Carbon Heat Trapping: Merely a Bit Player in Global Warming[1]

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Abstract

New calculations show that doubling of carbon dioxide (CO_2) will increase average global temperature by only about 1F (degrees Fahrenheit) or 0.55C (degrees Centigrade), much less than the range of 2C to 4.5C estimated by the United Nations International Panel on Climate Change (IPCC). These new calculations are based on NASA supported spectral calculations available on the Internet relating to greenhouse gases. The temperature increases are estimated to be somewhat more in winter in the colder climates because of reduced competing atmosphere water vapor, but smaller increases at other times and places. These calculations also estimate that a 10% increase of water vapor in the atmosphere, a stronger greenhouse gas than CO_2, or a reduction in the average cloud cover of only about 2 percent, will increase global temperature about as much as doubling CO_2 would. Each additional doubling of CO_2 will cause further temperature increases about the same as that caused by the first doubling. Greenhouse gases, except water vapor, only trap heat at certain narrow wavelengths of infrared radiation related to their molecular structures. Data shows that present concentrations of CO_2, a strong absorber, are already well above the saturation value at its principal wavelength, so increases in it have a relative small affect. These new calculations are based on atmospheric models of the energy absorption bandwidths of greenhouse gases coupled with Max Planck's equations relating to infrared wavelength distributions. A new simple technique is also proposed in the appendix to measure actual trapped heat being radiated back from the atmosphere to the Earth. This can be used to evaluate validate various estimating models. It also indicates that the role of clouds and their height above the Earth may have a larger role than previously thought. Since clouds operate as both powerful heat-trapping agents, overriding others, and a reflector of the sun's energy, they may be the key factor in the regulation of the average global temperature. At the present time, they are one of the least measured parameters in the computer models predicting future climate changes. Weather and climate forecasting considering all factors is very complex, thus this paper does not cover that subject. However it is felt that the simple role of long-term heat rises due to only CO_2 changes is a much simpler process and better estimated by basic models as used herein. Certain shortcomings in the IPCC data and estimates, as reported by others, are also summarized. Based on this new information, recommendations are made regarding future U.S. energy policy. While it does appear that the recent years show a warming trend, the role of CO_2 in this is very small, and perhaps beneficial in moderating winter temperatures in colder climates.

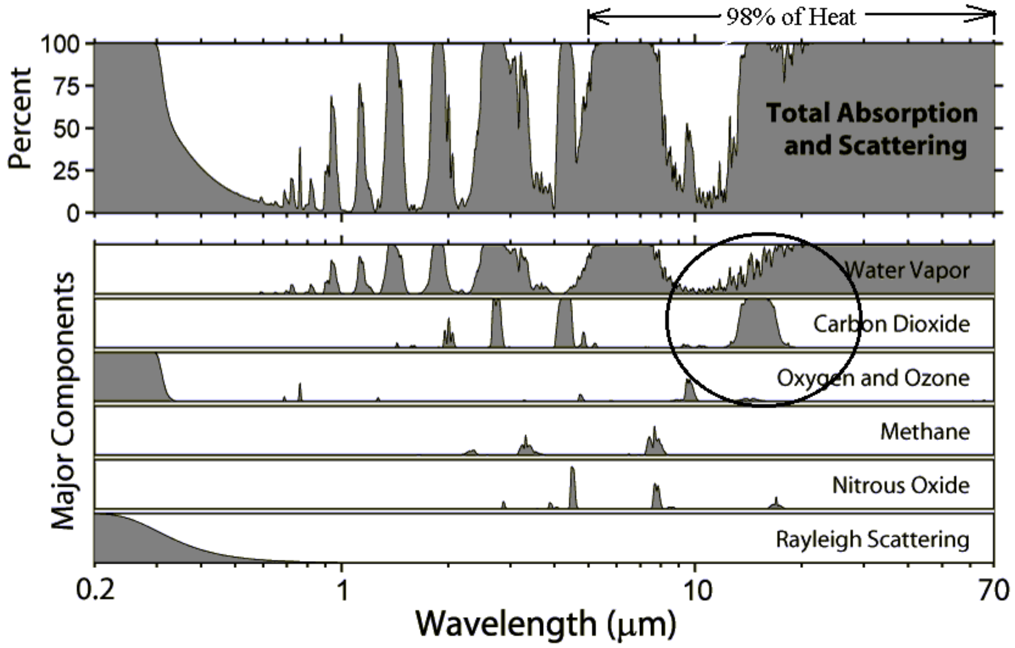
Understanding Heat "Trapping"

It is well known that certain gases such as carbon dioxide (CO_2), water vapor, methane, and others in the atmosphere absorb radiant infrared heat that is leaving the Earth's surface, warm the air, and re-radiate heat in all directions, including back to Earth. Infrared energy is an electromagnetic wave like visible light and radio waves, but of different frequencies or wavelengths. (This heat transfer process is incorrectly called "trapping", but at times we will use that term here because it is referred to so often in the media). However, it is not generally known that this heat absorption occurs only at certain wavelengths. These are the ones that have frequencies that resonate at certain values that relate to those of a particular molecule's structure. It is similar to a radio receiver picking up only signals that correspond to the frequency to which its tuner is adjusted. Some of these different gases have several resonant wavelengths and some of these overlap among them. This is the case for water vapor and CO_2. Since there are many more water vapor molecules in the air than CO_2, the ones for CO_2 that do not overlap, or only partially overlap water vapor, are of interest. Note: The term “greenhouse gas” is actually a misnomer. In real greenhouses the ceiling blocks the rising warm air from escaping. With little temperature differences, radiant heat transfer is very low. So phrases such as “heat trapping greenhouse gases” (two flawed concepts in only four words) are causing great concern and misleading the uninformed public. Hopefully, this paper will help to correct this situation.

Quantifying Carbon Dioxide Heat Trapping

Figure 1[2] shows the absorbing wavelengths for various greenhouse gases in the atmosphere and the percent of infrared heat each absorbs (the shaded regions represent absorption, the white depicts transmission). Wavelengths from about 5 to 70 microns cover close to 98 percent of the infrared energy at a typical Earth temperature at 50F, so this is the region of interest.

FIGURE 1



Radiation Transmitted by the Atmosphere

Image:Atmospheric Transmission.png
From Wikipedia, the free encyclopedia

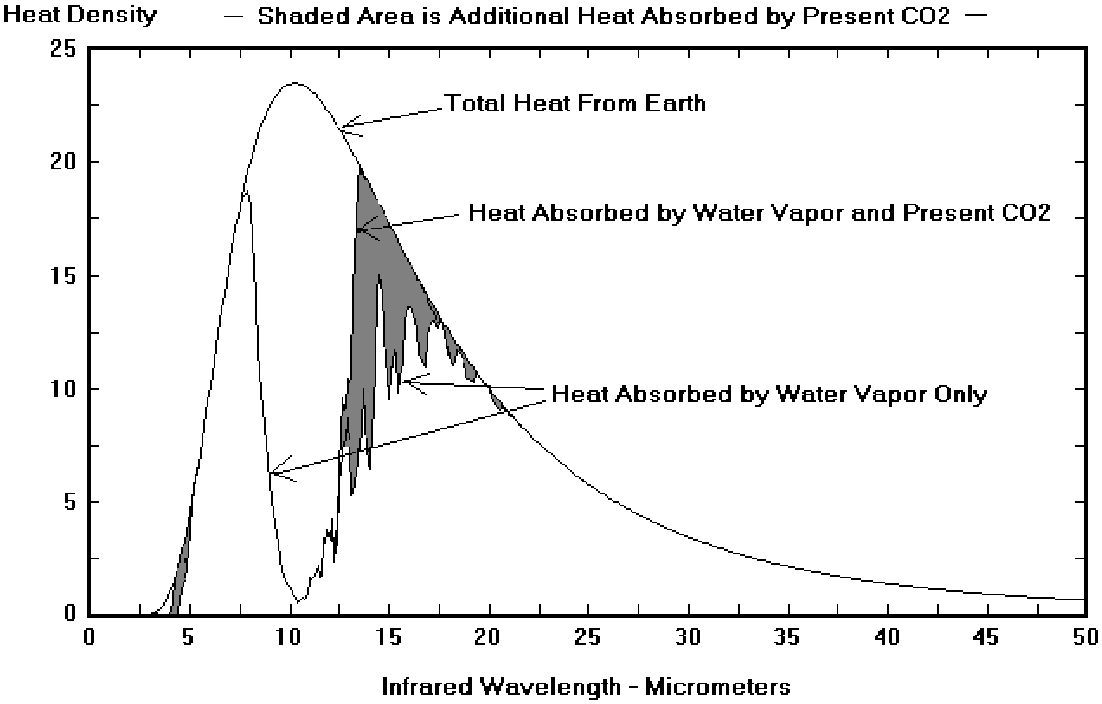
The total heat radiated depends strongly on the temperature; it roughly doubles from 0F to 100F. However over this range, the wavelength where the peak energy occurs only moves about plus or minus 10 percent from that at 50F. Carbon dioxide has one major resonant value in this range at 15 micrometers, shown in the circled area. Note that this area reaches the 100 percent line and is flat for several micrometers with a steep rise and fall on the sides. This indicates that the amount of CO_2 in the atmosphere is highly saturated regarding absorption at this wavelength. The case is quite different for water vapor. It has some wide flat regions and some others with broad transitions from low to high absorption. This is because water vapor has many different absorbing wavelengths of varying strengths, so some are saturated and some are not. The weak ones do some absorption helped by the fact that there are about 20 times more water vapor molecules than those of CO_2 in the air at typical temperatures. Carbon dioxide on the other hand has very strong absorption, but at only over relatively narrow wavelength bands. Also note that there is considerable overlap of the CO_2 and water vapor absorption regions. This means that if the water vapor absorbs the energy at that wavelength, changing the amount of CO_2 will have little effect. It is interesting to note that some of the other gases shown do not reach the 100 percent line, so these are unsaturated. Oxygen and ozone reach a peak around 9.5 micrometers at 50 percent, and their contribution to the total can be seen in the total absorption in the top section. Also note that methane mostly overlaps with water vapor, so it may not be a major contributor that some people feel it is. It has been reported in the IPCC Report that methane absorbs 25 times the energy per molecule than CO_2. However this factor is already incorporated into the shaded areas for methane since they represent energy absorbed.

