



This is the print version of the [Skeptical Science](http://sks.to/evidence) article '[There's no empirical evidence](http://sks.to/evidence)', which can be found at <http://sks.to/evidence>.

Empirical evidence that humans are causing global warming

What The Science Says:

Direct observations find that CO₂ is rising sharply due to human activity. Satellite and surface measurements find less energy is escaping to space at CO₂ absorption wavelengths. Ocean and surface temperature measurements find the planet continues to accumulate heat. This gives a line of empirical evidence that human CO₂ emissions are causing global warming.

Climate Myth: There's no empirical evidence

"There is no actual evidence that carbon dioxide emissions are causing global warming. Note that computer models are just concatenations of calculations you could do on a hand-held calculator, so they are theoretical and cannot be part of any evidence." ([David Evans](#))

The line of empirical evidence that humans are causing global warming is as follows:

We're raising CO₂ levels

Human carbon dioxide emissions are calculated from international energy statistics, tabulating coal, brown coal, peat, and crude oil production by nation and year, going back to 1751. CO₂ emissions have increased dramatically over the last century, climbing to the rate of 29 billion tonnes of CO₂ per year in 2006 ([EIA](#)).

Atmospheric CO₂ levels are measured at [hundreds of monitoring stations across the globe](#). Independent measurements are also conducted by airplanes and satellites. For periods before 1958, CO₂ levels are determined from air bubbles trapped in polar ice cores. In pre-industrial times over the last 10,000 years, CO₂ was relatively stable at around 275 to 285 parts per million. Over the last 250 years, atmospheric CO₂ levels have increased by about 100 parts per million. Currently, the amount of CO₂ in the atmosphere is increasing by around 15 gigatonnes every year.

