Cold Facts on Global Warming

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Introduction

What is the contribution of anthropogenic carbon dioxide to global warming? This question has been the subject of many heated arguments. In this article, we will consider a simple calculation, based on well-accepted facts, that shows that the global temperature increase caused by doubling atmospheric carbon dioxide levels is bounded by an upper limit of 2.32 degrees centigrade. This result contrasts with the results of the IPCC's climate models, whose projections are shown to be unrealistically high.

The Greenhouse Effect

There is general agreement that the Earth is naturally warmed to some extent by atmospheric gases, principally water vapor, in what is often called a "greenhouse effect". The Earth absorbs enough radiation from the sun to raise its temperature by 0.5 degrees per day, but is theoretically capable of emitting sufficient long-wave radiation to cool itself by 5 times this amount. The Earth maintains its energy balance in part by absorption of the outgoing longwave radiation in the atmosphere, which causes warming.

On this basis, it has been estimated that the current level of warming is on the order of 33 degrees C [1]. That is to say, in the absence of so-called greenhouse gases, the Earth would be 33 degrees cooler than it is today, or about 255 K (-0.4° F) [2]. Of these greenhouse gases, water is by far the most important and accounts for 95% of the warming effect, or about 31.35 of the 33 degrees. Carbon dioxide, although present in much lower concentrations than water, absorbs more infrared radiation than water on a per-molecule basis and contributes about 3.62% of the total greenhouse gas effect.

Of course, this 33 degree increase in temperature is not caused simply by absorption of radiation by the gases themselves. Much of the 33 degree effect is caused by the Earth's adaptation to higher temperatures, which includes secondary effects such as increased water vapor, cloud formation, and changes in albedo or surface reflectivity caused by melting and aging of snow and ice. Accurately calculating the relative contribution of each of these components presents major difficulties.

Global Warming Potential (GWP)

Traditionally, greenhouse gas levels are presented as dimensionless numbers representing parts per billion (ppb) multiplied by a scaling factor (global warming potential or GWP) that allows their relative efficiency of producing global temperature increases to be compared. For carbon dioxide, this scaling factor is 1.0. The factors for methane and nitrous oxide are 21 and 310, respectively, while sulfur hexafluoride is 23,900 times more effective than carbon dioxide [3]. The larger GWP from carbon dioxide compared to water is partly due to its stronger absorption than water and the position of its absorption bands in the critical longwave infrared region at 2, 3, 5, and 13-17 micrometers.

Methane, nitrous oxide, ozone, CFCs and other miscellaneous gases absorb radiation even more efficiently than carbon dioxide, but are also present at much lower concentrations. Their high GWP results from their molecular structure which makes them absorb strongly and at different wavelengths from water vapor and carbon dioxide. For example, although ozone is usually thought of as an absorber of ultraviolet radiation, it also absorbs longwave infrared at 9.6 micrometers. These gases account for another 1.38% of the natural greenhouse gas effect. The increase in the global energy balance caused by greenhouse gases is called "radiative forcing".

The GWP of a greenhouse gas is the ratio of the time-integrated radiative forcing from 1 kg of the gas in question compared to 1 kg of carbon dioxide. These GWP values are calculated over a 100 year time horizon and take into consideration not only the absorption of radiation at different wavelengths, but also the different atmospheric lifetimes of each gas and secondary effects such as effects on water vapor. For example, methane contributes indirectly to the production of tropospheric ozone and stratospheric water vapor. For some gases, the GWP is too complex to calculate because the gas participates in complex chemical reactions. Most researchers use the GWPs compiled by the World Meteorological Organization (WMO).

Even though most of the so-called greenhouse effect is caused by water vapor, about 1.19 degrees of our current empirically-measured temperature of roughly 288 K (59° F) can be attributed to carbon dioxide. Water vapor at least 99.99% of 'natural' origin, which is to say that no amount of deindustrialization could ever significantly change the amount of water vapor in the atmosphere. Thus, climatologists have concentrated mostly on carbon dioxide and methane.

Carbon Dioxide Levels

Figures from the U.S. Department of Energy show that the pre-industrial baseline of carbon dioxide is 288,000 ppb. The total man-made addition of carbon dioxide so far has been 11,880 ppb, while natural emissions have added an additional 68,520 ppb. This raises the total current carbon dioxide to 368,400 parts per billion, or 0.0368% of the atmosphere. Man-made carbon dioxide is therefore currently about 3.2% of the total atmospheric carbon dioxide.

