ELECTRONOTES

ENWN-15

THE ALARMING CONCENTRATION OF CO$_2$

Find the red x in the array below:

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Did you find it? It's the 15th x in the fourth row from the bottom. There are 2500 x's in the array, so 1/2500 is the same as 400/1,000,000, which is <u>about the concentration of CO_2 gas in the atmosphere, or 400 ppm (parts-per-million) at this time</u>.   The black x's are about 78% nitrogen and about 21% oxygen, 1% argon, with other trace gases making up a small portion. Water vapor may alter these percentages by displacing up to 4%.   Note that CO_2 at 400 ppm is 0.04%.

<div align="center">

Should you be alarmed?
Perhaps you should – it may be dangerously low!

</div>

Handling numbers as ppm is something that may confuses even those fairly good at math. **SEE NOTE 1 AT END**.   I will resist the temptation to reproduce the grid on page (1) four times but still with just the one red x.   This would be a concentration of 100 ppm. If CO_2 were this low, plants would not survive (they must have 150 to 180 ppm minimum). Without any plants, animals would not survive either, as they all eat plants somewhere down the food chain. Remember that you are an animal.   Do you enjoy lunch on a regular basis? Plants eat too. **SEE NOTE 2 AT END.**

So CO_2 is rare, and maybe uncomfortably rare.   It is said that at the start of the industrial age, CO_2 was at 280 ppm. Currently it has reached nearly the 400 ppm mentioned here, and this is "blamed" on our use of fossil fuel. If true – good for us. We almost starved.   Or, perhaps Nature knows what She is doing even without our concern.

Note as well that many population alarmist some years back declared us to have already food-starved in the 1970's and 1980's. The population of the Earth was getting too high they said. Through technology and by other means, we are still making enough food, or at least potentially are, if we weren't perversely trying to burn food (!) to replace fossil fuels. In fact, it is likely that the increase in CO_2 has been an important factor in keeping food production high enough to support large population levels.

So why do environmentalists want us to cut CO_2 emissions; and they hope atmospheric concentration back to perhaps 350 ppm or lower.   Perhaps back to 280 ppm. Because they say, CO_2 concentration is causing "Global Warming".   They say it's getting too hot and that all sorts of bad things are happening.   Well, they are almost certainly not happening – not even one of them. You can easily find lively discussions. <u>But here I am only worried about properly viewing CO_2 concentrations in the correct perspective</u>.

The CO_2 gas is supposed to trap heat by a "greenhouse effect" and this is a terrible name for what happens. Sunlight blasts through the atmosphere as high-frequency (visible light) radiation and heats the surface. This heat in turn tries to leave the surface as low-frequency infrared photons (heat). Much of the heat is trapped, but not by CO_2 as inside a "glass-like" barrier. Because the frequency of a band of photons are agreeably matched to molecular vibrations of CO_2 (and other gasses, principally water vapor, H_2O, which is immensely more concentrated, and highly variable), some photons are trapped in the sense that they are converted to mechanical kinetic energy (heat).

Now, here is what I am **<u>NOT</u>** going to say:

~~"The heating effect of CO_2 is negligible because the gas is so rare."~~

We hear this quite often, and the argument is bogus. At least the reason stated is bogus. What I will contend is that any **<u>increased</u>** trapping is negligible because even at the near-plant-starvation levels of today there is enough to trap all the photons available to CO_2.

True, a glance at page (1) will convince you that CO_2 is rare in an absolute sense of 1/2500. Further, if we put ourselves in a position of a photon at the Earth's surface, about to head through the atmosphere toward outer space, what is its chance of being intercepted? First of all, we need to assume that the photon in question has an energy (wavelength) that is within the correct bandwidth to be captured by CO_2. Making that assumption if we consider our photon to be looking up through the array on page (1) we would correctly consider its chances of escaping past the red x as near certainty. It is useful to bring in the complication that water vapor, H_2O, also captures across the CO_2 bandwidth. H_2O can be as high as 4% (100 times CO_2), so in a new array on page (4) we have added, just for an example, 2% blue x's as additional traps. Chances of escape still look quite good.

What we have not considered yet is a third dimension to the array. Our escaping photon needs to get through many many layers. When we consider this, it looks rather like there is <u>very little chance</u> of getting away. Our guess thus swings to no escape. To swing back to the uncertain, we consider in addition that there are a very very large number of photons at the surface attempting escaped. Now we need to take a more careful look.

