Central Coast Climate Science Education

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Misperception #1: The amount of CO_2 generated from fossil fuel consumption by humans over the last century is far too small to significantly affect the Earth's climate.
(This misperception took the form of the following statement in a recent letter to the Atascadero News):
Only 1 molecule out of every 10,000 in the atmosphere represents CO_2 added due to fossil fuel combustion in the last 100 years. ("Pennies" were used to illustrate this point in lieu of "molecules").

Response:
The arithmetic above is approximately correct. So is the following statement:

Since the start of the industrial revolution, fossil fuel combustion by humans has added about 10**40 CO_2 molecules to the Earth's atmosphere.
(In more familiar notation that is:
10,000,000,000,000,000,000,000,000,000,000,000,000,000 CO_2 molecules.
(See the Appendix below if you wish to see how this number was calculated)

Sounds a little more impressive than "one penny's worth", doesn't it! But this number is only slightly more relevant than the "one penny" analogy, which itself is utterly irrelevant.

Here's why:

The heat trapping effect of the CO_2 simply depends upon the amount of CO_2, not on the fraction of CO_2 compared to the nitrogen and oxygen, which play no role in the greenhouse effect.

In more detail:

The Earth's atmosphere consists mostly of nitrogen (N_2) molecules (about 80%) and oxygen (O_2) molecules (about 20%.) There are much smaller amounts of 'trace gases' including argon, water vapor and carbon dioxide.
The nitrogen, oxygen and argon molecules are transparent to both visible light and infrared radiation, so they play no role in the greenhouse effect.

Consider an imaginary tube with an area of one square inch extending from the ground to outer space. Consider further a tiny beam of infrared radiation starting anywhere inside this tube and trying to escape into space. Its passage is impeded by those gases--like carbon dioxide--which will absorb that beam, depending upon the exact wavelength of that infrared radiation. Each such CO2 molecule presents a target ("cross section") for the beam to collide with the molecule. Figure 1 is a simple diagram depicting the situation:

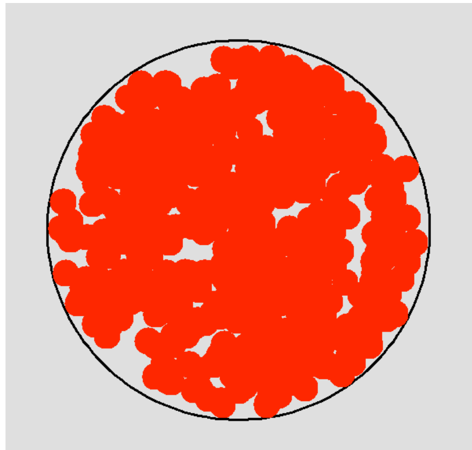

Figure 1

We are looking out towards space from the bottom of the tube. The large circle represents the imaginary tube. The small red circles represent the 'cross section' for each CO2 molecule for intercepting a beam of infrared radiation of a particular wavelength. (This is ***not*** the same as the actual physical size of the molecule). The number of CO2 molecules is sufficient that in this end-on view the cross sections overlap, but they are separated from each other in space.

(For this figure we have vastly exaggerated the size of the cross sections, but we have also vastly reduced the actual number of CO2 molecules over every square inch of the Earth's surface. (About 50,000,000,000,000,000,000,000 of them!)

You can see that the odds of any given beam starting anywhere inside the tube missing all the targets and escaping into space is very small. These odds have ***nothing to do*** with how many oxygen and nitrogen molecules there are, but only how many CO2 molecules there are in that tube. If we ***increased*** the number of N2 and O2 molecules 10 times, the ***fraction*** of CO2 molecules would go down (4 pennies to 0.4 pennies) or if we ***decreased*** the number of
N2 and O2 molecules by 10 times, then the ***fraction*** of CO2 molecules would go up (4 pennies to 40 pennies). But there would be **NO CHANGE** in the likelihood of the infrared beam escaping, since it depends only on the number of CO2 molecules in the tube, not on the fraction of CO2 compared to the more abundant O2 and N2, whose cross sections for intercepting infrared radiation are zero. ***The fraction is completely immaterial*, and while the 'one penny' analogy is rhetorically clever, *it is scientific nonsense.***

