



This is the print version of the [Skeptical Science](http://sks.to/greenhouse) article '[Increasing CO2 has little to no effect](http://sks.to/greenhouse)', which can be found at <http://sks.to/greenhouse>.

# How do we know more CO2 is causing warming?

## What The Science Says:

An enhanced greenhouse effect from CO2 has been confirmed by multiple lines of empirical evidence.

## Climate Myth: Increasing CO2 has little to no effect

"While major green house gas H2O substantially warms the Earth, minor green house gases such as CO2 have little effect.... The 6-fold increase in hydrocarbon use since 1940 has had no noticeable effect on atmospheric temperature ... " ([Environmental Effects of Increased Atmospheric Carbon Dioxide](#))

## Predicting the Future

Good scientific theories are said to have 'predictive power'. In other words, armed only with a theory, we should be able to make predictions about a subject. If the theory's any good, the predictions will come true.

Here's an example: when the Table of Elements was proposed, many elements were yet to be discovered. Using the theory behind the Periodic Table, the Russian chemist Dmitri Mendeleev was able to predict the properties of germanium, gallium and scandium, despite the fact they hadn't been discovered.

The effect of adding man-made CO2 is predicted in the theory of greenhouse gases. This theory was first proposed by Swedish scientist Svante Arrhenius in 1896, based on earlier work by Fourier and Tyndall. Many scientist have refined the theory in the last century. Nearly all have reached the same conclusion: if we increase the amount of greenhouse gases in the atmosphere, the Earth will warm up.

What they don't agree on is by how much. This issue is called '[climate sensitivity](#)', the amount the temperatures will increase if CO2 is doubled from pre-industrial levels. Climate models have predicted the least temperature rise would be on average 1.65°C (2.97°F) , but upper estimates vary a lot, averaging 5.2°C (9.36°F). Current best estimates are for a rise of around 3°C (5.4°F), with a likely maximum of 4.5°C (8.1°F).

## What Goes Down...

The greenhouse effect works like this: Energy arrives from the sun in the form of visible light and ultraviolet radiation. The Earth then emits some of this energy as infrared radiation. Greenhouse gases in the atmosphere 'capture' some of this heat, then re-emit it in all directions - including back to the Earth's surface.

Through this process, CO2 and other greenhouse gases keep the Earth's surface 33°Celsius (59.4°F) warmer than it would be without them. We have added 42% more CO2, and temperatures have gone up. There should be some evidence that links CO2 to the temperature rise.

So far, the average global temperature has gone up by about 0.8 degrees C (1.4°F):

"According to an ongoing temperature analysis conducted by scientists at NASA's Goddard Institute for Space Studies (GISS)...the average global temperature on Earth has increased by about 0.8°Celsius (1.4°Fahrenheit) since 1880. Two-thirds

of the warming has occurred since 1975, at a rate of roughly 0.15-0.20°C per decade."

The temperatures are going up, just like the theory predicted. But where's the connection with CO<sub>2</sub>, or other greenhouse gases like methane, ozone or nitrous oxide?

The connection can be found in the spectrum of greenhouse radiation. Using high-resolution FTIR spectroscopy, we can measure the exact wavelengths of long-wave (infrared) radiation reaching the ground.