The major area of interest regarding CO_2 is on the left half of the circled region of its absorption band because this is where the water vapor absorption is less that 100 percent.

The outer curve in Figure 2 shows the distribution by wavelength of the radiated infrared heat coming from the Earth's surface at an approximate average global temperature of 50F. To get the heat absorbed by a gas at a small range of wavelengths, the total energy at that wavelength (outer curve) is multiplied by the fraction absorbed by the gas at that same wavelength. Shown in Figure 2 is the heat absorbed by water vapor only and by water vapor plus CO_2. For the total heat absorbed, these are multiplied by the width of the range used and added (this numerical sum or integration was done by computer at small micrometer intervals and explained more in the appendix). It is represented by the area under each curve and is the total heat in watts per square meter.

Figure 2

Heat Radiated From Earth and Heat Absorbed by Water Vapor and CO2



Note the curve for water vapor has two peaks as would be expected from the atmospheric absorption shown in Figure 1. The gray shaded areas represent today's added absorption due to CO_2 over water vapor wavelengths in the 4.3 and 15-micrometer regions. It amounts to 7.4 percent of the total heat from the Earth after water vapor absorbs what it can. The region between the two water vapor peaks is the “atmospheric window”, where very little absorption occurs.

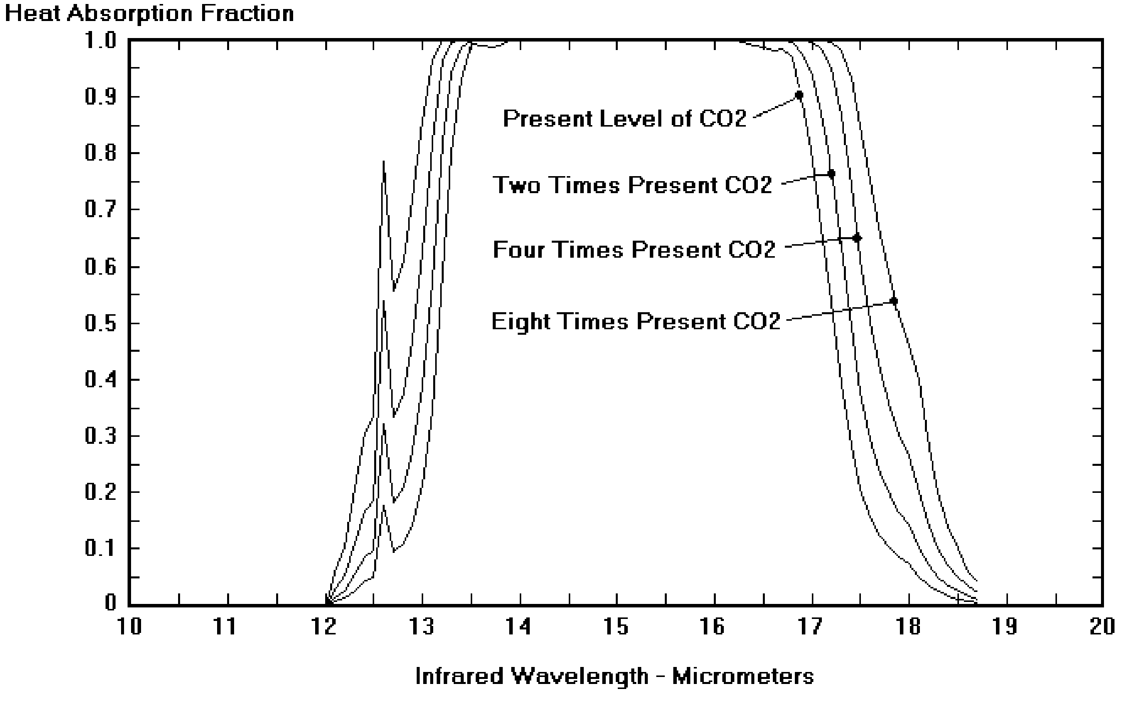
Two important questions are: How will an increase in the amount of CO_2 in the atmosphere increase the total heat absorption, and how much will that increase the average temperature of the Earth?

Quantifying the Effect of Increasing Carbon Dioxide Levels

The data used here are from the Spectral Calculator available through the Internet[3]. Various gases can be selected along with their concentrations, temperatures, pressures, and infrared wavelengths of interest, together with the path length through which transmission is calculated. What is not transmitted is absorbed by the gas, which warms it, and this is conducted to the surrounding atmosphere. For these calculations a 10-kilometer atmosphere path was used, broken into ten 1-kilometer segments in series, each with reducing pressures, and temperatures consistent with rising altitudes in the atmosphere. The amount of water vapor was also reduced with the colder temperatures. The parts-per-million (ppm) of the CO_2 were held constant with atmosphere; however, with reduced pressure at the higher altitudes, the density of the molecules drops. Absorption was about 40 percent of the maximum after one kilometer and 99 percent or more after 10 kilometers for both water vapor and CO_2. Runs were done with CO_2 levels at 350 ppm representing recent levels of CO_2 and double that at 700 ppm. The absorption for these is shown in Figure 3 expanded around the 15-micrometer region to better show the differences.

Figure 3

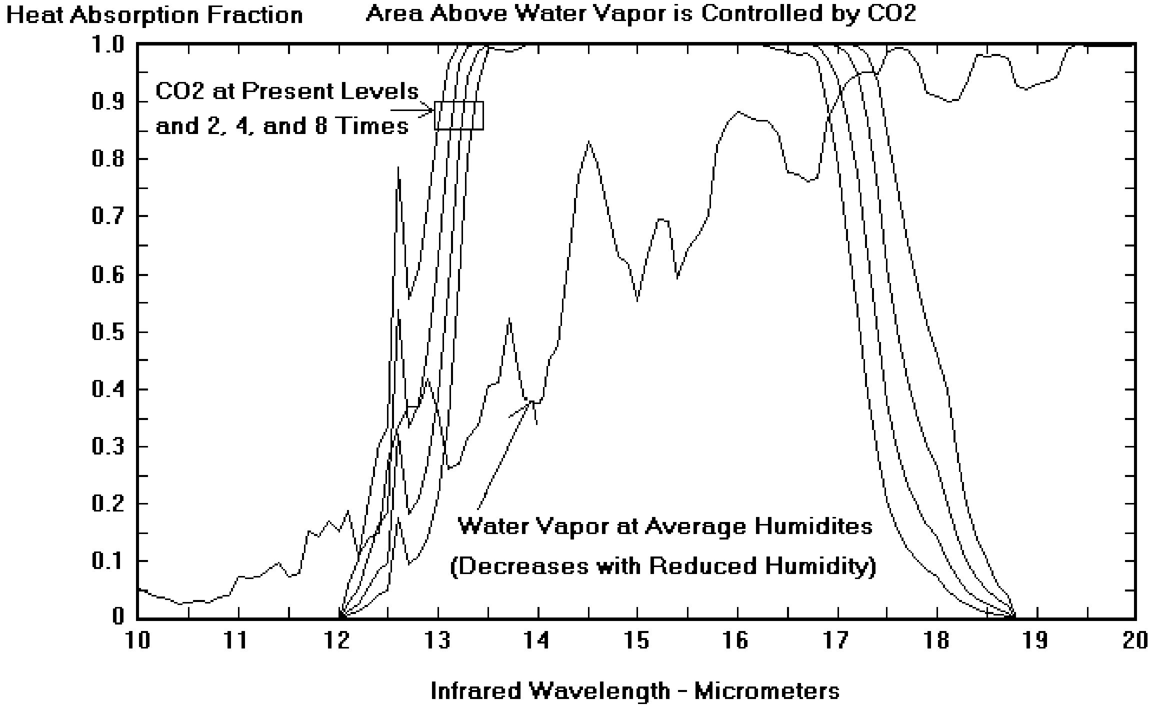
CO2 Absorption for Various Levels of CO2



On the 0 to 50-micrometer scale of Figure 2, they would be hard to see. As can be seen, there is not much difference in the absorption curves. The amount of heat captured is proportional to the area between the curves and the lower horizontal axis. In this case, doubling the CO_2 concentration increased this by 8.4 percent. However, due to water vapor competing with CO_2, the total increase in absorption is less than this. This is depicted in Figure 4 where the absorption curve of water vapor has been added.