The ocean and biosphere possess a large buffering capacity, mainly because of carbon dioxide's large solubility in water. Because of this, it is safe to conclude that the anthropogenic component of atmospheric carbon dioxide concentration will continue to remain roughly proportional to the rate of carbon dioxide emissions. In other words, the carbon dioxide buffers are in dynamic equilibrium with atmospheric carbon dioxide and are not in any danger of being saturated, which would allow all the emitted carbon dioxide to go into the atmosphere. This means:

- The percentage of emitted carbon dioxide that ends up in the atmosphere can be treated as approximately constant.
- The effects of carbon dioxide emissions are not cumulative. That is, lowering carbon dioxide would produce an almost instantaneous reduction (on a climatological scale) in any warming effect that it was producing.
- If fossil fuel use increases or decreases, atmospheric carbon dioxide will also increase or decrease proportionately.

From the above numbers, it can be seen that, to a first approximation, the anthropogenic carbon dioxide currently in the atmosphere would account for 0.116% of the estimated total global warming effect, or approximately +0.038 degrees. If surface temperatures are increasing in excess of these levels, it must be due to some other factor.

Amplification and Dampening

Of course, climate, like weather, is complex, nonlinear, and perhaps even chaotic. Increased solar irradiation can lower the albedo, which would amplify any effect caused by changes in solar flux, making the relation between radiation and temperature greater than linear. Increased temperatures also cause increased evaporation of sea water, which can cause warming because of water's greenhouse effect, and also can affect the radiation flux by creating additional clouds. On the other hand, increased plant growth, especially in the oceans, would tend to extract carbon dioxide from the atmosphere, making the fraction of emitted carbon dioxide that stays in the atmosphere lower. Thus, higher emissions would probably cause a slightly smaller proportion of carbon dioxide to remain in the atmosphere than is currently the case, tending to make the relation less than linear.

The arithmetic of absorption of infrared radiation also works to decrease the linearity. The concentration of carbon dioxide is already high enough to absorb all the infrared radiation in the CO_2 absorption bands over a distance of only a few km. Thus, even if the atmosphere were heavily laden with carbon dioxide, it would still only cause an incremental increase in infrared absorption over current levels. This means that a situation like Venus could not happen here. The atmosphere of Venus is 90 times thicker than Earth's and is 96% carbon dioxide, making the atmospheric carbon dioxide concentration on Venus 300,000 times higher than on Earth. Even so, the high temperatures on Venus are only partially caused by carbon dioxide; a major contributor is the thick bank of clouds containing sulfuric acid [6]. Although these clouds give Venus a high reflectivity in the visible region, the Galileo probe showed that the clouds appear black at infrared wavelengths of 2.3 microns due to strong infrared absorption [7]. The infrared absorption lines by carbon dioxide are also broadened by the high pressure on Venus [8].

Very little of the radiation from the sun at the wavelengths at which carbon dioxide absorbs reaches the surface of the Earth directly; most of the infrared at these wavelengths is produced by scattering or black body radiation from objects that have been heated up. This means that if the carbon dioxide levels increase, it will have little effect on the total amount of infrared radiation that is absorbed from the sun. The main effect would be to trap radiation originating at the surface at lower levels in the atmosphere, where it is slightly more difficult for the heat to be re-radiated back into space.

The net effect of all these processes is that doubling carbon dioxide would not double the amount of global warming. In fact, the effect of carbon dioxide is roughly logarithmic. Each time carbon dioxide (or some other greenhouse gas) is doubled, the increase in temperature is less than the previous increase. The reason for this is that, eventually, all the longwave radiation that can be absorbed has already been absorbed. It would be analogous to closing more and more shades over the windows of your house on a sunny day -- it soon reaches the point where doubling the number of shades can't make it any darker.

The analogy with a greenhouse would be that the glass in the roof becomes slightly thicker. The effect of warming also depends on the conditions inside the greenhouse. If the greenhouse were full of ice at exactly -0.01 degrees Celsius, making the glass 3.6% thicker just might be enough to melt all the ice and flood the greenhouse. But if the greenhouse had some regions that were hot and some that were very cold (as the planet Earth does), it would have a very small overall effect.

