

Realities vs. Misconceptions about the Science of Climate Change

The issue of climate change has received so much attention in recent years that it has become difficult for interested citizens and policymakers to separate facts from fiction. Climate change is one of the most cutting edge research fields in modern science, but the field has existed for more than a century and much knowledge has been established with high certainty and confidence. This brief clears up some of the most common misconceptions about the science of climate change.

The Misconception: Recent global warming is caused by the sun.

The Reality: **The output of energy from the sun has been monitored by satellites for thirty years and has not increased during this period of rapid global warming.**

The Misconception: Climate has changed many times in the distant past, before humans began burning coal and oil, so the current warming cannot be caused by humans burning coal, oil, and natural gas.

The Reality: **There are several drivers that cause climate to change, and some of the key drivers have both natural and human sources. Recent increases in global temperatures result mostly from higher levels of heat-trapping gases in the atmosphere, which have been increasing because of human activities.**

The Misconceptions: The last few years have been cooler, so global warming can't be real; or, Global warming stopped in 1998; or, The world has been cooling for the past decade.

The Reality: **The climate is defined by long-term averages in global temperatures and other climate metrics, and those are still increasing.**

The Misconception: There is no scientific consensus on the existence or causes of global climate change.

The Reality: **A recent poll of earth scientists demonstrated that there is strong agreement that emissions of heat-trapping gases from the burning of fossil fuels make a significant contribution to global warming.**

Misconception: Scientists predicted global cooling in the 1970s.

The Reality: **When the next ice age might occur became a topic of debate during the 1970s, but there was no consensus on the topic and most of the debate was already focused on global warming.**

The Misconception: Atmospheric water vapor is the heat-trapping gas that is primarily responsible for global warming.

The Reality: **Water vapor is increasing in the atmosphere in response to rising CO₂ concentrations, amplifying the warming effect of manmade CO₂ emissions.**

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How do we know that the sun isn't causing the warming? We've been measuring the output of energy from the sun for thirty years from space and there's no net change.

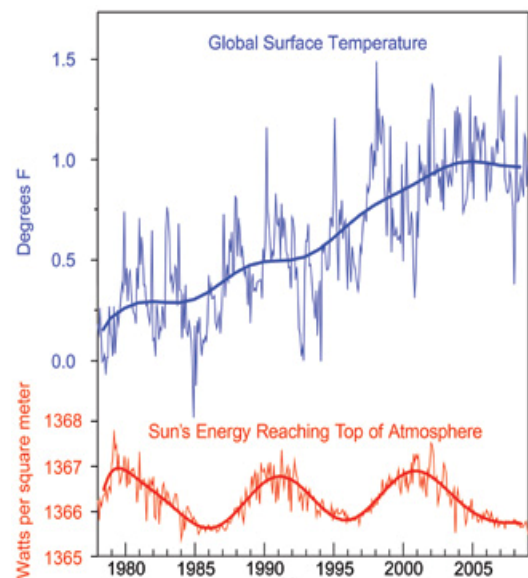
Prof. Bill Chameides,
Dean, Nicholas School
of the Environment,
Duke University

It's true that the sun provides the energy (both light and heat) that drives the Earth's climate; without the sun, the Earth would be a chilly place indeed! When the amount of energy coming from the sun changes, the climate responds in proportion to the change. However, scientists have been observing the sun with sophisticated satellites for three decades—during the period of greatest warming—and have observed no trends in solar activity.

Satellite observations clearly show the well-known 11-year solar cycle, during which the amount of sunlight reaching the Earth's surface varies by about 0.1 percent. This cycle causes the global temperature to fluctuate up and down by about 0.2° F, much less than the observed warming of about 1° F in the past 50 years. More importantly, the solar cycle causes an up-and-down cycle, not an upward trend similar to the trend in the global temperature. The sun's output has not increased over the past three decades (Figure 1).

Recently, two NASA scientists concluded that the solar effect on climate was “negligible” during the last 25 years and that “*none of the natural processes can account for the overall warming trend in global surface temperatures.*”¹ After analyzing several different types of data for solar activity (i.e. sunspot number, open solar flux, cosmic rays, and total solar irradiance), two respected solar physicists found that “*all the trends in the Sun that could have had an influence on the Earth's climate have been in the opposite direction to that required to explain the observed rise in global mean temperatures.*”² Similarly, after compiling the available evidence from many different studies, the U.S. Global Change Research Program concluded that “*direct satellite measurements of solar output show slight decreases during the recent period of warming.*”³

Figure 1. Satellite observations show no increasing trend in solar output. The 11-year solar cycle is evident, but this cannot be driving the overall increase in global average temperatures. (GCRP, 2009, p. 20)



¹ Lean, J.L. and D.H. Rind, 2008. “How natural and anthropogenic influences alter global and regional surface temperatures: 1889 to 2006.” *Geophysical Research Letters* Vol. 35, DOI: 10.1029/2008GL034864.

