



Realities vs. Misconceptions about Climate Change Science

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.

Misconception #1: 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.

Misconception #2: The climate is always changing or it has changed many times in the past before humans began burning coal and oil. So there is no reason to believe humans are causing warming today.

The Reality: This misconception falsely presumes that if the climate changes naturally, then humans have no role to play or that it is impossible distinguish manmade climate change from natural change. In reality, several climate drivers have both natural and human sources and scientists can tell them apart. The evidence strongly supports manmade CO₂ as the primary cause of recent warming.

Misconception #3: The world has been cooling for the past decade; or, Global warming stopped in 1998 or 2002 or {insert preferred year}.

The Reality: Short time periods of a decade or so often give the false impression that the Earth is not warming or that it is cooling. "Climate" is defined by long-term (e.g., 30 years) averages of climate metrics. Over the 20th century the long-term global average surface temperature has clearly increased.

Misconception #4: There is no scientific consensus on the existence or causes of global climate change.

The Reality: A recent poll of Earth scientists revealed strong agreement that emissions of heat-trapping gases from human activities make significantly contribute to present-day global warming.

Misconception #5: Scientists predicted global cooling in the 1970s. Since they were wrong about that, there is no reason to believe they are right about global warming.

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.

Misconception #6: 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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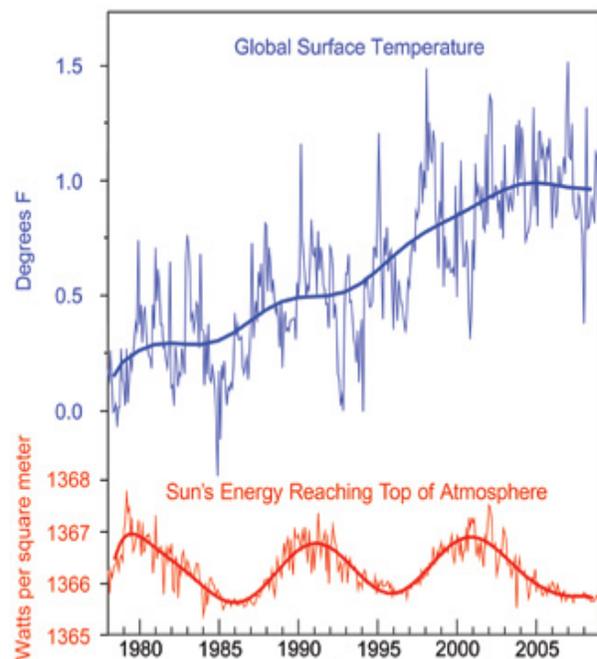
It's true that the sun provides the energy that drives the Earth's climate; without the sun, the Earth would be a chilly place indeed! When the amount of energy put out by the sun changes, the climate must respond in some fashion. However, scientists have been observing the sun with sophisticated satellites for three decades—during the period of greatest warming—and have observed no trend in solar activity.

How do we know that the sun isn't causing the warming? We've been measuring the output of energy from the sun for 30 years from space and there's no net change.

Prof. Bill Chameides
Duke University

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 (see figure).

Recently, two NASA scientists published a peer-reviewed study demonstrating that the Sun's effect on climate was **"negligible"** during recent decades 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), the authors of another peer-reviewed study concluded 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



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 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.

³ 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.



Misconception #2: The climate is always changing or it has changed many times in the past before humans began burning coal and oil. So there is no reason to believe humans are causing warming today.

The Reality: This misconception falsely presumes that if the climate changes naturally, then humans have no role to play or that it is impossible to distinguish manmade climate change from natural change. In reality, several climate drivers have both natural and human sources and scientists can tell them apart. The evidence strongly supports manmade CO₂ as the primary cause of recent warming.

The heat-trapping gas carbon dioxide (CO₂) has both natural and human sources, and scientists are able to distinguish between the two. In recent decades, natural sources have changed little and what natural change has occurred would have cooled the Earth's

Over the past three decades, human influences on climate have become increasingly obvious... During the same period, the Sun's energy output [exhibited] no net increase.