Figure 4

Interaction of CO2 and Water Vapor Absorption in the 10 to 20 Micrometer Wavelength Region



Now it can be seen that only the CO_2 region above the water vapor line will make any change in the total heat absorbed, thereby reducing the increase of absorption with increasing amounts of CO_2. As the absolute humidity changes, the slope of the water vapor line will move up and down with it. Further diminishing the effect of increasing CO_2 is the fact that the heat density radiated from the Earth in this 10 to 20 micrometer range is dropping as can be seen in the outer curve of Figure 2. All these factors are combined to get absorption percentages and how they change with higher levels of CO_2. These values were used in a greenhouse gas heat-capture model that calculates the change in average global temperature from a change in atmosphere heat capture. The model has one half the heat captured by the atmosphere returning to the Earth, along with the average heat from the sun, and the other half captured radiating to outer space. It finds the surface temperature of the Earth that will cause a balance of the energy leaving the outer atmosphere with that arriving from the sun. The average heat from the sun at the Earth' surface is about 240 watts per square meter. If there were no heat captured by the atmosphere, the Earth's average temperature would be about 0.6F to in order to radiate 240 watts per square meter back to outer space for temperature equilibrium to be established. The heat the Earth must radiate for balance is 240 / (1 – **a**/2), where **a** = the radiation absorption fraction. If the absorption is 75 percent, when **a** is 0.75, then the value for the Earth's radiation is 240 / (1 - 0.375) or 384 with 75 percent or 288 being absorbed, and one half or 144 being sent back to Earth. So 240 from the sun and 144 from the air or 384 arrives at the Earth, balancing that which is radiated out. The total planet at the outer atmosphere is also balanced since one fourth from the Earth, or 96, passed through the atmosphere and this combined with the captured half of 144 adds up to 240 which is balanced with the 240 arriving from the sun. More information on applying these equations can be found in the appendix. The value of absorption that matches the present average temperature is about 0.77 or 77 percent. There are other smaller heat transfers between the Earth, the atmosphere and the sun that do not involve radiation, and clouds trap heat from the Earth and reflect back some of the sun's heat. But greenhouse gasses do not play a role in these, and properly handled, these simple balancing equations can be used to estimate the results in changes in the global temperature resulting in changes in greenhouse concentrations. Equations for including additional heat transfers and examples for these are covered in the appendix. But it is shown there that properly handled there is little change in the calculation results, while if not done correctly major errors can be introduced.

Using the greenhouse gas climate model, the results of increasing concentration levels of CO_2 are shown in Table 1. If about 3 percent is added to these to account for other gases as shown in Figure 1, the results are quite close to that estimated required to match present temperatures.

Table 1 – Computer Results of CO_2 Concentrations on Global Temperature

Factor	Present CO_2 Level	Two Times CO_2	Four Times CO_2	Eight Times CO_2
CO_2 Absorption	7.4%	8.0%	8.7%	9.6%
CO_2 + Water Vapor Absorption	74.10%	74.75%	75.48	76.27%
CO_2 + Water Vapor Increase	0	+0.87%	+1.87%	2.93%
Earth's Temperature Change – F	0	+0.69°	+1.46°	+2.31°
Earth's Temperature Change – C	0	+0.38°	+0.81°	+1.28°

Note: Table 1 ignores effect of clouds, seasonal variations and feedback. See paragraphs below and Table 2.

These are much smaller temperature changes than predicted by the UN International Panel on Climate Change (IPCC) for doubling the CO_2 level. They estimated a range from 2C to 4.5C vs. only 0.38C here. Some adjustments to the above table are advised and explained below. But to match IPCC estimates, the atmosphere capture would have to increase by up to 6 percentage points. Anything close to this is absolutely impossible due to CO_2, with its narrow absorbing bandwidth, being already so saturated.

Compensating for Water Vapor Seasonal Variations

The amount of water vapor drops considerably in the winter and this causes the role of CO_2 to increase. So, additional runs were made to simulate (1) winter time with 20 percent of yearly average water vapor and 70 percent of normal sun exposure and (2) summer time with water vapor at two times average and sun exposure at 130 percent of average. These were then combined in a weighed average with 25 percent each to the summer and winter values and 50 percent to the average values shown in Table 1. This increased the combined temperature rises by approximately 35 percent.

Effect of Clouds on Heat Absorption

Neglected so far is the effect of clouds. Clouds are different than water vapor. They form when water vapor condenses into its liquid or ice state. Being virtually opaque to infrared, they are a much stronger absorber and radiator of heat than water vapor or any other gas in the atmosphere and this occurs basically over the full wavelength spectrum of interest. Furthermore, because they are opaque, all of their radiation (based on their temperature) goes back to Earth, while for greenhouse gas radiation only half goes down and the rest up. Increased water vapor causes clouds to form at a lower altitude. These lower clouds are warmer and radiate more heat back to Earth than higher clouds would. So, increased water vapor has two effects: it absorbs more heat as a gas and produces more clouds that absorb even more heat. (Clouds also reflect much of the sun's energy back to outer space, but this is mostly independent of their altitude, except for the very high, thin, wispy Cirrus clouds that reflect back less). In the calculations used above in

Table 1 for the global temperature changes due to increased levels of CO_2, an accepted cloud cover and related reflection of the sun's energy of 25 percent was used in estimating the net average heat at the Earth's surface from the sun at 240 watts per square meter, but they were not used in estimating absorption from the Earth. Clouds absorb 100 percent over the entire Earth's infrared spectrum, and they occur over about 25 percent of the Earth's surface on the average. If the clouds are high, the gases will have already absorbed most of the heat before it reaches the clouds, but all of the other half radiated upward will be captured by the clouds and reradiated back, but from a colder temperature. So when clouds are present, they override the heat capture of greenhouse gases and their effect. A conservative estimate is that clouds trap about 15 percent of the total trapped and 20 percent of the total heat radiated back to Earth. So the relative impact of changes from CO_2 have less influence on the total and should be reduced by 20 percent, or multiplied by 0.80, from those in Table 1.

Role of Positive or Negative Feedback

Positive feedback refers to the situation in which a global temperature change causes some factor to increase (or decrease) that produces an additional temperature change in the same direction. This will magnify the original temperature change. A negative feedback has the opposite effect, reducing the change. Some people have reported that the reason the IPCC estimations for future temperature change have such a high range of variation (2C to 4.5C) is that some of the models use strong positive feedback. It has been stated by some that while added CO_2 causes an initial small temperature increase, this rise increases the water vapor, and that being a stronger heat absorber causes a larger final increase. In other words, while the effect of CO_2 is small (similar to that estimated in this paper) it acts as a trigger or catalyst and produces an additional larger increase. But if the feedback were that strong, who needs CO_2? The feedback from water vapor to itself is much stronger than that of CO_2; as shown below, a 10 percent increase in water vapor does about the same as that of doubling of CO_2. This can't be ignored just because the water vapor in the atmosphere cycles through in a few weeks. There is a flaw in this strong positive feedback theory with regard to water vapor, because if it were larger than the original change from CO_2 it would result in thermal runaway. A second flaw is to apply it selectively to CO_2 as the originator and exclude water vapor or other sources. Of course, a computer model can always be written to do this, but that does not mean such results should be used.

The effect of positive feedback from CO_2 to water vapor was estimated using the methods here at most at about 1/3 of the original increase due to CO_2. This based on the fact that a rise of 1F in average air temperature for the same relative humidity will increase the water vapor by 3.7 percent which will cause an increase of 0.24F or 24 percent of the original change. Summing up further feedbacks from water vapor to itself where each is 0.24 times the previous one, converges to a total of about 32 percent increase or about a third of the original rise. This water vapor feedback would occur from all originating sources, not just changes in CO_2 levels. There are some negative feedbacks, but they are being ignored here so the estimates for CO_2 effects are considered to be sufficient as a maximum value.

Combining the Seasonal, Cloud and Positive Feedback Effects

If the seasonal effects multiply the temperature rises by 1.35 and that of the clouds multiply them by 0.80, and positive feedback though water vapor adds another 32 percent, the combined effect is to add 42.5 percent to the values from Table 1. The results are shown in Table 2.

Table 2 – Compensated Effect of CO_2 Concentrations on Global Temperature

Factor	**Present CO_2 Level**	**Two Times CO_2**	**Four Times CO_2**	**Eight Times CO_2**
Earth's Temperature Change – F	0	+0.98°	+2.08°	+3.29°
Earth's Temperature Change – C	0	+0.55°	+1.16°	+1.83°

Effect of Water Vapor Increases

Since it is well known, and as shown in Table 1, that water vapor absorbs much more heat in the atmosphere that CO_2, what is the resulting global temperature increase due to more water vapor? A computer run was done with only 10 percent more water vapor. It showed that the contribution due to CO_2 dropped from 7.4 percent to 6.8 percent while total absorption increased by 0.85 percent, resulting in a global temperature rise of 0.66F compared to 0.69F for doubling CO_2. So only a 10 percent increase in water vapor about the same effect on global temperature as that of doubling CO_2!

Some people argue that water vapor changes should be ignored because the atmosphere will adjust to the change in a month or less through more or less precipitation or evaporation. This may be true, but it seems very likely that the new stable level of water vapor will change as well. What can be the driving mechanism to determine some predetermined constant water vapor level independent of water vapor generation?

