by the sun. These radiate their heat back into the local atmosphere. While the amount of heat generated is too small to affect the global temperature, the warming caused by this "urban heat island effect" can affect thermometer readings, and is often mistakenly attributed to the greenhouse effect. Ross McKitrick and Patrick Michaels concluded the net warming bias from urban heat islands accounted for "about half" of the estimated 1980–2002 global average temperature trend over land.[19]

Jet contrails – the white clouds produced by the engines of jet airplanes – are another way the combustion of fossil fuels affects surface temperatures, unrelated to CO_2 or the greenhouse effect. Contrails are composed of ice crystals that act as catalysts for clouds, which trap heat at night, and reflect sunlight in daytime, reducing diurnal temperature ranges.[20] Haze over airports contributes to higher temperatures in urban areas, which can also be mistakenly attributed to or cited as evidence of "global warming."

6. In grade school many of us were taught that humans exhale CO_2 but plants absorb CO_2 and return oxygen to the air (keeping the carbon for fiber). Is this still valid? If so why hasn't plant life turned the higher levels of CO_2 back into oxygen? Given the increase in human population on Earth (four billion), is human respiration a contributing factor to the buildup of CO_2?

Yes, it is still true. Plants do indeed absorb CO_2 and use the carbon to grow by producing hydrocarbons, including fiber, and return the excess oxygen back into the atmosphere. The original atmosphere of Earth (like Venus and Mars today) had much higher levels of CO_2 and

[19] R.R. McKitrick and P.J. Michaels, "Quantifying the Influence of Anthropogenic Surface Processes and Inhomogeneities on Gridded Global Climate Date," *Journal of Geophysical Research* 112 (2007). See also, Craig D. Idso, *et al.*, *Climate Change Reconsidered II: Physical Science*, *supra* note 9, Section 4.1.2, pp. 358–376.

[20] D.J. Travis, *et al.*, "Contrails Reduce Daily Temperature Range," *Nature* 418 (August 8, 2002): 601.

almost no free oxygen. All the atmospheric O_2 has been generated by photosynthesis, thus making oxygen-breathing animal life possible.

Humans breathe in oxygen and use it to power our metabolism, producing CO_2 in the process, thus replacing the CO_2 that the plants initially consumed. Breathing does not contribute to an increase in atmospheric CO_2 because we are simply recycling the CO_2 that was absorbed by the plants we eat.

The photosynthesis carried out by marine algae is responsible for about 50 percent of the oxygen in the atmosphere.[21] Higher atmospheric CO_2 levels are causing plants to grow better, and numerous studies show that they are improving global agricultural productivity, on average by at least 15%.[22] "C3" plants benefit the most, including all vegetables, almost all fruits and trees, and most grains other than corn. A substantial net greening of the planet has been measured by satellites, especially in arid areas, and including more than 36 percent of Africa.[23]

The IPCC's Fifth Assessment Report estimates that greening from "CO_2 fertilization" is removing more than one-fourth of the CO_2 produced by human activity, each year. It is an important (and growing) "negative feedback" that reduces the effect of CO_2 emissions.

While the human population has increased significantly, our breathing produces a small amount of CO_2 compared to other sources. Every human breath contains about 40,000 ppm CO_2, which is about 39.3 milligrams of CO_2. At an average rate of 12 breaths per minute for humans, simple arithmetic shows that 8 billion people will exhale about two metric gigatonnes of CO_2 per year. Total emissions from the combustion of fossil fuel is about 38 gigatonnes, nearly 20 times as much. Both sources are dwarfed by CO_2 emissions from natural sources such as decaying vegetation and the oceans, which amount to 750 gigatonnes per year.

7. What are the main sources of CO_2 that account for the incremental buildup of CO_2 in the atmosphere?

The atmospheric CO_2 trend is a minute residual between titanic sources and sinks that mostly cancel out each other. However, most of those are very short duration, e.g., plants that grow (consuming CO_2) and then rot within a year or two (releasing the same CO_2).