As an aside, the term "greenhouse effect" is actually a misnomer. In greenhouses, most of the warming that is observed is not caused by carbon dioxide, or by absorption of infrared radiation by the glass as many people think, but by reduction in convection [5].

Linear Climate Projections

From the above numbers, it is easy to calculate, assuming a linear dependence of temperature on greenhouse gas concentrations, that a doubling of atmospheric carbon dioxide, if such a thing could happen with no other secondary effects, should produce an additional warming of 0.0362 x 33 = 1.194 degrees centigrade. This is probably an upper limit, because sulfate aerosols, which are typically emitted along with carbon dioxide, tend to counteract the warming effect.

This calculation does not include the secondary and amplification effects caused by increased water vapor, changes in albedo, and so forth, caused by incrementing carbon dioxide. While the overall, empirically-based 33 degree increase was made by a combination of radiative effects from the gases and the Earth's adaptation to the resultant warming, our 3.6% increase does not yet account for the Earth's adaptation. In effect, although we could increase water vapor by 3.6% without affecting CO2, we can't increase CO2 by 3.6% without affecting water vapor. Using the same assumptions of approximate linearity (see graph below), a 3.6% increase in greenhouse gases emitted as pure carbon dioxide would produce a 3.6 x (1 + 0.95)% = 7.02% increment in total greenhouse warming equivalents, which includes CO2 plus other secondary effects (lumped together as water vapor equivalents). This correction converts our imaginary CO2 increase to the same units as the graph below, and allows us to predict the overall temperature increase as 2.32 degrees. This number includes secondary effects of water vapor, changes in albedo, and other responses.

The linear projection shown here is a more straightforward argument than those used in climate models, because it does not treat the radiative forcing caused by carbon dioxide separately from the planet's adaptation to it. In other words, we did not just build a model and add carbon dioxide, but instead took numbers that are based on empirical measurements and extended them by 3.6%. If, on the other hand, we had postulated an increase in solar radiation, or if we wished to do an ab initio calculation like those attempted by some climate researchers, it would not be so simple. In this case it would have been necessary to calculate secondary effects like changes in albedo and water vapor. This would require an enormously complex computer model, similar to the models many climatologists have created.

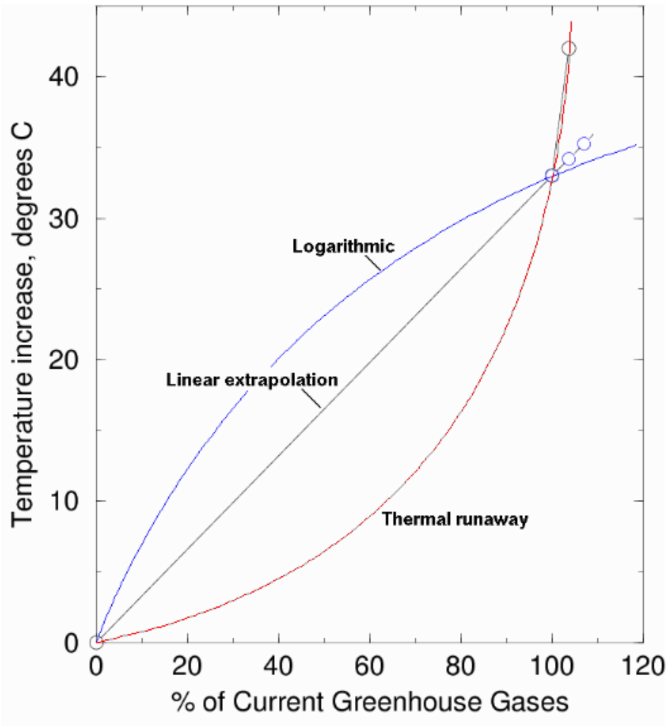

Fig.1 Estimated greenhouse gas-induced global warming plotted against greenhouse gas concentrations expressed as a percentage of current-day values. The black curve is a linear extrapolation calculated from the DOE estimates of total current greenhouse gases. The sharp jump at the right is the data point from one computer model that predicts a nine degree increase from doubling current levels of carbon dioxide. Marked, unphysical deviations from linearity resulting in thermal runaway (red curve) are required to fit this data point with the two known points. Such a strong nonlinear effect is difficult to reconcile with our current understanding of climate.