Case with no Water Vapor and Only CO_2

Since the presence of water vapor can absorb heat before CO_2 can, it reduces the influence of increases of CO_2 in the atmosphere. A computer run was done with no water vapor and CO_2 only with the following results compared to those with present with water vapor levels: The amount of heat trapped went up from 7.4 percent with water vapor present to 18.75 percent with no water vapor. The average global temperature dropped from 58F to 12F due to the loss of water vapor heat trapping. When the amount of CO_2 was doubled, the amount increased to 21.17 percent. However, the corresponding global temperature increase was only 1.26F or 0.7C. This is considered to be the upper limit on the impact of doubling CO_2 levels. The primary reason for this relatively low increase is because the present amount of CO_2 is well above its saturation level as can be easily seen in Figure 3.

More Data on CO_2 versus Water Vapor

An interesting but under-reported study was done in 2002 by Slade Barker, retired U.S. Naval Oceanographic Dept[4]. He used data from 1900 to 1994 of daytime warming (heat gain) and nighttime cooling (heat loss) from various locations in New Mexico. This is a good state for this type of study, being an arid and semi arid region with few clouds to affect the data and low humidity to minimize water vapor covering up CO_2 absorption. The temperature trend line during this period showed an increase with time, as did the CO_2 level. However, his technique was interesting in that he could separate out heat gain in the day from heat loss at night. The year-to-year variations from the trend showed nearly zero correlation of heat loss with the amount of CO_2 in the atmosphere, but a significant correlation with the amount of water vapor as evidenced by the amount of rainfall that year. This confirms that water vapor is a more important factor than CO_2 regarding global temperature.

Role of Clouds in Cooling

As was covered earlier, clouds are a major factor absorbing the Earth's heat and radiating it back down. A section in the appendix (on measuring heat from the atmosphere) has more data on that. Clouds also have a major impact in that they reflect much of the sun's energy that strikes them back into space thus reducing the Earth's heat gain during daytime. Since the Earth is always losing heat, this is the same as a cooling effect. And the clouds have a larger net effect in cooling than maintaining heat in daytime. One interesting exception is when the ground is covered with snow. Then the sun's heat will be reflected back by the snow so clouds have no additional cooling effect, but will still have one of warming. It can be shown that for ground temperatures below about 30F with snow cover, that there is more net heat loss on sunny days than cloudy days. Clouds are also a good example of a both positive and negative feedback. An increase of water vapor absorbs more heat in the atmosphere causing the Earth to warm and evaporate more water and raise the water vapor concentration which in turn creates more clouds which also "trap" more heat. Finally, as the cloud cover increases it has a cooling effect by blocking out the sun's heat. This is negative feedback. This may create more clouds as the air is cooled and more water vapor will condense into more clouds. Now we have positive feedback again, but in the cooling direction. The effects of clouds also depend on the time of day or night, their height above Earth and distance from the equator. An interesting concept discussed in the appendix is *cloud cover differential.* It refers to a difference in average clouds between day and night or winter and summer. These can cause significant temperature changes. <u>So it appears that clouds are a major and complex regulator of the global temperature. Yet they are one of the least measured, understood, and modeled of the factors affecting climate</u>. Another major consideration is the "atmospheric window" in the infrared spectrum from about 8 to 12 micrometers in which no known molecule has a resonant wavelength to absorb energy. The exception is ozone, but it is mostly found in the upper atmosphere. This open window places an upper limit on the amount of heat that greenhouse gasses in the atmosphere can absorb or "trap", but does not limit cloud absorption that operates over the entire infrared spectrum of interest. Of course all of these things have been going on before there were any changes in CO_2 content.

<u>What's Causing the Warming?</u>

So why does what appears to be a recent warming trend, correlate with increased CO_2 levels? IPCC reports state that the oceans hold 50 times the amount of CO_2 than does the atmosphere. One explanation is that the warming oceans release more dissolved CO_2 because of certain chemical reactions and also because warm water holds less gas. (Observe a pan of water that when heated will release bubbles long before it boils). So the warmer oceans cause an increase in CO_2, not the reverse effect. The warmer oceans also release more water vapor that is much stronger than CO_2 in trapping heat, as shown earlier. It is well known that desert regions with low humidity cool off at night much more than humid ones. Thus cities with higher humidity, because of peoples' activities, will cool off less at night and in the winter with the water vapor produced from burning oil and natural gas. Other considerations cast doubt on the climate data that the IPCC report chose to ignore. Some reports indicate that much of the reported global temperature increases are biased because many of the recording stations that were in rural areas years ago are now in urban areas because of population growth and are affected by the well know city "heat island" effect. Even the reported dramatic increases in CO_2 levels in recent years are in doubt. Many of the low "pre-industrial" values are based on ice core samples. The way the amount of CO_2 is tested in these, depending on the pressure inside the ice, can allow various amounts of the CO_2 to escape before it is measured. A paper by a well-known chemist[5] states that back as far as 1812, it was a common procedure to measure the amount of CO_2 in the atmosphere by chemical means with good accuracy. The 19th century averaged 341 ppm compared to about 380 ppm now. There were many results of CO_2 levels higher than those of today with peaks in 1820 and 1857. But the IPCC ignored these results because they apparently did not fit their predetermined outcome. It has been reported that the sea ice in the north arctic region is melting more rapidly than normal. Floating ice is over 80 percent under water. And water conducts heat much more than air. For long-term climate changes the oceans will lag any air temperature changes because of the continual ocean currents that mix water from different levels. The rapid ice melting is probably from shifting warmer water currents that are transferring heat from other ocean areas that in turn are being cooled in the process.

Using the basic heat balance model as described in the appendix, a 1 percent increase in heat trapping would slowly increase the average Earth temperature by a total of 0.81F in order to restore a heat balance. For a 1 percent increase in energy from the sun (or an equal amount from any other source of heat), the corresponding value is a 1.3F increase. While measurements show the sun's energy only varies slightly, a 3 percent change in average cloud cover will change the amount of heat at the Earth's surface about as much as would that of change of 1 percent in the sun's energy. Recently it has been reported that the amount of cosmic rays entering the atmosphere change the amount of certain aerosols in the atmosphere that can alter cloud formation. The amount of cosmic rays from the sun varies considerably, as does that arriving from distant galaxies in the universe. Besides the sun, other sources of heat include man-made burning of fossil fuels for heating, electricity production and transportation, all electrical energy consumption and human body heat (about 100 to 200 watts per person). Man-made structures such as roads, parking lots, and buildings absorb more of the sun's heat than areas with vegetation. Some natural heat sources include that from the Earth's hot core in unknown regions where it is closer to the surface or the floor of the ocean, and decaying of vegetation. The later is offset by the cooling effect of photosynthesis of growing plants, grasses and trees which process also removes CO_2 from the air.

Electricity Production Tradeoffs

It is interesting to note that if it were more important to reduce water vapor (that causes temperatures to rise more than CO_2 emissions do); coal would be preferred for electricity production. It has almost no hydrogen which produces water vapor, while natural gas consists of about one-half hydrogen in its molecules. This is the opposite of current thinking that favors natural gas. Coal is cheaper for electricity, but not well suited for heating, where natural gas is a very good solution, being easily distributed to the user. What about nuclear energy? Well, it does not generate either CO_2 or water vapor. If increased carbon will have such disastrous results as predicted by carbon alarmists, why do they never propose more nuclear energy?

Recommendations

With such dire predictions about global warming due to carbon "heat trapping" and the drastic actions being proposed to reduce it, it seems only prudent to question and more fully verify what if any additional man-made carbon dioxide has to do with the recent warming trends. The results of this paper indicate the future temperature increases from CO_2 will be minor and are not a cause for concern. It is recommended that we enlist besides climate specialists, practical engineers and people experienced in applied physics and chemistry to evaluate the work done here and pursue further practical evaluations of <u>only increased CO_2</u>. Workers that managed the United Nations IPCC project should not be included in this project. Their minds, or at least their spokepersons, are already made up. Very large parts of the IPCC reports are excellent, and many competent scientists contributed to it. However it appears that only a few people put together quantitative numbers that estimated past CO_2 and temperature trends and possible future changes from increases in CO_2. These models predict such widely varying amounts of changes one must question their validity. <u>The IPCC should publish for each of the models used the resulting average values of the radiation from the atmosphere to the earth in watts per square meters for both the present level of CO_2 and that estimated when CO_2 is doubled</u>. This would allow atmosphere measurements as proposed in the appendix to see if they are reasonable and would be one way to test some of these models' features before putting any faith in them. Work on long term climate change due to other factors than CO_2 is much more complex, and it should continue. But regarding CO_2, we need a fresh, unbiased look at this independent of International politics. It would be well worth the expenditures. At the same time, if carbon turns out to be a major problem, one good solution, or at least a strong hedge in the interim, seems to be acceleration of nuclear energy for electricity. No added carbon or water vapor emissions. Since government regulations are the main impediment to otherwise cost effective and profitable nuclear energy production, the government should offset this by providing loans with payments to be delayed until revenues begin. Solve the political NIMBY waste burial problem with a commission outside of Congress ala the Armed Forces base-closing method. Or perhaps other countries will see a business opportunity to handle the waste. Wider use of electric cars that do not emit any gases will also reduce demand for foreign oil. And electricity consumption at night to charge vehicles costs less because it does not require additional production or transmission capacity. And nuclear energy works most efficiently at high capacity.