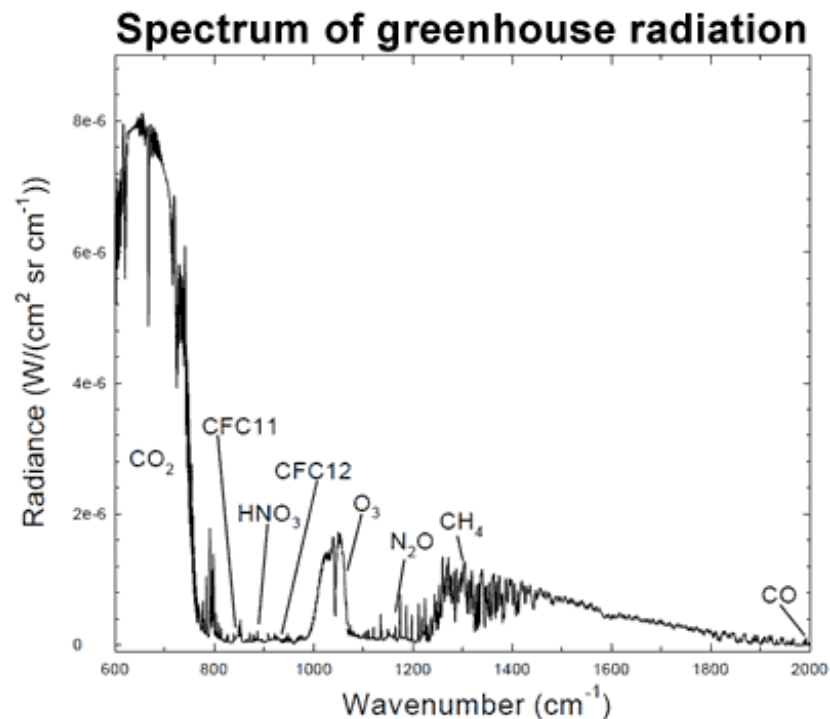


Figure 1: Spectrum of the greenhouse radiation measured at the surface. Greenhouse effect from water vapour is filtered out, showing the contributions of other greenhouse gases ([Evans 2006](#)).

Sure enough, we can see that CO<sub>2</sub> is adding considerable warming, along with ozone (O<sub>3</sub>) and methane (CH<sub>4</sub>). This is called surface radiative forcing, and the measurements are part of the empirical evidence that CO<sub>2</sub> is causing the warming.

### ...Must Go Up

How long has CO<sub>2</sub> been contributing to increased warming? According to NASA, "Two-thirds of the warming has occurred since 1975". Is there a reliable way to identify CO<sub>2</sub>'s influence on temperatures over that period?

There is: we can measure the wavelengths of long-wave radiation leaving the Earth (upward radiation). Satellites have recorded the Earth's outbound radiation. We can examine the spectrum of upward long-wave radiation in 1970 and 1997 to see if there are changes.

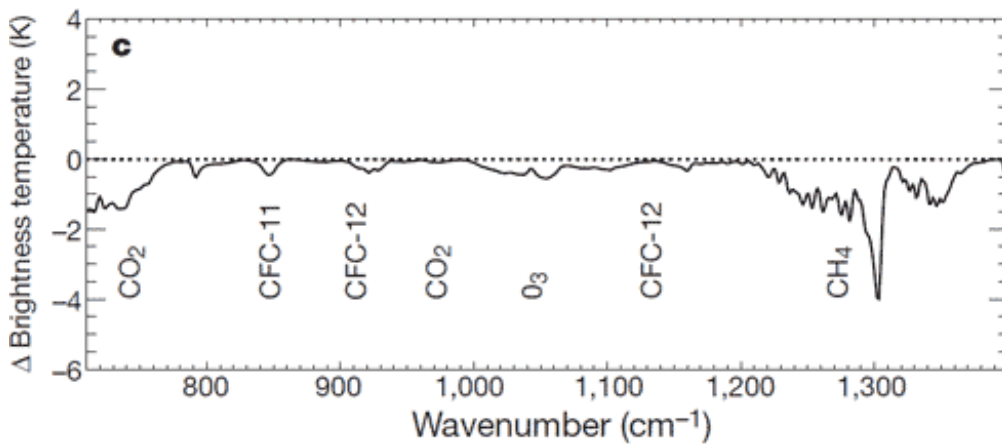


Figure 2: Change in spectrum from 1970 to 1996 due to trace gases. 'Brightness temperature' indicates equivalent blackbody temperature ([Harries 2001](#)).

This time, we see that during the period when temperatures increased the most, emissions of upward radiation have *decreased* through radiative trapping at exactly the same wavenumbers as they *increased* for downward radiation. The same greenhouse gases are identified: CO<sub>2</sub>, methane, ozone etc.

## The Empirical Evidence

As temperatures started to rise, scientists became more and more interested in the cause. Many theories were proposed. All save one have fallen by the wayside, discarded for lack of evidence. One theory alone has stood the test of time, strengthened by experiments.

We know CO<sub>2</sub> absorbs and re-emits longwave radiation (Tyndall). The theory of greenhouse gases predicts that if we increase the proportion of greenhouse gases, more warming will occur (Arrhenius).

Scientists have measured the influence of CO<sub>2</sub> on both incoming solar energy and outgoing long-wave radiation. Less longwave radiation is escaping to space at the specific wavelengths of greenhouse gases. Increased longwave radiation is measured at the surface of the Earth at the same wavelengths.

### **These data provide empirical evidence for the predicted effect of CO<sub>2</sub>.**

Basic rebuttal written by [GPWayne](#)

#### **Update July 2015:**

Here is a related lecture-video from [Denial101x - Making Sense of Climate Science Denial](#)





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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