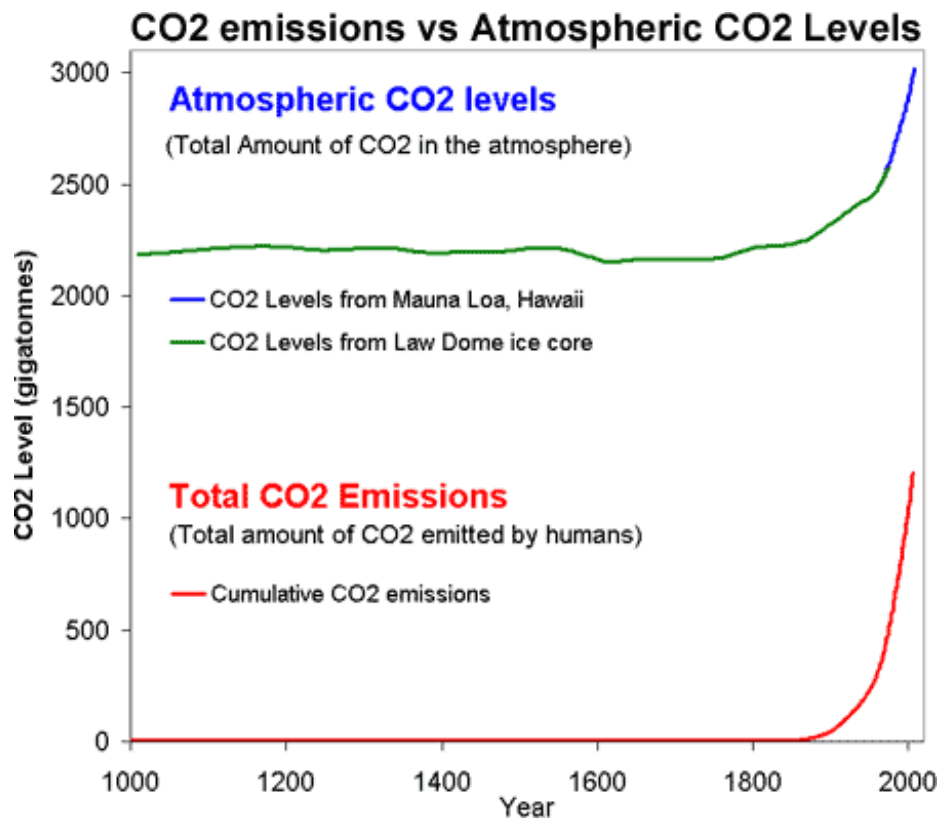


Figure 1: Atmospheric CO₂ levels (Green is [Law Dome ice core](#), Blue is [Mauna Loa, Hawaii](#)) and Cumulative CO₂ emissions ([CDIAC](#)). While atmospheric CO₂ levels are usually expressed in parts per million, here they are displayed as the amount of CO₂ residing in the atmosphere in gigatonnes. CO₂ emissions includes fossil fuel emissions, cement production and emissions from gas flaring.

Humans are emitting more than twice as much CO₂ as what ends up staying there. Nature is reducing our impact on climate by absorbing more than half of our CO₂ emissions. The amount of human CO₂ left in the air, called the "[airborne fraction](#)", has hovered around 43% since 1958.

CO₂ traps heat

According to radiative physics and [decades of laboratory measurements](#), increased CO₂ in the atmosphere is expected to absorb more infrared radiation as it escapes back out to space. In 1970, NASA launched the IRIS satellite measuring infrared spectra. In 1996, the Japanese Space Agency launched the IMG satellite which recorded similar observations. Both sets of data were compared to discern any changes in outgoing radiation over the 26 year period ([Harries 2001](#)). What they found was a drop in outgoing radiation at the wavelength bands that greenhouse gases such as CO₂ and methane (CH₄) absorb energy. The change in outgoing radiation was consistent with theoretical expectations. Thus the paper found "*direct experimental evidence for a significant increase in the Earth's greenhouse effect*". This result has been confirmed by subsequent papers using data from later satellites ([Griggs 2004](#), [Chen 2007](#)).

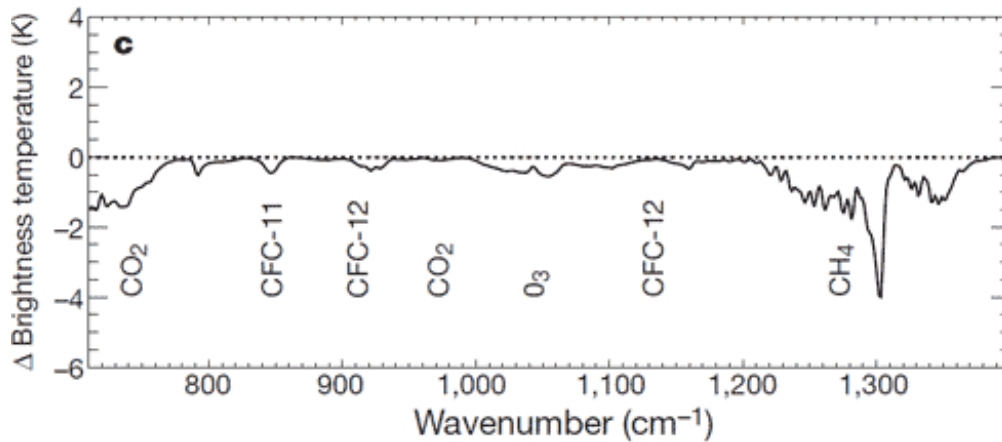


Figure 2: Change in spectrum from 1970 to 1996 due to trace gases. 'Brightness temperature' indicates equivalent blackbody temperature ([Harries 2001](#)).

When greenhouse gases absorb infrared radiation, the energy heats the atmosphere which in turn re-radiates infrared radiation in all directions. Some makes its way back to the earth's surface. Hence we expect to find more infrared radiation heading downwards. Surface measurements from 1973 to 2008 find an increasing trend of infrared radiation returning to earth ([Wang 2009](#)). A regional study over the central Alps found that downward infrared radiation is increasing due to the enhanced greenhouse effect ([Philipona 2004](#)). Taking this a step further, an analysis of high resolution spectral data allowed scientists to quantitatively attribute the increase in downward radiation to each of several greenhouse gases ([Evans 2006](#)). The results lead the authors to conclude that *"this experimental data should effectively end the argument by skeptics that no experimental evidence exists for the connection between greenhouse gas increases in the atmosphere and global warming."*