A photon originating at the surface is the result of short-wave (visible) light from the sun striking the Earth's surface, coming in through the atmosphere virtually unimpeded. It departs from the surface as long-wave (infrared, or heat). If it encounters a CO_2 or H_2O molecule, the molecule can capture the energy from the photon and carry it as kinetic

energy – very quickly bumping into other molecules (most likely N_2 or O_2) and partly transferring the kinetic energy. Soon the molecule (or molecules) will emit their own photons and give back their kinetic energy. This photon could be going any direction, perhaps then escaping to outer space, returning to the surface, or bumping into other receptive molecules. One horrendous mix.   Soup.

It is NOT the case that the energy is trapped and raises the temperature of the atmosphere, except as the whole system may be slightly out of equilibrium, and tiny temperature adjustments are occurring.   Eventually, <u>just as much energy as arrives from the sun returns to outer space</u>.   What has happened is that an overall layer of atmosphere, and a region near the atmosphere associated with the surface, and in particular with the oceans, has been established with a <u>temperature structure</u>.   The

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temperature <u>profiles</u> within the oceans, surface, and atmosphere may shift around a bit as the chemical composition of the atmosphere changes. This is all very complex of course. In addition, this laddering up to the top of the atmosphere and to outer space is not just a matter of photons hopping about. In addition, molecules may directly transfer kinetic energy (bumping together – weak conduction) and higher energy molecules may be transported upward physically (as in thunderstorms – convection, the major mechanism of upward energy transfer). **SEE NOTE 3 AT END.**

Given all this, how does the actual concentration of CO_2 affect the picture?

The notion of layers of heat-trapping molecules is a bit inaccurate but still widely presented and useful, as it leads to the fact that temperature increases are a logarithmic function of concentration of greenhouse gases. Accordingly, each additional CO_2 molecule (more realistically, each increase in terms of ppm) added to the atmosphere leads to less temperature increases than the previous molecule (or same increase in ppm). This is well established 100+ year old physics. **SEE NOTE 4 AT END.**

The "greenhouse effect", the effective warming of the Earth as a result of having an atmosphere rather than having no atmosphere, warms the surface about 30°C (from about -15°C to +15°C). This warming is essential for life as we know it. Most of this 30°C of warming is due to water vapor, and about 3.5°C is due to CO_2. About 1.7°C of this (about half) is due to the <u>first 20 ppm of CO_2</u>. The second 20 ppm, from 20 ppm to 40 ppm, gives us less than 0.4°C. The contribution of successive 20 ppm additions continue to decrease. At the point where concentrations reach the current 400 ppm, each additional 20 ppm is contributing only about 0.02°C. Thus, even the 1/2500 (400ppm) is already what we should term "far more than enough", at least in its role in greenhouse warming.

In terms of change in temperature, we might like to know what is called the "climate sensitivity" (found in several forms) as to what we can expect from a doubling of CO_2 ppm. This is roughly (again 100 year old physics) found from:

$$\Delta T = K\, Log_2 \frac{C_2}{C_1}$$

where K is a constant of about 1.1 (1 is a good estimate), C_2 is the final concentration, C_1 is the original concentration, and ΔT is the change in temperature in degrees Celsius (Centigrade or Kelvin as well). Note the log base 2. A 2:1 ratio has a log base 2 of 1, and ΔT, the "sensitivity" is thus about 1°C. Accordingly, if the CO_2 ppm changes from "pre-industrial" 280 ppm to 560 ppm, we would expect ΔT = 1°C of warming. Reaching today's 400 ppm would be about ΔT = 0.5146°C relative to pre-industrial.

The main point here was to show that while CO_2 is quite rare, it is "enough" as far as its full greenhouse warming is concerned, and currently "enough" for plant life although a bit low for comfort. But – any argument that CO_2 warming is not possible <u>because CO_2 is so rare</u> is bogus. Additional CO_2 warming of significance is not possible because <u>the effect is logarithmic</u> and in this regard, the atmosphere is essentially <u>already saturated</u>.

But in a larger sense, CO_2 as a greenhouse is not only NOT all the story but may be only a small part of the story. Climate is so complex and multi-faceted we should not suppose much is for certain.

So we will only discuss one additional point with regard to CO_2, and that's feedback. One major problem is that over the period of about 1970 to 2000, although CO_2 ppm increased considerably, the increase was <u>not even close to being enough</u> to account for the warming also claimed. That is, using the equation above for ΔT, given the concentration change ratio, the observed warming is way too much. If CO_2 were all that is involved, we would need K of about 3 (range 2 to 5) to agree to the observed warming. Because the alarmist want to blame only CO_2 (man-made CO_2 in fact) it is necessary to postulate an amplification. This they attribute to positive feedback.