Over the last million years, changes in atmospheric CO_2 level are believed to have been primarily due to release or absorption by the ocean. However, fossil fuel combustion is the main cause of the recent increase. Other sources include land use changes and the manufacture of concrete.

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[21] Russell Leonard Chapman, "Algae: The World's Most Important 'Plants' – An Introduction," *Mitigation and Adaptation Strategies for Global Change* 18, no. 1 (2013): 5–12.

[22] CO2Science Plant Growth Study Database (website).

[23] R. Myneni, The Greening Earth, Arctic Biomass Project, 2015.

In 900,000 years of ice core records, increases in the surface air temperature were very often followed by increases in CO_2 concentrations about six centuries later. This makes sense, as the oceans hold more CO_2 when cool than when warm. As the oceans warm up they release more CO_2 to the atmosphere. A six century lead time is not unreasonable.

During the past 150 million years, CO_2 concentrations in the atmosphere declined from between 2,000 and 2,500 parts per million (ppm) to about 280 ppm. In other words, the atmosphere lost about 90 percent of its CO_2, presumably through biological processes. We do know that 18,000 years ago, at the depth of the last major glaciation, CO_2 was at a geo-historical low of 180 ppm, which is only 30 ppm over the level when C3 plants begin to die as a result of insufficient CO_2. Even at the present 400 ppm of CO_2 we are at one of the lowest levels in Earth's history.

Deforestation is often cited as a contributor of CO_2 into the atmosphere, but the well-documented "greening of the Earth" caused by the increase in atmospheric CO_2 appears to have offset any reduction in global biomass due to clearing and for agriculture.[24]

8. What are the main sources of heat that account for the incremental rise in temperature on Earth?

The general answer is "the sun." The sun is responsible for nearly 100 percent of the heat coming to Earth. A very small fraction is contributed by heat rising through the crust from the molten core.

Beyond that, the answer depends on the time frame. For example, if the time frame were "over the last 18,000 years," the answer would be that more extreme seasonal variation, due to Milankovitch cycles, caused warmer summers that increased summer melting of the great northern hemisphere ice sheets, and colder winters that decreased snowfall on those ice sheets, with the net effect that the ice sheets retreated, reducing the albedo of the Earth.

If the time frame is "over the last century," then the answer would be natural variability and possibly anthropogenic factors including greenhouse gas emissions, changes in land use, and urban heat island effects.

We say "possibly" because there is considerable uncertainty about the reliability of temperature measurements and proxies used to estimate pre-instrument temperatures. The estimated rise in global temperature during the past century is comparable to the margin of error of the surface-based temperature record.[25] The recent warming trend is not unlike similar previous warming periods, when anthropogenic greenhouse gases could not have been a major factor.

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[24] R. De Jong, J. Verbesselt, M.E. Chaepman, and S. De Bruin, "Trend Changes in Global Greening and Browning: Contribution of Short-Term Trends to Longer-Term Change," *Global Change Biology* 18 (2012): 642–55. See also Craig D. Idso, Sherwood B. Idso, Robert M. Carter, and S. Fred Singer, *Climate Change Reconsidered II: Biological Impacts*, Section 4.2 (Chicago, IL: The Heartland Institute, 2014), pp. 493–508.

[25] Patrick Frank, "Uncertainty in the Global Average Surface Air Temperature Index: A Representative Lower Limit." *Energy & Environment* 21 (2010): 969–89.

Although it is known from other indicators that the climate has warmed, it is not really known by how much and at what rate. "Other indicators" include the poleward movement of the northern tree line and the slightly longer growing season. The evidence of the northern tree line reveals the recent warm period is only now approaching temperatures that prevailed during the Medieval Warm Period.

Air temperature has changed far more quickly in the past, than now. For example, we know from isotopic studies of ice cores that repeated "Dansgaard–Oeschger" events have caused air temperatures to warm at rates of about 10 degrees per century, 10 times the apparent recent rate of warming. There have been about 20 such warming events in the past 80,000 years. No one knows what causes such rapid warming, but it is certainly not due to CO_2.