² Lockwood, M. and C. Frölich, 2007. “Recent oppositely directed trends in solar climate forcings and the global mean surface air temperature.” *Proceedings of the Royal Society A*, Vol. 463, p. 2447-2460.

³ GCRP, 2009. *Global Climate Change Impacts in the United States*. Edited by T. Karl, J. Melillo, T. Peterson and S.J. Hassol. U.S. Global Change Research Program, Washington, D.C.

The Misconception: *Climate has changed many times in the distant past, before humans began burning coal and oil, so the current warming cannot be caused by humans burning coal, oil, and natural gas.*

The Reality: *There are several drivers that cause climate to change, and some of the key drivers have both natural and human sources. Recent increases in global temperatures result mostly from higher levels of heat-trapping gases in the atmosphere, which have been increasing because of human activities.*

During the past 50 years, the sum of solar and volcanic forcings would likely have produced cooling.

IPCC, 2007, p. 5

As a result of human activities, the present carbon dioxide concentration of about 385 ppm is about 30 percent above its highest level over at least the last 800,000 years.

GCRP, 2009, p. 6

This misconception leans on the false presumption that the existence of natural climate drivers precludes the existence of human drivers. In reality, there are some key climate drivers that have both natural sources and human sources, and scientists are able to distinguish between them. The changes that have occurred in natural climate drivers in recent decades would likely have caused a small amount of cooling, not warming.⁴ During the past century, human activities have been the only sustained source of the extra heat-trapping gases that have been added to the atmosphere. Scientists have demonstrated that the primary human source (80 percent) is the burning of coal, oil, and natural gas, and the secondary human source (20 percent) is deforestation and other land use changes.⁵

Those who insist that climate change can be explained entirely by natural factors must address two issues. First, they must identify a natural climate driver that has changed in a way that is consistent with the observed temperature increase. The most common claim is that changes in the sun are responsible, but thirty years of satellite observations show no trend in solar output (see above). Second, they must explain why the documented increase in atmospheric heat-trapping gas concentrations over the past 50 years would not be the main cause of global warming today, given that it is absolutely certain that these gases trap heat. In spite of tremendous effort both by the mainstream scientific community and by interests that oppose efforts to limit future emissions of heat-trapping gases, no one has been able to overcome these two issues in the search for an alternative primary cause of contemporary climate change. On the other hand, scientists have established an internally consistent body of evidence showing that heat-trapping gases produced by human activities have been increasing in the atmosphere and that no other climate driver is changing in a way that is consistent with recent warming.

⁴ IPCC, 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by R. K. Pachauri and A. Reisinger. IPCC, Geneva, Switzerland, p. 5.

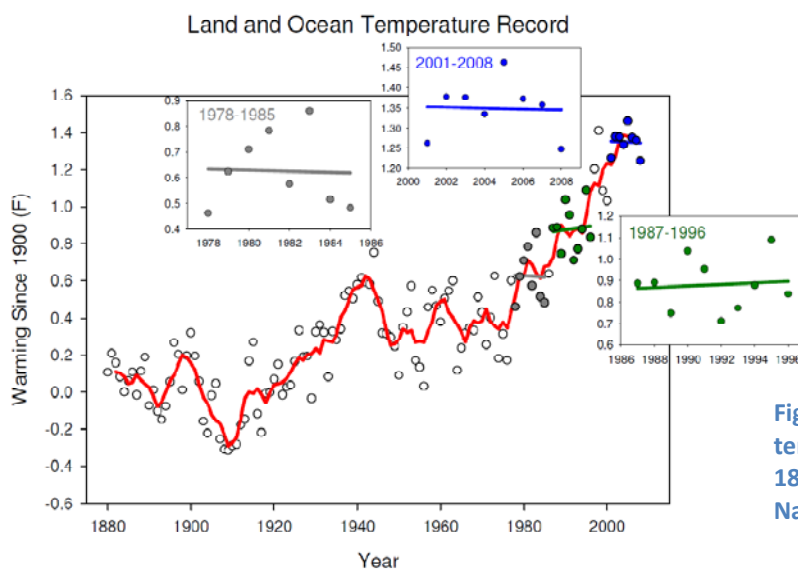
⁵ GCRP, 2009. Op Cit.