We have recently published on the amplification possibilities of feedback:

<u>http://electronotes.netfirms.com/EN219.pdf</u>

and in that article positive feedback due to water vapor was discussed, and it was argued that the proposed scheme <u>did not make any sense physically</u>, <u>nor was it consistent with the observation that warming had apparently slowed or stopped</u>. We won't reargue this here.

In closing out this note, please remember that our main purpose was to say that CO_2 is rare, and if anything is alarming, it is its low concentration. None the less, it is a factor in "greenhouse" warming. There are many factors that influence warming/cooling in addition to CO_2, some probably more significant. Any argument that CO_2 can not cause warming simply because it is rare is specious. <u>It is simply saturated with regard to its ability to warm further.</u> If we were to argue that nothing as rare as 0.04% could possibly be relevant to anything, could 0.08% relative to drunk driving be valid? Sticking with CO_2, would someone not argue in turn that its concentration is so low that it can't possibly be of any importance to plant growth!

Be careful with implications of 400 parts-per-million.

NOTE 1: WHAT'S A LITTLE 0.2% TO WORRY ABOUT

We are fairly comfortable with ordinary integers. As children we went to the store with dreams of coming back with two or three candy bars.   Later we came to terms with larger numbers, hundreds, even thousands. Somehow millions, let alone billions were out of reach. Today politicians speak happily of funds to be spent and have to clarify whether they said "million" or "billion" and seem not to be too comfortable with the distinction themselves.   It just means lots of money!

On the flip side, people are even more uncomfortable with parts-per-million (ppm) and parts-per-billion (ppb).   Both seem to just mean: "too little to worry about".   Some years back in a famous murder trial a prosecutor was cross-examining an expert witness who claimed that the environmental "background level" of a particular chemical (a clot-preventing blood preservative if I recall) was (if I recall correctly) 2000 ppb. The prosecutor showed the witness a paper where it was stated instead as 2000 ppm. The witness without hesitation and with some irritation said that was nonsense, to which the prosecutor objected that this was a difference of opinion, to which the witness countered that if it were 2000 ppm we would all be dead. Indeed.   Since 2000 ppm is really 0.2%, it is the cases that if you are intoxicated with 0.2% alcohol, you are most certainly drunk, if not risking death.   The same concentration of a life-destructive chemical in the general environment!   Well, I guess it is rocket science. Who need numbers and facts when opinions are so much more easily obtained.

It is perhaps a handy reference that 0.04% CO_2 is what the atmosphere has, and that a 0.04% blood-alcohol content is "half-drunk" in many localities, and a violation for some commercial drivers.   No – the atmosphere is not drunk.   We are just offering a commentary on how little we normally relate to, or rank concentration numbers in different circumstances.

NOTE 2: PLANTS LIKE TO HAVE BREAKFAST

It is well known that "Global Warming" and rising CO_2 gets the blame for anything and everything that could be bad.   A few years back there was a blurb (showing the famous three-leaved outline) that increased CO_2 caused poison ivy to grow faster. I wonder if this was intentional "bait", or a joke.   Of course it was true, as most plants grow better when there is more CO_2 available. In fact, it is frequently noted that horticulturists often pump in CO_2 (like to 1000 ppm or more) to glass greenhouse enclosures.   This is impractical for open-field agriculture, but some studies (Google it) suggest that the modern rises in concentration have increased crop yields (e.g., wheat) something like 20%.   That's quite significant, and highly important to reduce world hunger.

Less famous than poison ivy or wheat stories are reports such as:

http://joannenova.com.au/2013/09/plants-suck-half-the-co2-out-of-the-air-around- them-before-lunchtime-each-day/

[This Sept 26, 2013 blog link leads to an online-available paper from U. Iowa from 1954, and further suggests this idea is 200 years old]

http://www.plantphysiol.org/content/29/6/500.full.pdf+html

relating that when the sun comes out in the morning, plants (corn in this case) tend to quickly start to suck up CO_2 as though its going out of fashion.   Of course there are conditions and restrictions on finding this result, such as there being little natural mixing (little wind, etc) so that the "table" is not restocked every minute or so.   But if there is a calm night, CO_2 levels become normal or slightly higher (due to soil chemistry/biology changes), and when the sun comes out, the corn draws down this CO_2 by as much as half by lunch time.   Eventually (sooner rather than later) the average concentration is restored.

Just a nice fact to have, but it certainly makes the point about CO_2 being rare from a plants point of view.