Although so-called "greenhouse gases" such as carbon dioxide, methane, and water vapor do warm the Earth, all the heat came from the sun.

Based on the best available evidence, the warming effect of anthropogenic greenhouse gas emissions is modest, benign, and difficult to distinguish in the atmospheric data from natural influences. Looking back millions of years, there were no runaway greenhouse catastrophes during times of high CO_2, and the logarithmically diminishing warming effect of additional CO_2, along with resources limits that constrain plausible long-term emissions,[26] ensure that such a catastrophe is not plausible now.

4. Comments on Question 9

Question 9 reads:

9. Please bring to the tutorial a copy of the full GCC presentation referred to in Paragraph 67 of the Oakland complaint as well as the full GCSCT memo referred to in Paragraph 68.

The plaintiffs' case rests on the false claim that individuals and organizations that received money from companies such as ExxonMobil were paid to lie or to hide what they knew about global warming.

The claim originated in then-Senator Al Gore's office in 1991, was taken up by Ozone Action (now Greenpeace USA), and was heavily promoted by retired reporter Ross Gelbspan, socialist historian Naomi Oreskes, and former Greenpeace staffer Kert Davies.[27] Of these "merchants of smear," perhaps the most prominent is Oreskes, whose book *Merchants of Doubt* and movie by the same title have gotten widespread attention.

[26] J. Wang, *et al*., "The Implications of Fossil Fuel Supply Constraints on Climate Change Projections: A Supply-Side Analysis," *Futures* 86 (February 2017): 58–72.

[27] R. Cook, "Merchants of Smear," *Policy Brief*, The Heartland Institute, September 19, 2014.

Dagfinn Reiersøl, the author of a six-part series of blog posts titled "Debunking Oreskes," wrote in 2015:

> These are my principal findings from studying [*Merchants of Doubt*]: Given these main 'bad guys', I find that the links between these individuals and the two main issues are weak at best. The link between the Handful and tobacco is practically non-existent. The link between the Handful and climate change is based on old information (only Singer is still living) and has questionable relevance to the current controversy. The idea that they were obscuring the truth about global warming is based primarily on the idea that they were attacking a scientific consensus, but according to Oreskes and Conway themselves, the period during which they were active hardly overlaps the time during which there has been a consensus.[28]

Also debunking the Gore-Gelbspan-Oreskes-Davies claim are Fred Singer,[29] Judith Curry,[30] and a feature on the website of The Heartland Institute titled "Reply to Our Critics."[31]

5. About The Heartland Institute

By Jay H. Lehr, Ph.D., Science Director, The Heartland Institute

The Plaintiffs' "response to motions to file amicus curiae brief and tutorial presentation, and statement of nonopposition" filed with Judge William Alsup on March 21, 2018, contained numerous misstatements of fact regarding The Heartland Institute intended to damage the credibility of the *amici*. The text referring specifically to Heartland is the following:

> One of the two attorneys on the brief identifies himself as a lawyer for Heartland, and the first four proposed amici (Monckton, Soon, Legates, and Briggs) are also affiliated with Heartland; three are explicitly listed by Heartland as its "policy advisors." And Heartland has a well-known history of attacking scientific conclusions to gratify its corporate funders, including defendant Exxon Mobil Corporation. Between 1997 and 2006 Heartland reportedly received at least $676,000 directly from Exxon or its predecessors or subsidiaries; at one time Heartland's "Government Relations Advisor" was apparently an Exxon executive. Heartland previously accepted money from Philip Morris, and its solicitations for more cash boasted about its prior attacks on the science on secondhand

[28] Dagfinn Reiersøl, "Debunking Oreskes Part 2: The Wicked 'Handful of Scientists'," *Evil Questions* (website), 2015. Accessed April 4, 2018.