The Misconceptions: *The last few years have been cooler, so global warming can't be real; or, Global warming stopped in 1998; or, The world has been cooling for the past decade.*

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Some people claim that the planet has entered a cooling phase either since 1998 or since 2005, depending on which data set one examines. However, just because 1998 and 2005 are the two warmest years on record so far does not mean that a long term warming trend is not continuing. The climate is defined by long-term averages, not the ups and downs that occur every few years. Even with the variability in global average temperatures, it is easy to see that the long-term warming trend remains (see Figure 2). For instance, the ten warmest years in the 150-year thermometer record have all occurred in the twelve years between 1997 and 2008.⁶ Thus, none of the previous 15 decades has been as warm on average as the last decade. Just because the average temperature has dropped in the past three or four years from a recent peak year (in this case, since 2005), or that no single year in the past decade has been warmer than 1998, in no way suggest that global warming has stopped or reversed. Even with the pause in warming since 2005, the past three years rank in the top ten of the past 150!

But what if the pause in warming since 2005 continues for several more years? Even then, concluding that global warming had stopped would require much more evidence. Scientists at the U.S. National Climatic Data Center⁷ found that over the past 34 years, three separate roughly ten-year periods had no warming, yet during the entire period the global average temperature rose by about 1 °F (Figure 2). Clearly, the climate has natural internal



fluctuations that occur on the decade time scale with or without global warming. With global warming, these fluctuations simply “ride” on top of a long-term upward trend.

Figure 2. Global average surface temperature (both land and ocean) from 1880 to present. Data obtained from the National Climatic Data Center.

⁶ NASA, 2009. “Global Temperature Trends: 2008 Annual Summation,” <http://data.giss.nasa.gov/gistemp/2008/>

⁷ Easterling, D.R. and M.F. Wehner, 2009. “Is the climate warming or cooling?” *Geophysical Research Letters*, Vol. 36, DOI: 10.1029/2009GL037810.

The Misconception: *There is no scientific consensus on the existence or causes of global climate change.*

The Reality: *A recent poll of earth scientists demonstrated that there is strong agreement that emissions of heat-trapping gases from the burning of fossil fuels make a significant contribution to global warming.*

Many concepts in climate science are well established and are not being actively debated among mainstream climate researchers. Scientists have called the warming trend “unequivocal” on the basis of multiple lines of physical evidence.⁸ Physical and statistical “fingerprinting” studies⁹ have linked the warming of recent decades, as well as several other aspects of climate change, directly to increasing emissions of heat-trapping gases from human activities.¹⁰ The U.S. Global Change Research Program, sponsored by 13 federal agencies, concluded in a 2009 report that “global warming is unequivocal and primarily human-induced.”¹¹

In fact, the evidence for human-induced climate change is so strong that scientists are in unusually strong agreement about it. A January 2009 poll of more than 3000 earth scientists found that 82 percent of them, regardless of their specialties, agree that human activity is a significant contributor to changing average global temperatures.¹² The consensus is even stronger among active climatologists who publish the majority of their work on climate studies: 97.4 percent agree! This level of consensus is astonishing in a community where reputations are made by proving others wrong.

Rather than providing accurate information, ‘balanced’ reporting may instead perpetrate informational bias regarding scientific opinions on human contributions to climate change.

M. Boykoff, 2007

It seems that the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes. The challenge, rather, appears to be how to effectively communicate this fact to policy makers and to a public that continues to mistakenly perceive debate among scientists.

P. Doran &
M. Zimmerman,
2009

In contrast to the strong consensus among earth scientists, a 2007 Newsweek poll found that less than half of the American public believes most climate scientists agree that human activities cause global warming.¹³ This misconception may stem in part from the traditional practice of journalists of quoting a voice on each side of an opinion issue. In this case, however, one view represents the mainstream scientific opinion and the other represents the fringe.¹⁴

⁸ IPCC, 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by R. K. Pachauri and A. Reisinger. IPCC, Geneva, Switzerland, p. 2.

⁹ <http://www.pewclimate.org/global-warming-basics/science-brief-092006>

¹⁰ <http://www.pewclimate.org/brief/science-developments/June2009>

¹¹ GCRP, 2009. Op Cit.

¹² Doran, P.T. and M.K. Zimmerman, 2009. “Examining the Scientific Consensus on Climate Change.” *Eos: American Geophysical Union* Vol. 90, p. 22-23. Available at: http://tigger.uic.edu/~pdoran/012009_Doran_final.pdf

¹³ <http://www.pollingreport.com/enviro.htm> (search for “Newsweek” in this document).

¹⁴ Boykoff, M.T., 2007. “Flogging a dead norm? Newspaper coverage of anthropogenic climate change in the United States and United Kingdom from 2003 to 2006. *Area* Vol. 39, p. 470-481

The Misconception: *Scientists predicted global cooling in the 1970s.*

The Reality: *When the next ice age might occur became a topic of debate during the 1970s, but there was no consensus on the topic and most of the debate was already focused on global warming.*

Although new data from a Greenland ice core led scientists to discuss the timing of the next ice age in the 1970s, no consensus was ever reached. By the end of the decade, most scientists studying climate were convinced that increasing heat-trapping gas emissions would soon overwhelm any cooling that might occur in the absence of human activity. This thinking has proven correct over the last three decades, contributing to the strong scientific consensus that exists today regarding global warming.