Our calculation also assumes that the increase in temperature is linearly proportional to the greenhouse gas levels. However, as indicated above, the relationship is not linear, but logarithmic. A plot of temperature vs. gas concentration (expressed as a percentage of current-day levels) would be a convex curve, something like the blue curve in Figure 1. Thus, 2.32 degrees is an upper bound, and depending on the exact shape of the blue curve, could be a large overestimate of the warming effect.

This estimate of 2.32 degrees is somewhat higher than the estimate of 1.4 degrees associated with the "empiricist" school of the University of Delaware, University of Virginia, and Arizona State University. An increase of 1.4 degrees was also predicted by P.J. Michaels and R.C. Balling using the NCAR Community Climate Model 3 model, after the large increases in projected carbon dioxide in the original paper in which the model was described were replaced with more realistic ones.

Comparison with IPCC projections

These modest increases are quite different from the results of climate models endorsed by the IPCC. Their climate models predict temperature increases from a doubling of carbon dioxide ranging from 3 to as much as 9 degrees! Which is correct?

It goes without saying that the results shown here depend on the accuracy of the original 33 degree estimate and the validity of extrapolating of the existing curve by an additional 3.6% of its length. However, we can check the plausibility of the IPCC's result by asking the following question: Instead of 33 degrees, what number would result if we calculated backwards from the IPCC estimates?

Using the same assumption of linearity, if a 9 degree increase resulted from an increase of greenhouse gas levels by 3.6% above current levels, the current greenhouse gas level (which is by definition 100%) would be equivalent to a greenhouse gas-induced temperature increase of 9 ÷ 1.95 ÷ 0.036 = 128 degrees C. This means the for the 9 degree figure to be correct, the current global temperature would have to be about 255 + 128 - 273 = 110 degrees Centigrade, or 230° Fahrenheit! A model that predicts a current-day temperature well above the boiling point of water is clearly in need of serious tweaking. Even a 5 degree projection predicts current-day temperatures of 53°C (128°F). These results clearly cannot be reconciled with observations.

But it gets worse. In order for the 9 degree estimate to make sense from a physical standpoint, we are forced to draw an exponential curve through the graph above (shown in red) through the three points instead of a straight line. However, this curve creates an even worse result: it predicts a thermal runaway. A thermal runaway is a reaction that suddenly switches from a smooth curve and goes wildly out of control. For example, in an electronic circuit, if a transistor gets too hot, the chemical properties of the silicon can change and its resistance decreases, causing more and more current to flow, which causes it to burn up. Similarly, for the the nine-degree climate model to fit the observations, the curve that we must draw predicts that a 10 or 20% increase in greenhouse gases above their current levels would cause an infinite increase in temperature! Of course, some other factor (such as explosion of the Earth in a supernova-type explosion) would undoubtedly kick in to save us before an infinite temperature could be reached. But even so, it can be seen that an above-linear increase in temperature with increasing gas concentration is not only unphysical, but inconsistent with observations.

In order to prevent absurd conclusions from the IPCC projections, it is necessary to make some additional assumption -- for example, assuming that the dependence of radiative forcing on gas concentration depends critically on the exact percentage of each component of greenhouse gases as a function of altitude, or perhaps that the relationship between gas concentration and temperature is sigmoidal, and levels off at some point above the predicted increase. Yet no physical basis for such a sigmoidicity has been proposed. This means that these projections of extreme climate changes are unlikely to be accurate, or at the very least, worthy of great skepticism.

Although the estimates of global warming made by the IPCC and the predictions of "environmental catastrophe" made by environmental groups have gradually creeping back down as climate models gradually improve, environmentalists still worry that temperatures could increase by as much as 3 to 5 degrees over the next century.

However, as shown above, even a 5 degree increase in temperature would constitute a significant departure from the previous rates of increase. It is clear from Figure 1 that this too would be a marked deviation from the curve. Such strong nonlinear effects, especially when they are in the wrong direction from a physical standpoint, are difficult to reconcile with our current understanding of climate.

Conclusion

Although carbon dioxide is capable of raising the Earth's overall temperature, the IPCC's predictions of catastrophic temperature increases produced by carbon dioxide have been challenged by many scientists. In particular, the importance of water vapor is frequently overlooked by environmental activists and by the media. The above discussion shows that the large temperature increases predicted by the computer models are unphysical and inconsistent with results obtained by basic measurements. Skepticism is warranted when considering computer-generated projections of global warming that cannot even predict existing observations.

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