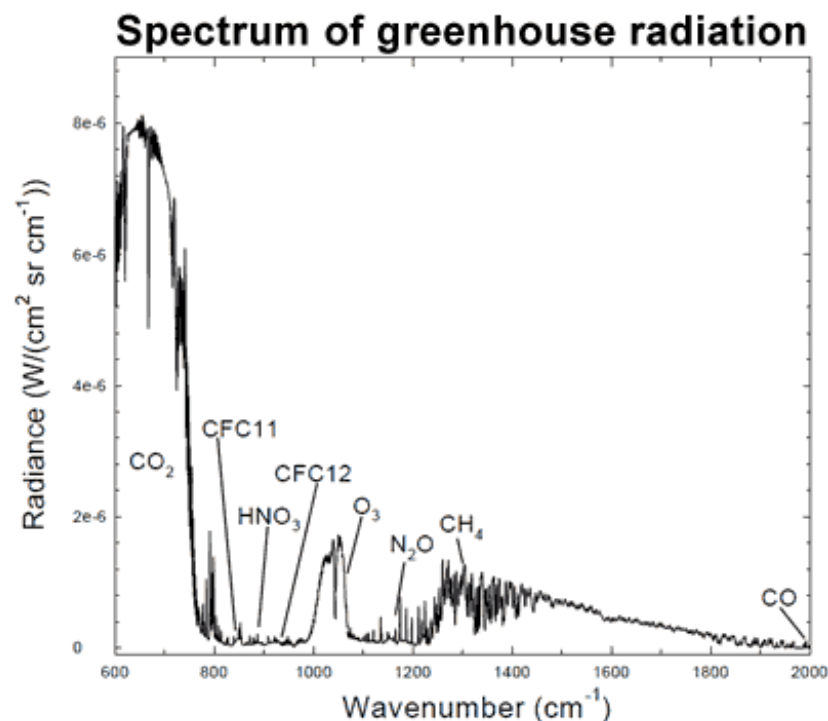


Figure 3: Spectrum of the greenhouse radiation measured at the surface. Greenhouse effect from water vapor is filtered out, showing the contributions of other greenhouse gases ([Evans 2006](#)).

The planet is accumulating heat

When there is more energy coming in than escaping back out to space, our climate accumulates heat. The planet's total heat build up can be derived by adding up the heat content from the ocean, atmosphere, land and ice ([Murphy 2009](#)). Ocean heat content was determined down to 3000 metres deep. Atmospheric heat content was calculated from the

surface temperature record and heat capacity of the troposphere. Land and ice heat content (eg - the energy required to melt ice) were also included.