Summary

This paper uses simple engineering concepts, combined with basic infrared physics and greenhouse gas absorption characteristics to estimate long term average global temperature rises caused by increased levels are carbon dioxide (CO_2). They are much less, 1 degree Fahrenheit for CO_2 doubling, than the higher values estimated by the UN International Panel on Climate Change. Fortunately, temperature rises above the average are predicted in winter months in the colder climates (due to reduced competition from water vapor) and below the average at other times and in warmer climates. But none of the temperature changes are considered to be detrimental, and some should be beneficial in the colder climates. In the last 20 years, atmospheric concentrations of CO_2 have increased about 10 percent. According to the calculations here, that would cause a global temperature rise of only 0.14 degree Fahrenheit, a value difficult to measure. Any long-term temperature changes much greater than this that may be occurring are believed to be from other causes, not increased amounts of carbon, whose effect is limited to only part of the infrared bandwidth where it is absorbing power is already saturated. Whether human activity or other natural factors are the major causes of the recent increases in carbon dioxide is another question, but that question was not considered here.

About the Author

Richard Petschauer after serving in the Air Force during the Korean War, graduated from the University of Minnesota in 1956 with a degree in Electrical Engineering and a degree in Business Administration. In 1987 he was named the first Unisys Fellow for his pioneering work on computer magnetic memories that started in the late 1950s; later he did work on semiconductor memory systems, logic circuits and packaging for large, high-performance mainframe computers, and managing engineering departments of over 100 people. He also developed statistical design techniques for limits of on-chip wiring and computer clock speeds; his latest patents were on controlling signal wiring crosstalk on dense, high-speed digital semiconductor chips. After retirement he developed over thirty computer-based tools of statistical techniques for engineering design, quality, and product failure/lifetime prediction. He also became involved with improved methods of humidity and temperature control for large residential buildings where he became familiar with the advantages of modern infrared thermometers, later applied in this report.

Recently he had trouble understanding how a rise of carbon dioxide, or any substance, in the atmosphere from such low values as 0.035 percent could have such an overly large influence on the Earth's future temperature as some predict. So he decided to read and learn about this from the perspective of an individual with a technical background, but not in the field of climate. After a few infrared measurements on summer nights showed that the amount of heat being radiated from the atmosphere was much less than some climate models predicted, he began an intensive study resulting in his own computer simulations based on available atmospheric data and well-known laws of infrared physics. While weather predictions and long-term climate are very complex and beyond the author's expertise, he feels the single issue of heat absorption and radiation due to carbon dioxide is much simpler, well understood, and better modeled and measured as proposed here. For reasons explained in the report, he went from being unknowledgeable to skeptical to now very doubtful about a harmful future temperature rise due to increased carbon dioxide levels.

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Appendix

1) Infrared Radiation and Absorption

All bodies radiate electromagnetic energy based on their temperature. For very hot objects such as the Sun or an incandescent light bulb, the wavelengths are very short and some fall in the visible light spectrum. For cooler objects, nothing can be seen by the eye, but it can be measured. When objects are struck with these waves, the energy arriving is distributed into three components of varying proportions: reflected, absorbed, or transmitted. These proportions depend on the properties of the material, and they can vary with the wavelength. For temperatures such as on the Earth and its atmosphere, these wavelengths are invisible and of a lower frequency with longer wavelengths that are in the infrared range. A "black body" is defined as one that absorbs all the energy, reflecting and transmitting none for all wavelengths. The absorption factor is fraction of the energy that is absorbed. This will be converted into heat inside the object. It is 1 for a black body. Black bodies also radiate the maximum energy for a certain temperature, with an emissivity factor of 1. A body with an emissivity factor of 0.5 will radiate one half the energy of a black body at the same temperature. It turns out that for any uniform surface of an object, the absorption factor will equal the emissivity factor. So it is common to use the term "emissivity factor" for both radiation and absorption when making calculations. Most solid objects that are not shiny, as well as water, have emissivity factors close to 1 in the normal temperature ranges that involve infrared wavelengths. Window glass that transmits visible light acts closely to that of a black body for most infrared wavelengths, as do clouds. The various gases in the atmosphere mostly transmit infrared except for certain so called "greenhouse gases" that absorb energy over a certain narrow spectrum of wavelengths related to their molecular structure.

2) Infrared Radiation Equations for Wavelengths and Power

Max Planck, a pioneering physicist in quantum mechanics, developed an equation that defines the distribution of the infrared wavelengths that radiate from an object depending on its temperature.

Let T_f = the temperature in degrees F
L = the wavelength in micrometers (microns)
Then $T_c = (T_f - 32) * 5/9$ (convert to degrees C)
Then $T_k = T_c + 273.15$ (degrees above absolute zero, Kelvin)

(2.1) W = e * C1 / (L^5 * (exp(a)-1)) in watts per square meter per delta wavelength

Where
e = emissivity factor = 1 for a black body
C1 = 3.7477e8
a = 14387 / (L * T_k)

The wavelength for the maximum power density is approximately 2898 / T_k micrometers. The outer curve in Figure 2 (above in the main body of this report) was calculated with the above equations for a temperature of 50F.

The total power for all the wavelengths is the integration, or sum, of the area of the curve from the equation, or it can be calculated directly.
Let $T_k = 5 / 9 * (T_f - 32) + 273.15$ (degrees Kelvin above absolute zero)
Then

(2.2) H = e * 5.670e-8 * T_k^4 in watts per square meter

where again e = emissivity factor = 1 for a black body
and 5.670e-8 is the Stefan-Boltzmann constant.

Calculations for Figure 2 and Table 1 in the Main Body of the Report

Using the Spectral Calculator (Spectral.com) of GATS, Inc on the Internet which implements the LINEPAK system of calculating absorption spectra from the HITRAN2004 spectroscopic database, transmittance calculations (the fraction of the heat transmitted) were run for water vapor and CO_2 at 350 ppm and 700 ppm over wavelengths from 3 to 70 micrometers in over five thousand steps. The Spectralcalc site provides downloads of the data files. To estimate how much heat is transmitted (and thus not absorbed) through the atmosphere, a 10-kilometer (km) path was shown sufficient for absorption to be virtually complete. The path was broken into ten 1-kilometer segments, and runs made for each at several thousand discrete wavelengths stepped over the range of interest. Radiation leaving the Earth proceeds at all angles from parallel to the surface to straight up. Measured from the vertical, they are all within 0 to 90 degrees. So a path angle of 45 degrees from vertical was used for an average angle leaving the Earth’s surface. The pressure, temperature, and water vapor concentration, all of which decrease with altitude, were set for the midpoint of each segment. The combined transmittance of the total path at each wavelength step is obtained by the cumulative product of the transmittances in all the path segments at that wavelength. The results of this, for present levels of CO_2 for the 12 to 18 micrometer wavelength range, are shown in Figure A1. Shown are the absorption fractions of each segment separately and for the total path. Note that for the segments, the width of absorbing region decreases with altitude since with the reduced pressure, the density of the CO_2 molecules drops. Also note that each 1-km segment curve is flat on top showing that for those wavelengths, saturation has already taken place. In the range of 14.8 to 15.2 micrometers, a separate run showed that absorption was over 95 percent complete in CO_2 after only 100 meters. This verifies that CO_2 is a strong absorber near to its 15-micrometer wavelength.

Figure A1

Fractions of Heat Absorbed Entering Each 1-km Segment and Total Absorbed by all Ten Segments