[29] S.F. Singer, "A Response to 'The Climate Change Debates'," *Energy & Environment* 21, no. 7 (2010): 847–51.

[30] J. Curry, "Bankruptcy of the 'Merchants of Doubt' meme," *Climate Etc*. (website), March 15, 2015. Accessed April 4, 2018.

[31] The Heartland Institute, "Reply to Our Critics," *The Heartland Institute* (website). Accessed April 4, 2018.

smoke and its publication of articles like "Joe Camel Is Innocent." Heartland is a veteran antiscience mercenary.

Here is our response.

The amicus brief was written by the amici without guidance or editing by anyone working for or representing The Heartland Institute. Heartland's only role was to assist with finding legal counsel in California and the filing of the brief on the *amici*'s behalf.

The Heartland Institute has never "attack[ed] scientific conclusions to gratify its corporate funders." For 34 years it has provided a forum for many distinguished scientists, economists, policymakers, and other experts to present their findings on a broad range of topics including education, health care, tax, and environmental issues. Heartland has policies in place that protect the integrity of its researchers and its publications from undue influence from donors, as virtually all think tanks and universities do.

The Heartland Institute has received funding from Exxon and many other corporations over the years, as is true of hundreds of think tanks and advocacy groups over the years, including many groups with liberal agendas. Exxon's funding was reported in its annual reports at the time and is public information. Heartland has not received funding from any of the defendants, including Exxon and any of its affiliates or subsidiaries, in more than a decade, and the funding it received in the past never amounted to more than 5 percent of its annual budget. No Exxon executive ever served on Heartland's staff, and no evidence has ever been presented that Exxon had undue influence over Heartland's research and publications.

The Heartland Institute's work on tobacco issues features research and commentary by respected experts in the tobacco control policy arena and focuses on unfair taxes, the violation of private property rights inherent in smoking bans, and the benefits of "vaping" – electronic cigarettes and the like – compared to smoking. The Heartland Institute has probably done more to encourage smokers to stop smoking and switch to safer alternatives than any other free-market-leaning think tank in the United States. Heartland's relationship with Philip Morris was never improper, and once again no evidence has ever been produced that Philip Morris had undue influence over Heartland's research and publications.

Finally, some of the amici are identified as being Heartland policy advisors or having spoken at Heartland events. The Heartland Institute has more than 500 policy advisors. They are not paid to be policy advisors, though they are occasionally paid to write policy studies or books or to speak at events. Affiliation with The Heartland Institute should not be construed as meaning these individuals endorse everything Heartland does or to imply any kind of association or communication between these individuals and Heartland's donors.

About the Authors

Jay H. Lehr, Ph.D., is science director of The Heartland Institute. He is editor of *Rational Readings on Environmental Concerns* (1992), *McGraw-Hill's Handbook on Environmental Science, Health and Technology* (2000), *Wiley's Remediation Technologies Handbook* (2004), *Environmental Instrumentation and Analysis Handbook* (2005), the six-volume *Water Encyclopedia* (Wiley Interscience, 2005), Wiley Interscience's *Nuclear Energy Encyclopedia: Science, Technology, and Applications* (2011), and Wiley Interscience's *Alternative Energy and Shale Gas Encyclopedia* (2016), among other publications. He received the nation's first Ph.D. in groundwater hydrology from the University of Arizona.

Patrick Frank, Ph.D., is a member of the scientific staff at the Stanford Synchrotron Radiation Lightsource/SLAC, Stanford University, located in Menlo Park, California. He received his Ph.D. in chemistry from Stanford University, and uses X-ray absorption spectroscopy to investigate questions in the field of inorganic biochemistry.

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Patrick Moore, Ph.D., is a co-founder of Greenpeace and served for nine years as president of Greenpeace Canada and seven years as a director of Greenpeace International. In recent years, Moore has been focused on the promotion of sustainability and consensus-building among competing concerns. He received his Ph.D. in ecology from the Institute of Resource Ecology, University of British Columbia.