The CO2 molecules also emit the same infrared radiation that they absorb. When they do, however, some of the radiation will be sent upwards, but some will head downwards and returned to the Earth. Furthermore the amount of radiation emitted by the CO_2 molecules depends upon the temperature of the atmosphere where they happen to be located. Only near the top of the atmosphere are there sufficiently few CO_2 molecules left to impede the infrared radiation from escaping into space. But it is much colder and the amount of radiation escaping into space is much reduced. This is illustrated in Figure 2:

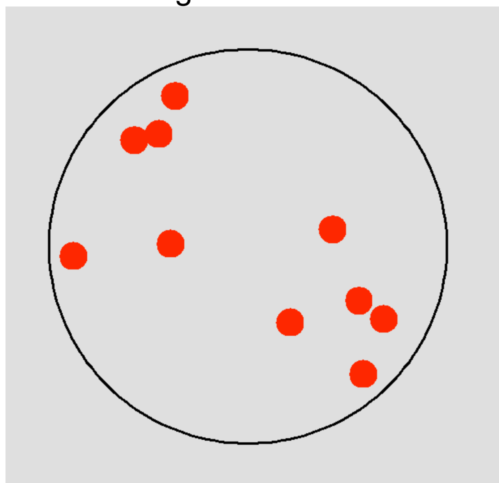

Figure 2

So how do scientists determine the actual size of the 'targets' presented by CO_2 molecules? The principle is very simple: Fill a real tube with a known number of CO_2 molecules. Pass infrared radiation of any particular wavelength through the tube from one end and see how much escapes to the other end. It is then a simple matter to calculate the 'cross section' of a CO_2 molecule for any given infrared wavelength. This data can then be applied to the real atmosphere, since we know the number of CO_2 molecules present. The increased trapping of heat caused by these 10**40 added CO_2 molecules ***is very significant and is producing an energy imbalance in the Earth's climate system.*** (See Lesson 5) in the Tutorials page. This is not a guess, nor a hunch, nor a 'theory' but the application of laboratory measurements and basic physical laws. It is moreover confirmed by measurements from space of the decreased infrared radiation which escapes our atmosphere at those wavelengths where CO_2 strongly absorbs.

Appendix

How many CO_2 atoms have humans added to the Earth's atmosphere since the start of the industrial revolution?
(Powers-of-ten notation is used here: consult any algebra or middle school math text if you are a little rusty on this subject.)

From a textbook on the Earth's atmosphere or any of several internet sources we learn that the mass of the Earth's atmosphere is 5 * 10**15 metric tonnes (see for example: http://en.wikipedia.org/wiki/Atmosphere_of_Earth) or 5 *10**18 kg or 5*10**21 grams. (Note: A metric 'tonne' is about 1.1 times the U.S. ton; it is spelled differently to avoid confusion.)

About 80 percent of the molecules in the atmosphere consists of the N2 molecule with a mass about 28 times that of the hydrogen atom, and about 20 percent consists of the O2 molecule with a mass about 32 times the hydrogen atom. So the average mass of a molecule is about 0.8 * 28 + 0.2* 32 or about 28.8 times the mass of the hydrogen atom.
The mass of the hydrogen atom is 1.67 * 10 **(-24) grams, so the average mass of a molecule of air is about 4.8 * 10** (-23) grams. Therefore the total number of molecules in the atmosphere is obtained by dividing the number of grams in the atmosphere by the weight of the average molecule: 5*10**21 / 4.8*10**(-23) = 1.04 * 10**44 molecules (let's round that number off to 10**44).

At the start of the industrial revolution about 2.8*10** (-4) of all molecules were CO2 molecules. So 2.8*10**(-4) times 10**44 of these were CO2 molecules. Now there are nearly 3.88 * 10**(-4), (lets call it 3.8 * 10**(-4) so we have added about 10**(-4) * 10**44 = 10**40 CO2 molecules to the Earth's atmosphere.