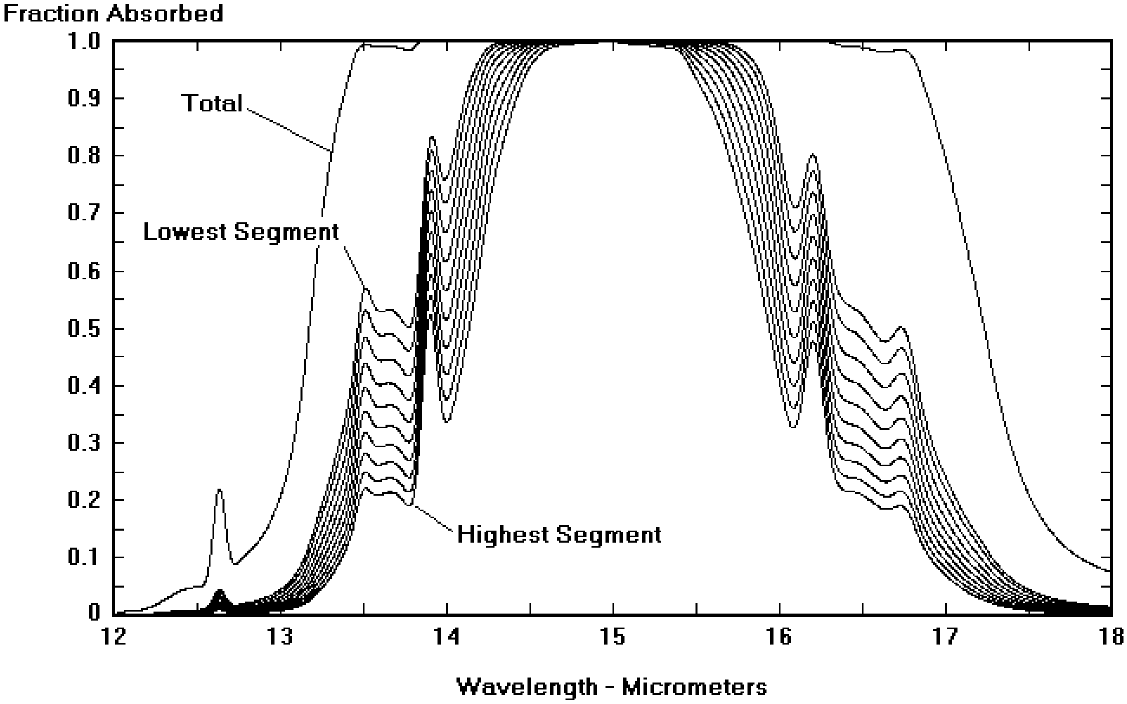
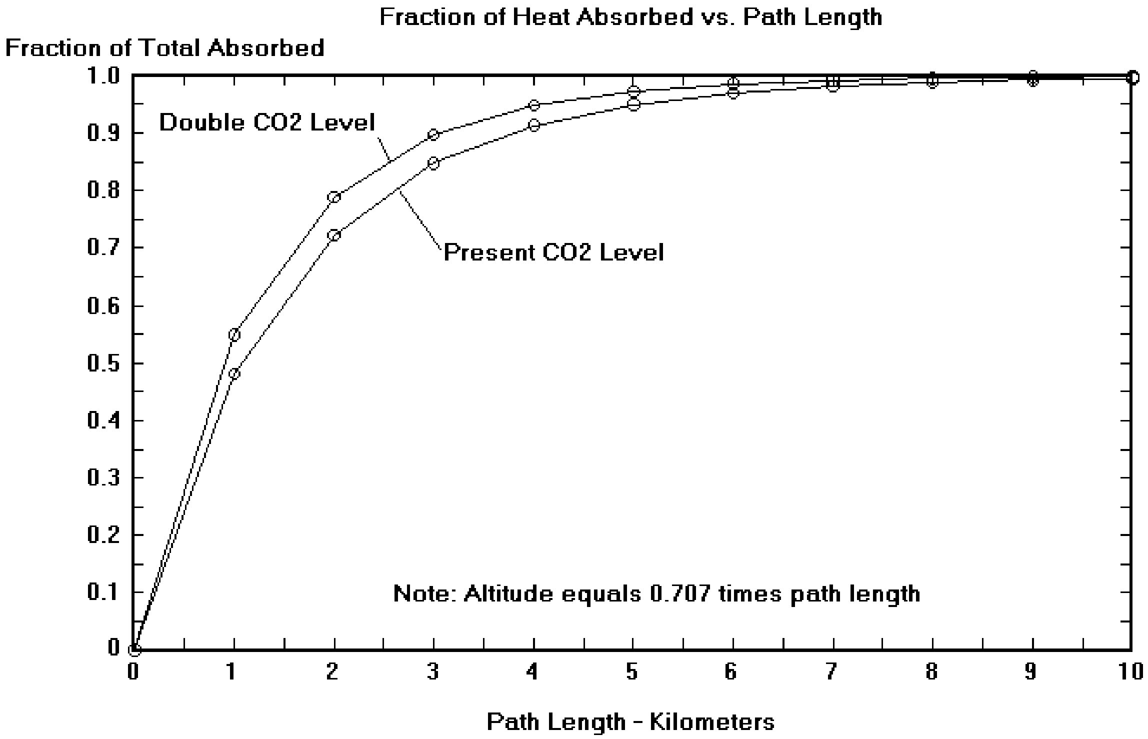


Figure A2 shows how for the 10-km path the cumulative absorption relative to the final absorption varies along the path moving up through the atmosphere.

For water vapor absorption, which varies highly for small changes in wavelength, a 20-step moving average was used to smooth the data. The data were then computer interpolated at 0.1-micrometer intervals to reduce the number of steps and provide a standard interval step size. From a probability standpoint, it would be expected that transmittances at each wavelength step of a combination of different gases with varying concentrations could be estimated by the product of the transmittances at the same steps. Several runs on the Spectralcalc site verified this. This reduces the number of runs that need to be made. For the case of doubling CO_2, however a separate run was done for each concentration for the best accuracy. For additional increases of CO_2 and for combining water vapor and CO_2, transmittance multiplication was used. For different increases or decreases of concentrations of the same gas, the transmittance at each wavelength step is raised to a power, **k** that corresponds to the ratio of the new to the original concentration. The value of **k** need not be an integer and can be less than one to get a reduced concentration. Finally, the combined absorption factor equals 1 minus the combined transmittance factor. The results were checked with measurements manually taken from enlargements of the circled area of Figure 1 in the main body of this report. The two areas of the absorption curves for water vapor differed by less than 1 percent; the CO_2 area from the spectral calculations was 6.7 percent larger, considered to be in reasonable agreement.

Figure A2



The next step was to combine elements by multiplying the absorption factors at each wavelength interval with the infrared heat density radiating from the Earth at that same interval and multiplying by each by the wavelength interval width and then summing these to get the total heat absorbed by that gas or combination of gases. This was converted to the percentage of the total heat radiated from the Earth over the same entire spectrum. This computer work was done using Matlab® with programs written by the author for this project.

3) Basic Greenhouse Gas Climate Model

This model has been known for many years and is based on comparing the average heat being added to the planet from the Sun to that leaving the planet. Here we define the planet as including the Earth and its atmosphere. If the heat being added equals that leaving, the average temperature will remain stable. The only way heat can leave the planet is through infrared radiation to outer space. This can be radiation from the Earth directly through the atmosphere that is not absorbed or from heat that is absorbed by the atmosphere from the ground and then radiated outward. If the heat being added and that leaving are not equal, then the temperature of the planet must increase to lose more heat or cool to lose less heat in order to obtain a new balance. The same applies to the surface of the Earth. It receives heat from the Sun that is not absorbed by the atmosphere or reflected back to space by things such as clouds or snow cover, and loses most of its heat by radiation in addition to some loss by warm air rising and evaporation. The third part of this is the atmosphere that when in balance must receive and lose equal amounts of heat flux.

For the basic model we only consider heat loses from emitted radiation and gains from received radiation. The heat from the Sun as it arrives at the planet's outer atmosphere is about 1371 watts per square meter. It is captured by the Earth as a disk with the diameter of the Earth, but it has to be spread over the entire Earth's surface as it rotates. Since the area of a sphere is four times that of a disc of the same diameter, the average to the Earth's surface is 1371/4 or 342.8 watts per square meter. The normal convention estimates that about 25 percent of this is reflected back to space by clouds and about 5 percent more by the Earth's surface, mostly from snow and ice. This leaves 240 watts per square meter on the average that is absorbed by the Earth's surface.

The heat that is radiated from the ground to the atmosphere is partially absorbed by greenhouse gases in the atmosphere. This warmed atmosphere then radiates both up and down. The basic model has one half going down to Earth and the other half to outer space. (A more complex model covered later allows variations of this mix, but as will be shown below, the equal up/down split yields results close to actual average Earth temperatures). To calculate the warming of the Earth by this "greenhouse effect" let,

S = the heat flux from the Sun arriving at the ground
G = the heat flux radiated from the ground to the atmosphere
a = the fraction of the heat that is absorbed by the atmosphere
Then, since the heat that is absorbed by the atmosphere must also be radiated out to remain in balance, and with half of this up and half down, that radiated back to the ground from the atmosphere is $\mathbf{a} / 2 * G$.
So using an equation,

(3.1) $G = S + \mathbf{a}/2 * G$
Steps to solve for G gives,
(3.2) $G - a/2 * G = S$
(3.3) $G * (1 - \mathbf{a}/2) = S$

So,
(3.4) $G = S / (1 - \mathbf{a}/2)$ watts per square meter

From infrared equations for heat,

(3.5) $G = e * 5.670e\text{-}8 * T_k\text{^}4$ in watts per square meter

We assume **e**, the emissivity of the Earth's surface including the ocean, is equal to one. T_k is the absolute temperature of the Earth's surface in degrees Kelvin which is the temperature in Centigrade + 273.15. Solving equation (3.5) for T_k and using G from equation (3.4) we get:

(3.6) $T_k = [240 / (1- a/2) / 5.670e\text{-}8]\ \text{^}.25$

Converting to Centigrade and Fahrenheit

(3.7) $T_c = T_k - 273.15$
(3.8) $T_f = 5/9 * T_c + 32$

Using a value for "**a**" of 0.77 results in a temperature of about 14.9C or 58.8F. That is close to the present average of the Earth's surface. A value of "**a**", the absorption factor equal to 0.77, means that the atmosphere is absorbing 77 percent of the heat being radiated from the Earth. By putting in different values of "**a**", a person can calculate the expected change in average temperature after the new balance is achieved (which may take several years). For example, letting the absorption factor increase to 0.78, would cause a new temperature of about 15.6C, or a 0.6C increase. Or different values for the Sun could be used or different fractions of cloud cover that reflects the Sun. There are other ways that heat can leave the Earth besides through radiation. Warm air rises and can warm the atmosphere. Evaporation causes cooling at the Earth's surface. When the moist air rises and cools in the atmosphere the latent heat is released. When it rains, heat can be again transferred. There are many complex things that affect the weather. However, for the purposes of estimating the impact of long-term average global weather due to changes in the amount of carbon dioxide in the atmosphere, this basic model properly used should be adequate. (See Section 8 for more on this.) In the main body of this report, when the present absorption from only water vapor and CO_2 was estimated at 75.1 percent, an amount was added to account for other gases in order to get the total to 77 percent in order to match the present average global temperature. In this way we are calibrating the model to the real world today.