USGCRP, 2009
pp. 15-16

surface if it were acting alone. During the past century, human activity has been the only sustained source of rising CO₂ emissions to the atmosphere.⁴ Scientists have demonstrated that 80 percent of manmade CO₂ comes from the burning of fossil fuels (coal, oil, and natural gas) and 20 percent comes from deforestation and other land surface changes.⁵ We know that the extra CO₂ accumulating in the atmosphere is mostly from burning fossil fuels because ancient carbon has unique physical characteristics that scientists can readily detect.⁶

Those who claim that current climate change is entirely natural have failed to reconcile some key inconsistencies. For instance, they have not identified a natural climate driver that has changed in a way that could plausibly explain the observed warming. Some claim that the Sun has become more active, but satellite observations show the opposite (see Misconception #1). Second, they have not been able to explain why increasing CO₂ wouldn't explain the warming, given that we know absolutely that this gas traps heat. The most common claim is that the current CO₂ concentration (about 0.04 percent) is simply too small to affect the climate significantly. That notion is simply a gut reaction to what seems like a paltry amount of CO₂, but this sensibility is misleading. Consider the "fight or flight" response we experience when startled. This reaction results from a tiny shot of adrenaline that reaches only about 0.00000005 percent in the bloodstream!

In contrast, scientists have repeatedly detected a clear "fingerprint" of manmade CO₂ in spatial and temporal patterns of change in several components of the climate system,

³ USGCRP, 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.

⁴ USGCRP, 2009. *Op cit.*, p. 15-16.

⁵ USGCRP, 2009. *Op cit.*, p. 14.

⁶ Forster, P., et al., 2007. Changes in atmospheric constituents and in radiative forcing. In: *Climate Change 2007: The Physical Science Basis*. (Soloman S., et al., Eds.) Cambridge University Press, Cambridge, U.K. and New York, N.Y., pp. 138-139.



including global surface warming, the vertical penetration of heat into the oceans, and the progressive increase in the vertical thickness of the lower atmosphere.⁷

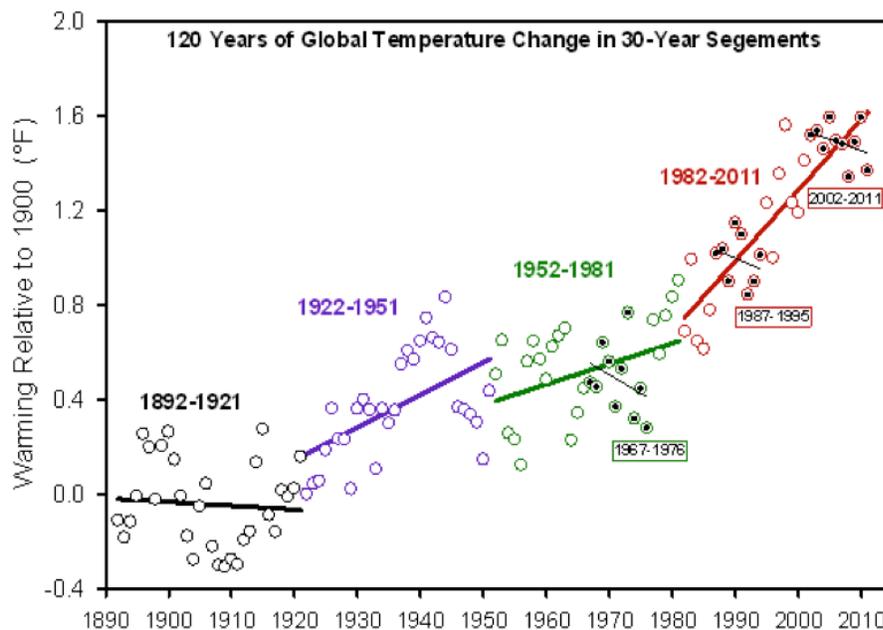
⁷ Gullede, J., 2012. The Causes of Global Climate Change. Center for a New American Security, Arlington, Virginia, USA. Available at <http://www.c2es.org/science-impacts/basics/fact-sheets/causes-global-warming>

Misconception #3: The world has been cooling for the past decade;
or, Global warming stopped in 1998 or 2002 or {insert preferred year}.

The Reality: Short time periods of a decade or so often give the false impression that the Earth is not warming or that it is cooling. “Climate” is defined by long-term (e.g., 30 years) averages of climate metrics. Over the 20th century the long-term global average surface temperature has clearly increased.

Some people claim that the Earth’s surface stopped warming and some even claim it began to cool in recent years (e.g., after 1998 or 2002). By definition, *climate* is determined by long-term averages, not by the ups and downs that occur over a decade or so. For example, weather forecasters define “normal” daily temperatures as the 30-year average for a given date. Similarly, *climate change* is defined by a detectable change in these long-term averages. When global average surface temperature is examined in 30-year intervals, it is very clear that warming is ongoing.