NOTE 3: WEATHER STIRS THE POT

We hear the notion that without greenhouse warming, the Earth's surface would be too cold for life as we know it. As stated, without the greenhouse warming it would be about -15°C (+5°F a cold winter day not favorable to liquid water!) and with the warming it is +15°C (+59°F a cool but acceptable day). So is it the case that the +15°C is the "best effort" greenhouse warming can give? According to alarmist, not at all. They fear increased CO_2 concentrations will produce too much additional warming. But there is generally more to the story!

Roy Spencer in his book *Climate Confusion* (2008) points out that greenhouse surface warming should reach about 140°F (60°C a very hot record-setting desert day) with the gases at their present levels.   This does not happen because of the "stirring" effects of weather.   As we mentioned, heat is removed from the Earth's surface to space in part through the "hopping" of photons. Photons are captured and other photons (generally with different energies) are released, and eventually escape to space. At the same time however, other parcels of energy get moved physically. That is, Nature is compelled to obey the 2nd Law of Thermodynamics: to move heat from regions where there is more to regions where there is less. That is a sufficient condition for Nature to invent such things as storms and all forms of what we call weather.   As Spencer shows, weather cools the surface while at the same time warming layers of the atmosphere higher up, relative to a greenhouse effect without weather. So things get evened-up.

One thing involved, in addition to obvious physical movement of air currents moving hot and cold air pockets around, is the involvement of "phase changes".   Here we are involving ourselves with water, and two important phase changes: both of which are familiar to us as everyday phenomenon as well as weather phenomenon. These are the freezing/melting of ice, and the condensation/evaporation of water vapor, with liquid water in between.

In response to heating at the surface, liquid water can evaporate, taking up energy, cooling the surface, but not immediately getting warmer itself.   This energy uptake is what is called "latent heat", involving the phase change from liquid water to water vapor. This is an amount of energy that is very large compared to what is necessary to change the temperature (kinetic energy) of liquid water.   Roughly 5 times as much energy is required to evaporate a quantity of water as it would have taken to change the temperature of that water from freezing to boiling. Accordingly, great amounts of energy can be removed from the surface and released much higher up (through condensation to water drops) through the stirring of updrafts and thunderstorms, etc. Thus the surface is cooled and the gradient reduced through the occurrence of weather.

NOTE 4: LOGARITHMIC CO$_2$

The notion that the heat trapping ability of CO$_2$ (or other "greenhouse gas" such as H$_2$O or CH$_4$) is a logarithmic function of concentration is famous. Variously this is presented popularly as a form of "diminishing-returns" such as additional coats of paint over a window, blankets on a bed, that sort of thing. I have compared it to adding outfielders in a baseball game in an attempt to prevent more fly balls from dropping.   In this Webnote we have shown a series of blocking grids that a would-be escaping photon would have to negotiate.   What would a graph of this sort of thing look like?

Here we start with the idea of some sort of array or grid with 10,000 locations, each of which is initially empty, but once populated will block passage. Further there is not just one such grid layers to negotiate, but L of them. The underlined probability that a grid location is populated with a blocker is 0.2.   This is, of course, very simple, but it shows why a diminishing-return or logarithmic result occurs in our "photon escape" example and in many similar examples in physics (such as radioactive decay).
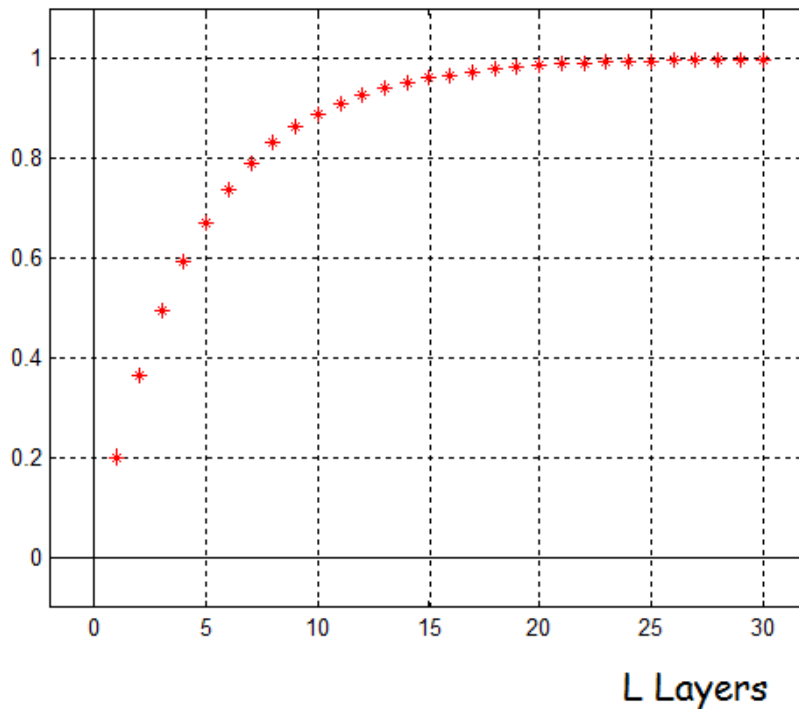
Fraction of photons captured trying to escape through L layers of a grid with grid populated with a probability of 0.2.