The IPCC and others have a convention of breaking the temperature rise caused by a change in greenhouse concentrations into two steps: (1) the Radiation Forcing Heat (F) and (2) the Temperature Sensitivity Factor (S). Then the average Earth's surface temperature change is F times S. For the calculations shown in table 1 in the main body of the report that showed for CO_2 doubling a temperature rise of 0.38C, F is 1.27 watts per square meter and L is 0.30. The equation for F is G/2 times the change in the absorption factor, **a**, caused by the change in the greenhouse content.

4) Case for the Basic Climate Model

It is much easier to estimate changes in long-term average global temperature due only to increase in CO_2 levels than other factors. This is compared to weather forecasting that is far more complex. For the former the only consideration is the balance of input and output heat flows to the Earth, and the primary thing CO_2 can do is change the absorption and temperature of the atmosphere which affects the outflow to outer space by radiation. There are many other things that can also affect the inflow and outflow, and long-term climate change, but these do not involve CO_2 and is a different question than the one this paper is concerned with. Weather, on the other hand, is a function of how the heat in the atmosphere and oceans at all levels and the Earth's surface are transferred among themselves on a continual basis which is very complex in the short term and that many times involves unstable conditions. This will happen even with a perfect balance in the heat entering and leaving the planet and its atmosphere. Later in Section 8 it is explained how adding other factors for heat transfer to and from the atmosphere to the basic climate model can cause large errors if not handled properly and not supported by simple temperature measurements of the atmosphere. In a similar way, infrared absorption and re-radiation inside the atmosphere before the heat is finally emitted either up or down is also a complex process and subject to modeling errors. Instead, basic models for net heat in and heat out can be used and are less subject to model errors, especially when they are verified with typical measurements.

5) Extensions to the Basic Greenhouse Model -- Measuring Actual Atmosphere Absorption

An interesting feature of this basic model for the effect of greenhouse gases is that the equivalent temperature of the atmosphere from which the heat is being radiated back to the Earth with an emissivity factor of "**a**" can be directly calculated from the Earth's temperature and surprisingly is independent of the Sun's heat and the emissivity or absorption factor. When expressed in degrees Kelvin the equation is:

(5.1) $T_{ak} = 0.5\text{^}.25 * T_{gk} = 0.8409 * T_{gk}$

Where T_{ak} and T_{gk} are the air and ground temperatures in degrees Kelvin, which is the temperature in centigrade plus 273.15. For Centigrade and Fahrenheit temperature scales we have:

(5.2) $T_{ac} = 0.8409 * (T_{gc} + 273.15) – 273.15$
(5.3) $T_{af} = 0.8409 * (T_{gf} + 459.67) – 459.67$

These estimates are useful to measure the actual absorption of the atmosphere as described next.

Calculating infrared radiation from solid or liquid surfaces on the Earth based on the temperatures involved is considered to be well understood. However, for gases in the atmosphere it is more complicated since there is no defined boundary and since different gases radiate with different strengths (emissivity factors) and at intermediate stages can absorb and re-radiate among other gas molecules before finally escaping to either the ground or outer space. It seems that using an infrared thermometer and measuring the temperature of the atmosphere *as seen by the measuring device at the Earth's surface* would allow, for purposes of estimating heat transfer, replacing the air with a sheet of solid black body material at the measured temperature. Then, using well-known equations, calculations of the heat energy radiated from the atmosphere back to the Earth become simple. There is also heat that leaves the Earth due to convection (warm air rises), but coming from above there is no such flow, only radiation down. Relatively inexpensive infrared thermometers that can read temperatures down to –76F are now available.

Using the equations shown below, developed from those in the previous section on the basic greenhouse gas climate model, it now appears possible to calculate the combined absorption percentage of the greenhouse gases at any location only by measuring the temperature of the Earth's surface and the atmosphere from the ground using an infrared thermometer. For reasons shown later, this only applies to clear skies, not cases with cloud cover, even of small amounts. Another limitation is that for ground temperatures below about 30F, the measured atmosphere temperature is below minus 76F and a special infrared thermometer is required.

The absorption factor "**a**" equals the emissivity factor "**e**" which can be shown to equal (T_m/T_a)^4 where T_m is the measured or apparent atmosphere temperature and T_a is the atmosphere temperature that can be calculated from the climate model. It can be shown that T_a equals 0.5^4 times the ground temperature when both are expressed in absolute temperature terms <u>for all values of Sun heat and absorption fractions</u>. Combining this fact with the equation for emissivity, and since 2 is the reciprocal of 0.5, and since **a** = **e**, we get:

For temperatures in F:

(5.4) $a = 2 * [(T_m + 459.67)/(T_g + 459.67)]$^4

For temperatures in C:

(5.5) $a = 2 * [(T_m + 273.15)/(T_g + 273.15)]$^4

Where **a** = the absorption factor of all combined greenhouse gases, T_m and T_g are the measured temperatures of the atmosphere and the ground from the ground using an infrared thermometer <u>on clear days and nights only</u> and using the average of day and night values. The above equations can be an important tool in validating the use of the basic climate model. It is cold in December and January, where the author resides in Minnesota, resulting in measured apparent atmosphere temperatures being below –76F on clear days. So these equations have not been tested yet. However, it can be shown that they are consistent with the climate model by first calculating the ground temperature as in equation (3.4) in the previous section. Then get the heat flux, A, from the atmosphere which is equal to:

(5.6) $A = \mathbf{a} * S / (2-\mathbf{a})$.

From this, calculate the temperature that would generate this using heat flux for an emissivity of 1 which is what an infrared thermometer would read:

(5.7) $T_{mk} = (A / 5.670e-8)^{0.25}$ degrees Kelvin

Converting to degrees Centigrade or Fahrenheit,

(5.8) $T_c = T_k - 273.15$

(5.9) $T_f = 9/5 * T_c + 32$

Convert T_{mk} to either degrees F or C as desired and use this in equation (5.4) or (5.5) and the result will be the value of "**a**", the absorption factor, used originally regardless of the value for the heat from the Sun of from the value of "**a**" used. <u>So this demonstrates that the effective fraction of the Earth's heat that is absorbed by all the greenhouse gases that is consistent with the climate model can be estimated from averaged measurements taken from the ground on days and nights with clear skies.</u> If the calculated "**a**" is larger than 1, this indicates clouds were present when the measurements were taken. Since the water vapor content varies with the dewpoint, expect about 5 to 10 percent lower values of "**a**" in cold winter months and about 5 percent higher in summer months compared to the average at temperatures of 50F to 60F.

<u>6) Special Considerations for Cloud Cover Based on Direct Measurements</u>

It has been noticed that on clear nights water in things such as birdbaths will freeze and frost can be seen on the ground even if the surrounding air is a few degrees above the freezing point. This is evidence of substantial infrared radiation heat loss to a clear sky.

Tests were done with an inexpensive but accurate infrared thermometer that can measure temperatures down to about minus 76F. It is interesting to note that on clear winter nights, the atmosphere temperatures are off the scale on the low end (less than –76F). So it must be lower than –76F. On cloudy nights, many readings are in the range of plus 10F to 50F. In one case, the clouds were only 5F cooler than the ground, indicating very little heat leaving the Earth (maximum trapping) from either net infrared radiation, or due to warm air rising from the Earth (convection heat loss), since in the ground and air temperatures were so close. (This is close to real "greenhouse" behavior.)

Clouds are not water vapor, but suspended liquid water or ice crystals. They trap nearly all the infrared energy received. It appears that the temperature of the clouds compared to the ground is mostly a function of their distance above the ground. So low, warmer clouds will radiate more back to Earth than high, cooler clouds. Clouds also reflect back to outer space much of the energy from the Sun that strikes them, reducing heat gain during the day. In this case, the height of the cloud above the Earth would not affect very much the amount reflected.

Table A1 compares the net radiation from the Earth with a ground temperature 50F at four different equivalent atmosphere temperatures, two with cloud covers of different heights and two with different hypothetical amounts of greenhouse gases and clear skies. The apparent atmosphere temperature is that read by an infrared thermometer from the ground level pointing up. It can be seen that the net radiated heat loss varies a great deal, by a factor over 15 to 1, with cloud cover being the strongest factor affecting this.

Table A1 – Comparison of Earth Heat Loss with Various Atmosphere Conditions

- Heat values in watts per square meter -

[6] Condition	Apparent Atmosphere Temperature	Radiation From Earth to Atmosphere	Radiation From Atmosphere Back to Earth	Net Radiation From Earth
Low Clouds	45F	365	350	15
High Clouds	15F	365	274	91
Clear Sky with more CO_2, H_2O	-40F	365	170	195
Clear Sky with less CO_2, H_2O	-65F	365	132	233

Notes for Table A1: Earth surface at 50F; apparent atmosphere temperature as measured by infrared thermometer from ground. Radiation using Stefan-Boltzmann equation for a black body equivalent, W = 5.670e-8T_k ^4 watts per square meter, where T_k is in degrees Kelvin (absolute temperature).

<u>7) Climate Model Cannot be Used Directly with Cloud Cover</u>

At first thought, cloud cover could be handled by simply using a high value of "**a**" such as 1 in the climate model described above. However the measurements in Table 3 with low clouds with relatively warm temperatures show that the heat flux from the clouds back to Earth and that from the Earth are nearly equal. In the climate model, the heat flux from above can be no more than one half that from the ground and this occurs with **a** = 1 or 100 percent absorption.