A review of the [peer-reviewed scientific] literature suggests that, on the contrary, greenhouse warming even then [i.e. 1970s] dominated scientists' thinking as being one of the most important forces shaping Earth's climate on human time scales.

T. Peterson et al., 2008

The idea that there was a consensus among scientists in the 1970s that an ice age was imminent is not supported by the facts at the time. A review of the scientific literature from 1965-1979, finds 73 peer-reviewed papers on the topic. Out of those, only 12 percent suggested cooling, while five times as many — 60 percent — suggested warming; the rest were neutral.¹⁵ In 1979, a panel of independent experts convened by the National Research Council to review the scientific literature and assess the state of scientific understanding of climate change, concluded that the potential risks of global warming caused by growing emissions of CO₂ from human activity were serious and could not be ignored. This seminal report made no reference to global cooling or future ice ages.

The discussion about the timing of the ice ages in the 1970s was simply an earlier phase of the decades-long discussion of the climate system that has led to our current understanding of global warming. The dawn of the satellite era at the end of the 70s, the retrieval of several more ice cores reaching further back in time from Greenland and Antarctica, and improvements in climate modeling have opened the door to a vastly superior understanding of the climate system today. Over the decades, converging lines of evidence from different sub-fields of climate science have forged a strong consensus among earth scientists that the current global warming trend is real and that heat-trapping gases from human activity are the dominant cause.¹⁶

¹⁵ Peterson, T.C., W.M. Connelley, and J. Fleck, 2008. "The Myth of the 1970s Global Cooling Scientific Consensus" *Bulletin of the American Meteorological Society* Vol. 89, p. 1325-1337.

¹⁶ IPCC, 2007. Op. cit.; Doran and Zimmerman, 2009, Op. Cit.

The Misconception: Atmospheric water vapor is the heat-trapping gas that is primarily responsible for global warming.

The Reality: Water vapor is increasing in the atmosphere in response to rising CO₂ concentrations, amplifying the warming effect of manmade CO₂ emissions.

About 150 years ago, John Tyndall deduced that water vapor absorbs more heat in the atmosphere than any other gas.¹⁷ He was correct. More than a century ago, Svante Arrhenius postulated that the amount of water vapor in the atmosphere changes in response to the amount of CO₂ and amplifies the temperature effect of the CO₂.¹⁸ He, too, was correct.

Here's how it works: As the amount of CO₂ in the atmosphere rises, it traps more heat, causing the surface air temperature to rise a bit. The higher temperature evaporates more water from the surface of the ocean and land. Since warmer air can hold more water vapor, the amount of water vapor in the atmosphere continues to increase as long as the concentration of CO₂ continues to rise. The extra water vapor traps heat in addition to that trapped by the rising CO₂, amplifying the CO₂ effect by about twofold. Scientists call this amplification a “positive feedback,” and it works in both directions: If atmospheric CO₂ were to decrease, some water vapor would rain out of the atmosphere, creating a positive feedback that would amplify the cooling effect of CO₂ removal.

The short “residence time” of water vapor in the atmosphere means that it cannot be said to drive global warming. Even if something spewed massive quantities of water vapor into the atmosphere, it would simply rain out within days, long before it had time to elevate the global temperature (it takes decades for heat to build up in the climate system). Therefore, only a driver that continues long term can cause climate change. The persistent heat-trapping activity of long-lived gases like CO₂, methane, and nitrous oxide keeps extra water vapor aloft so that it can amplify warming. These gases stay in the atmosphere for a decade to several centuries before they are removed by natural processes.

...if aqueous vapour is supplied to the atmosphere, it will be condensed [to rain] till the former condition is reached, if no other change has taken place [such as an increase in CO₂].

S. Arrhenius, 1896

In short, long-lived heat-trapping gases released by human activities—mainly CO₂—are driving global warming, and water vapor is responding and amplifying the initial warming by about twofold. This understanding dates back more than a century and has been confirmed through many theoretical advancements and modern atmospheric observations.¹⁹

¹⁷ Tyndall, J. (1861). On the absorption and radiation of heat by gases and vapours, and on the physical connexion of radiation, absorption, and conduction. *Philosophical Magazine* Vol. 22, p. 169-194, 273-285.

¹⁸ Arrhenius, S. (1896). On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine* Vol. 41, 237-276.

¹⁹ Ramanathan, V. and A. Inamdar, 2006. “The Radiative Forcing due to Clouds and Water Vapor” in *Frontiers of Climate Modeling*, J. T. Kiehl and V. Ramanathan, Editors, (Cambridge University Press 2006), pp. 119-151.