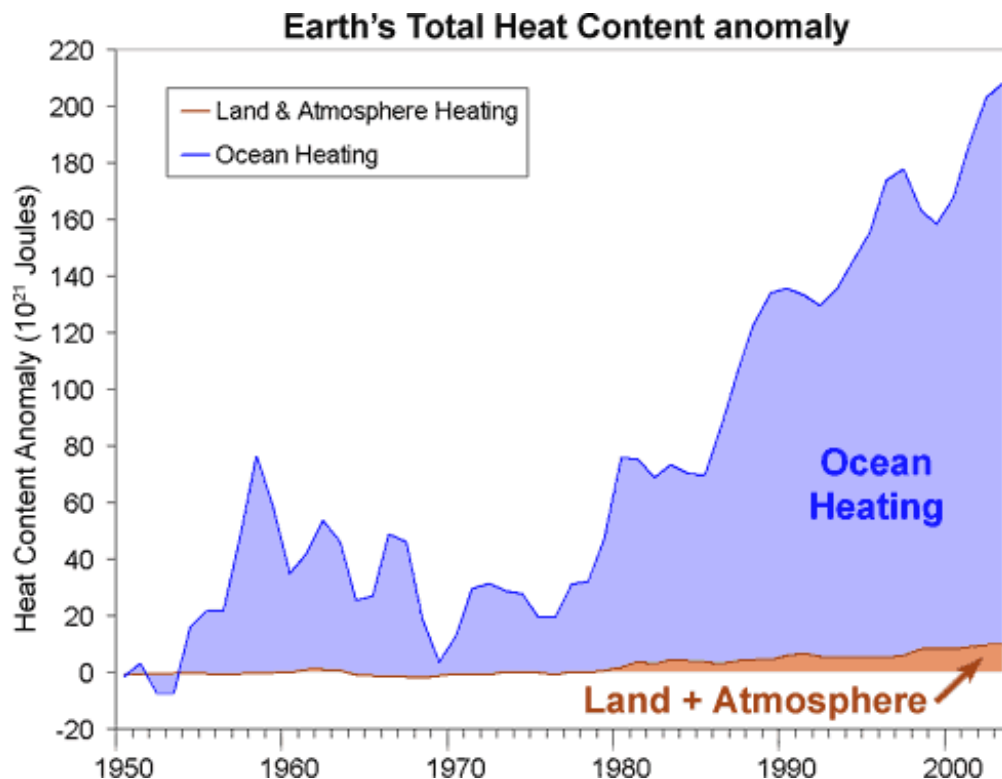


Figure 4: Total Earth Heat Content from 1950 ([Murphy 2009](#)). Ocean data taken from [Domingues et al 2008](#).

From 1970 to 2003, the planet has been accumulating heat at a rate of 190,260 gigawatts with the vast majority of the energy going into the oceans. Considering a typical nuclear power plant has an output of 1 gigawatt, imagine 190,000 nuclear power plants pouring their energy output directly into our oceans. What about after 2003? A map of of ocean heat from 2003 to 2008 was constructed from ocean heat measurements down to 2000 metres deep ([von Schuckmann 2009](#)). Globally, the oceans have continued to accumulate heat to the end of 2008 at a rate of $0.77 \pm 0.11 \text{ Wm}^{-2}$, consistent with other determinations of the planet's energy imbalance ([Hansen 2005](#), [Trenberth 2009](#)). The planet continues to accumulate heat.

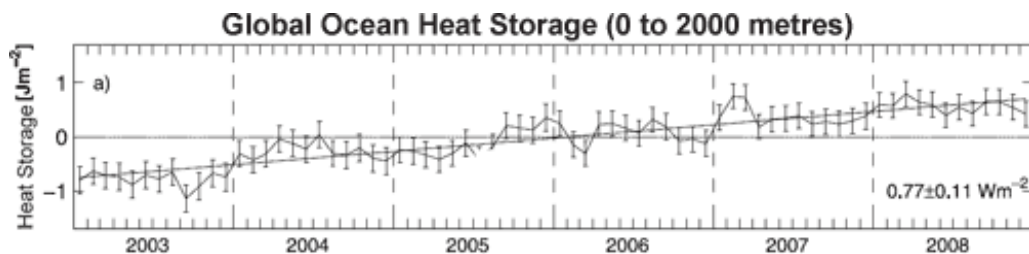


Figure 5: Time series of global mean heat storage (0–2000 m), measured in 10^8 Jm^{-2} .

So we see a direct line of evidence that we're causing global warming. Human CO2 emissions far outstrip the rise in CO2 levels. The enhanced greenhouse effect is confirmed by satellite and surface measurements. The planet's energy imbalance is confirmed by summations of the planet's total heat content and ocean heat measurements.

For more evidence that humans are causing global warming, check out [The human fingerprint in global warming](#).



Skeptical Science explains the science of global warming and examines climate misinformation through the lens of peer-reviewed research. The website won the Australian Museum 2011 Eureka Prize for the Advancement of Climate Change Knowledge. Members of the Skeptical Science team have authored peer-reviewed papers, a [college textbook on climate change](#) and the book [Climate Change Denial: Heads in the Sand](#). Skeptical Science content has been used in university courses, textbooks, government reports on climate change, television documentaries and numerous books.



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