So how should cloud cover be handled? It is recommended here to think about clouds, at least the lower relatively warmer ones, as a blanket over the Earth and therefore acting as an extension of the Earth. It is not in heat balance because on its Earth side not much heat is being gained while on its upper side it is gaining some from the Sun, but much of it reflected, and losing heat to the cold clear atmosphere the same as the Earth would at night with some being absorbed and radiated back from the atmosphere. So it appears that while the Earth is losing less heat than if there were no clouds, the clouds must be cooling and the rest of the atmosphere with it. The net heat loss to outer space by radiation may be nearly the same as from the Earth without clouds. So besides keeping the Earth warmer at night, clouds seem to have a cooling effect on the atmosphere. But in the day, they reflect much of the Sun's heat away, absorbing some from the Sun and some from the Earth, but still probably seeing a net loss from radiation to the atmosphere. If the climate model were modified to handle cloud cover, besides the present equations for clear days and nights, it probably would require two sets of equations to handle clouds, one for night and one for day. Then the heat gain or loss from each equation could be added. For the clouds, their height would have to be taken into account and the fact that there is a tendency for fewer clouds in the day because of the Sun's heating and more clouds at night because of cooling. This we define as *day/night cloud cover differential* which is covered in the next section. There it is shown that while this can cause an increase in expected average temperature, it does not change the estimate of the temperature rise due to changes in CO_2 levels.

8) Including More Factors in the Climate Model

There are heat transfers to the atmosphere and from the Earth that do not involve radiation that could be added to the climate model. However they do not affect the outcome regarding the impact of increases of CO_2 concentration. In fact they can introduce serious errors if done incorrectly. For example, consider adding two additional factors that actually happen: (1) The heat transferred from the Earth to the atmosphere from warmer air rising and that from water evaporation at the Earth's surface with the resulting warming of the air when the vapor later rises, cools and condenses to form clouds, and (2) the warming of the atmosphere, mostly via clouds, from the Sun. (The heat from the Sun to cloud banks is not included here since none of it is radiated down to the earth). This additional heat added to the atmosphere will be removed by radiation, part up and the rest down to Earth. These can be incorporated into the climate equation as shown below. We have also added a term to allow for the heat radiated from the atmosphere that goes up and down to be different from each other (not half up/half down as in the basic model).

(8.1) $G = (S - D - W + k * D + k * W) / (1 - k * \mathbf{a})$ net watts per square meter leaving earth

(8.2) $Ad = G * k * \mathbf{a} + k * (D + W)$ watts per square meter going down

(8.3) $Au = G * (1 - k) * \mathbf{a} + (1 - k) * (D + W)$ watts per square meter up from atmosphere

(8.4) $Win = G * (1 - \mathbf{a})$ watts passing straight through atmosphere

Where: D = the direct heat flux from the Earth to the atmosphere in addition to that from radiation; W = the heat flux from the Sun that is absorbed by the atmosphere, k is the fraction of the heat absorbed by the atmosphere being radiated back to earth with the remaining going up, and the other terms are the same as in equation (3.4). To further refine this, separate values of k could be used for D and W.

The extra equations above allow a person to validate that heat flux is balanced. At the earth's surface, G + D + W flux-out should equal flux-in which is S + A_d. At the planet level, flux-in, S, should equal flux-out which is W_{in} + A_u. At the atmosphere level, flux-in is G * **a** + D + W and should equal flux-out A_d + A_u.

We add one more important equation that can be used to check the validity of the value of A_d, the radiated heat flux coming down from the atmosphere. It is the expected measured temperature of the atmosphere measured from the ground with an infrared thermometer on a clear day. If they are off by more than about 10 degrees, the assumptions of **a**, k, D and/or W must be incorrect.

(8.5) $T(A_d) = (A_d / 5.670e\text{-}8)$ ^.25

Converting to degrees Centigrade or Fahrenheit,

(8.6) $T_c = T_k - 273.15$

(8.7) $T_f = 9/5 * T_c + 32$

The additional terms of D and W act as a cooling effect on the Earth. So, if the same values for the absorption factor, **a**, and the Sun are used, a reduced Earth temperature results. Some modelers then increase the absorption factor **a**, or allow **k** to be greater than 0.5, so that the estimated ground temperature more closely matches the actual average Earth's temperature. However, this can lead to estimates from excessive radiation from the atmosphere back to the

Earth. That is why it is so important to use an infrared thermometer and check the infrared radiation coming from the atmosphere arriving at the Earth's surface to see if it matches the value calculated in equation (8.5). In one reported case, that modeled many types, heat flows in addition to those due to radiation in order to make the model more complete, the calculated temperature for the atmosphere based on the back radiation based on the model was about 35F with a ground temperature of 59F. Infrared thermometers show that 35F is much warmer than would be measured with a clear sky and therefore shows this to be an erroneous estimating model. It also showed up to about two times (a major error) the ground temperature increase for the same increase in atmosphere heat absorption as the basic model estimated. Such a warm measured atmosphere temperature, implying high downward radiation, can only occur with a cloudy sky. But then CO_2 would not be a factor, and changing its concentration would do almost nothing. The apparent mistake made was to increase the value of **a** or **k** to increase the downward radiation to balance out the other non radiation sources added. So by adding additional terms to the model in the hopes of making it better confirm to the real world, compensating radiation terms were increased to balance the added terms. But the final result of sensitivity estimates due to CO_2 changes were in error.

We now propose a better way to handle this type of problem, using the following example. The same values in the basic model that estimated a ground temperature close to the present one (about 59F) using the Sun at 240 and absorption of 0.77, give a ground temperature of only 43F when extra heat to the atmosphere from the Earth and from the Sun were modest estimates of only 20 and 35 watts per square meter respectively.

So why can values for absorption values close to those estimated be combined with reasonable values for direct heat transfer to the atmosphere from the Earth and from the Sun cause such a low estimated surface temperature? It is believed that the reason is because these models do not include the effect of what we define as *day/night cloud cover differential*. This is the difference in average cloud cover between the day, when the Sun's heat on the clouds (it's not all reflected) warms the clouds and reduces their size through evaporation, and the night when the cooler temperature, through condensation, increases the cloud size. If the clouds at day cover a smaller area of the Earth's surface than those at night, the net affect is a larger heat gain in the daytime and a reduction in the heat loss at night than the model predicts, resulting in an increased average ground temperature. Only about a 6 percent decrease in cloud cover in the day and a 6 percent increase at night from the average are enough to increase the average temperature of 43F to about 59F. This seems to be a better model correction than arbitrarily increasing the absorption fraction above a value that matches known simulations of heat absorptions by the atmosphere. It demonstrates that greenhouse gasses and clouds are different entities and can't be substituted for each other or combined in a simple way in equations. A simple way to handle cloud day/night cloud cover differential in the model is to increase the heat flux from the sun enough to get the actual average Earth temperature.

Does it make much difference if these additional heat transfer mechanisms and a correction for them with the day/night cloud differential are made when estimating the global temperature increase resulting from higher CO_2 levels? Here are the results for the change in ground temperature for doubling CO_2:

Basic model with radiation only heat transfers and a ground temperature of 59F: + 0.686F.
Enhanced model with added heat transfers and a ground temperature of 43F: + 0.666F.
Enhanced model with Sun heat raised 11 percent to restore ground temperature of 59F: + 0.686F.

So when the enhanced model is compensated, it gives the same result as the basic model. This indicates that the basic model is sufficient. In is also interesting to note that the ratio of the changes for the basic and non-compensated models to their starting ground absolute temperatures are the same.

Again we see that predictions of future climate changes due to levels of CO_2 should be a much simpler than estimating long-range weather changes due to many other possible factors. The basic climate model should be close enough for practical use without the risk of adding factors to greenhouse gases.

9) Altitude Considerations

There are several properties of the atmosphere that vary with the altitude above the Earth's surface. The pressure drop with increasing altitude and the density of the air molecules drops with it. The temperature also drops at about 3.2F per 1,000 feet or 5.8C per km. Since colder air supports less water vapor, the density of these molecules drops rapidly. The fraction of the air made up of CO_2 remains constant for the altitudes where absorption occurs, but the density of the molecules will drop with the pressure. At sea level and average temperatures there are about 22 times as many water vapor molecules as those of CO_2, but at an altitude of about 7.5 km they become equal to each other. Here the pressure is about one-third of sea level so the absorbing power of CO_2 is down by about a factor of 3 and water vapor by a factor of about 66. Different wavelengths have different probabilities of being absorbed. Data from the ten 1-km paths showed that absorption for water vapor was about 43% complete at one km and 90% at five km. For CO_2 it was about 48% at one km and 95% at five km. It is interesting to note that at the higher altitudes, the infrared photons that are traveling down to Earth have a much higher probability of being absorbed by the atmosphere below it, where the molecular density is higher, than those traveling towards outer space are. The net effect is to sweep them to outer space and cool the upper atmosphere.

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[1] Copyright © (except Figure 1) 2008 by Richard J. Petschauer

[2] http://commons.wikimedia.org/wiki/Image: Atmospheric_Transmission.png#file. By Robert A. Rohde for Global Warming Art using Spectral Calculator. "98 % of Heat" & circle added by author

[3] Spectralcalc.com of GATS, Inc

[4] A New Method to Detect CO_2 Greenhouse Effect Applied to Some New Mexico Weather Data. Found at http://www.john-daly.com/bsarker/index.htm

[5] 180 Years of Atmospheric CO_2 Gas Analysis by Chemical Methods, Beck, Ernst-Georg, Energy & Environment, Volume 18, Number 2, March 2007, pp. 259-282(24), Multi-Science Publishing Co Ltd