L Layers

The figure above shows one view of what happens. Here we are looking at the total fraction captured after each layer.   No surprise, after the first layer there are about 20% captured (remember there at 10000 random trials – see code at end). This leaves

about 80% of the total to try their luck at the second layer. Now 20% of the 80% of those that got through the first layer, or 16% of the total, are captured and added for a total of 36% captured after two layers.   At the third layer we have the remaining 64% and capture 20% of 64% or 12.8% of the originals, for a total captured of 48.8%. And so on. It of course resembles a charging R-C low-pass.
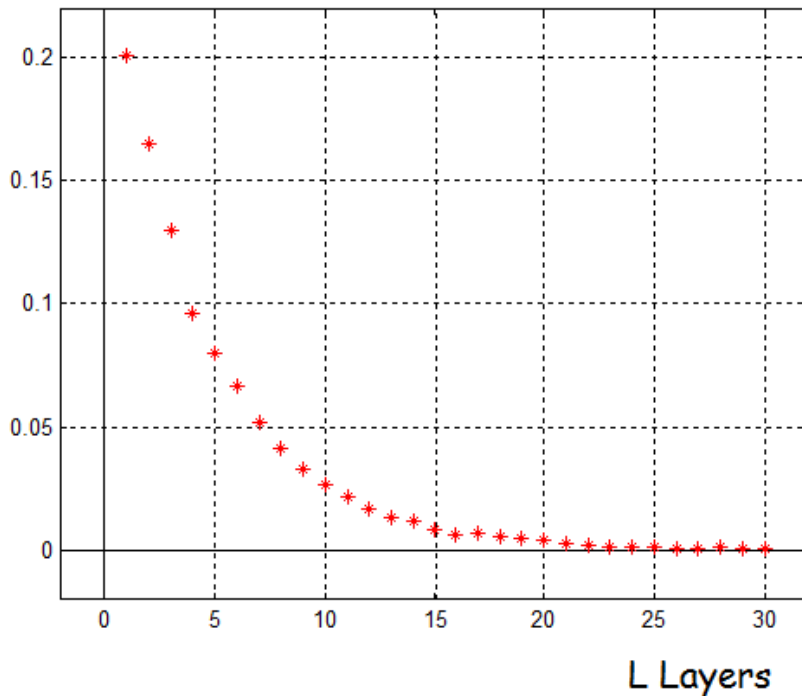
Fraction of photons captured by each successive layer of a grid with grid populated with a probability of 0.2.

L Layers

The second figure shown just above is the flip side of the view where we are now looking at the <u>number captured by each successive layer</u>.   This is really the diminishing-return view, as the percent of the original total added gets smaller and smaller. Of course, this is the derivative of the sequence in the first graph.   Although you can't read it off the graph, of the original 10,000 photons, the last four layers captured 5, 8, 5, and 2 photons, respectively, leaving just 16 that totally escaped beyond the 30 layers.   In contrast, the first four layers captured 2009, 1651, 1301, and 961 respectively.   So, the later layers aren't doing very much.

   That's the most basic "why?"

[Note that this sequence reaches half its starting value after $(0.8)^L$=0.5 which solves to L= $ln(1/2)/ln(0.8)$ or L = $-1/Log_2(0.8)$ = 3.106 (about every 3) layers.]

   Below is the Matlab code used to produce the figures.

```
% co2.m
%
x=zeros(1,10000);
TL=30
c=[];
cc(1)=0;
for L=1:TL
for k=1:10000
   if rand<0.2; x(k)=1; end
end
c(L)=sum(x)/10000;
if L==1; cc(L)=c(L); end
if L>1; cc(L)=c(L)-c(L-1); end
end
c
cc
figure(1)
plot([1:TL],c,'*r')
hold on
plot([-2 32],[0 0],'k')
plot([0 0],[-.2 1.2],'k')
axis([-2  32 -.1 1.1])
hold off
grid
figure(1)

figure(2)
plot([1:TL],cc,'*r')
hold on
plot([-2 32],[0 0],'k')
plot([0 0],[-.2 1.2],'k')
axis([-2  32 -.02 0.22])
hold off
grid
figure(2)
```