Thermometer measurements compiled by NOAA’s National Climatic Data Center show that the global surface temperature has been increasing since the 1920s (see figure).⁸ Looking at the last 30 years (1982-2011), it is clear that the temperature has been rising faster than it did earlier. However, one can easily “cherry pick” shorter periods of a decade or less when temperatures appeared to be declining (e.g., 1967-1976, 1987-1995 or 2002-2011). But viewing these years as part of a longer period shows that there was no cooling. Indeed, the Earth did not stop warming after, say, 1967 or 1987. For the same reason, there is no evidence that the Earth stopped warming in more recent years⁹



⁸ “Global Surface Temperature Anomalies,” NOAA National Climatic Data Center, <http://www.ncdc.noaa.gov/cmb-faq/anomalies.php> (retrieved June 26, 2012)

⁹ Easterling, D.R. and M.F. Wehner, 2009. “Is the climate warming or cooling?” *Geophysical Research Letters*, Vol. 36, DOI: 10.1029/2009GL037810.



Misconception #4: There is no scientific consensus on the existence or causes of global climate change.

The Reality: A recent poll of Earth scientists revealed strong agreement that emissions of heat-trapping gases from human activities make significantly contribute to present-day global warming.

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.

Doran & Zimmerman, 2009

Many concepts in climate science are well established and no longer require scientific debate. Scientists base their conclusions about climate change on multiple lines of evidence.¹⁰ Physical and statistical “fingerprinting” studies¹¹ have linked the warming of recent decades, as well as many other aspects of climate change, directly to increasing emissions of heat-trapping gases from human activities.¹² The U.S. Global Change Research Program, sponsored by 13 federal agencies with deep scientific expertise, concluded in a 2009 report that “global warming is unequivocal and primarily human-induced.”¹³

In fact, the evidence for human-induced climate change is so convincing that scientists have reached an unusually strong consensus. A January 2009 poll of more than 3000 Earth scientists found that 82 percent of them, regardless of specialty, agreed that human activity has contributed significantly to warming the Earth’s surface.¹⁴ The consensus

is even stronger among specialists who publish the majority of their work on the subject of climate: 97 percent of them agreed! This level of agreement is uncommon in a professional community where reputations are made by proving others wrong.

Unfortunately, this high level of scientific agreement remains largely unfamiliar to the public. A March 2012 poll by researchers at Yale University and George Mason University found that around one-third of Americans think most scientists agree that global warming is happening, and 41 percent “believe there is a lot of disagreement among scientists” on the question.¹⁵ These results show how widespread this misconception is.

¹⁰ 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.

¹¹ Gulledege, J., 2012. The Causes of Global Climate Change. Center for a New American Security, Arlington, Virginia, USA. Available at <http://www.c2es.org/science-impacts/basics/fact-sheets/causes-global-warming>.

¹² Pew Center on Global Climate Change, 2009. Key Scientific Developments Since the IPCC Fourth Assessment Report. Available at <http://www.c2es.org/publications/science-developments-since-ipcc-fourth-assessment>.

¹³ GCRP, 2009. Op Cit.

¹⁴ 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

¹⁵ Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Hmielowski, J. D. (2012) Climate change in the American Mind: Americans’ global warming beliefs and attitudes in March 2012. Yale University and



Misconception #5: Scientists predicted global cooling in the 1970s. Since they were wrong about that, there is no reason to believe they are right about global warming.

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 by the mid-1970s the debate mostly 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. At the time, most climate scientists were already convinced that increasing heat-trapping gas emissions would soon overwhelm any cooling that might have occurred naturally in the absence of human influences. 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 notion that there was a consensus among scientists in the 1970s that an ice age was imminent is not supported by the historical facts. A review of the scientific literature from 1965-1979, found 73 peer-reviewed papers on contemporary global climate change. Twelve percent of those papers suggested cooling, while five times as many — 60 percent — suggested warming; the rest were neutral.¹⁶ 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. Since then, the dawn of the satellite era, the retrieval of many ice cores reaching further back in time from Greenland and Antarctica, detailed analyses of surface temperature observations from around the globe, and major improvements in computational climate simulation, 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.¹⁷

George Mason University. New Haven, CT: Yale Project on Climate Change Communication. <http://environment.yale.edu/climate/files/Climate-Beliefs-March-2012.pdf>

¹⁶ 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.

¹⁷ IPCC, 2007. Op. cit.; Doran and Zimmerman, 2009, Op. Cit.



Misconception #6: 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.¹⁸ 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 CO₂.¹⁹ And 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 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.

[I]f 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 [e.g., increased 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.²⁰

¹⁸ 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.

¹⁹ Arrhenius, S. (1896). On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine* Vol. 41, 237-276.

²⁰ 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.