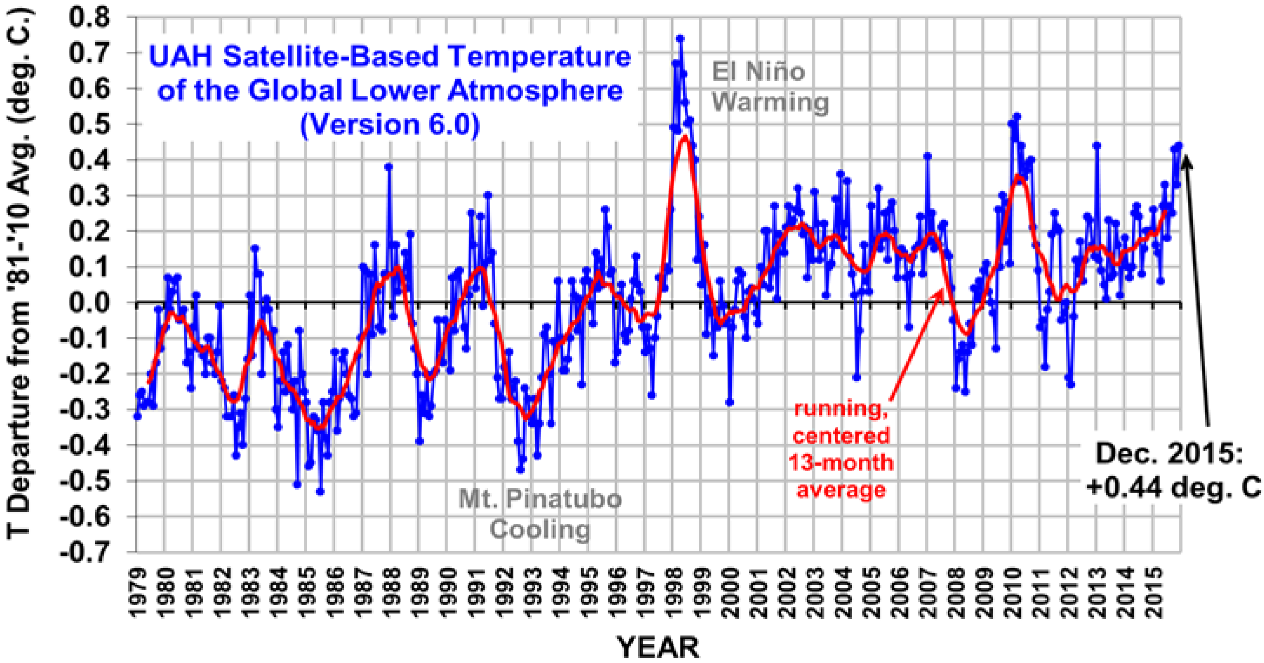
Smoke and Mirrors?



Some comparisons between Earth and Venus

Scientists and non-scientists often give Venus as an example of a planet with a runaway greenhouse effect. However, some years ago I came across an analysis with a different conclusion. I shall say more about this later. Firstly, let us look at some vital statistics:

	Earth	**Venus**
Average Distance from Sun	149.6 million km	108.2 million km
Diameter	12,756 km	12,104 km
Mass	5.972×10^{24} kg	4.867×10^{24} kg
Density	5520 kg/m^3	5250 kg/m^3
Atmosphere	78% N_2, 21% O_2, 1% Ar	96% CO_2, 3% N_2
Albedo (reflectivity)	0.37	0.76
Acceleration due to gravity at surface	9.8 m/s^2	8.9 m/s^2
Pressure at surface	1 bar	90 bar
Average Surface Temp.	288^0 K (15^0C)	738^0K (465^0C)
Orbital period	365 days	225 days
Rotation period	Approximately 1 day	Approx. 225 Earth days
Moons	1	None

Although the size and density of the two planets are similar, the factor that most people find striking, is the extreme difference between the planets' surface temperatures. On Venus, the surface temperature is well over the melting pint of lead and some 45^0C above the melting point of zinc whilst on Earth the average temperature is only 15^0C above the freezing point of water. Is the difference due to the fact that most of Venus' atmosphere is composed of carbon dioxide? Well many scientists think not (some examples: H.D Huffman, A. Miatello and D J Cotton). To explain why, I will have to get into a little bit of physics and a little bit of mathematics. Please accept my apologies in advance to those who struggle with these disciplines.

Firstly for reasons that may become obvious a little later let's look at the temperature at the height in the atmosphere of Venus where its atmospheric pressure is the same as that on Earth at ground level (approximately 1000 millibars). On Venus, the average temperature at that height is about 338.6 degrees Kelvin (about 65.5^0C) compared with an average of 287.4^0K just above the earth's surface (14.3^0C). Of course, as we have seen from the data above, Venus is closer to the sun than Earth. The amount of solar radiation received depends on the inverse square of the distance of the planet from the sun. So roughly the radiation received by Venus in comparison with Earth is $(149.6/108.2)^2 = 1.911$. To convert this difference in radiation received to equilibrium temperatures then according to the Stefan-Boltzman Law we have to take the fourth root of 1.911, which is 1.176. So, if Venus was at the same distance from the sun as Earth it would have a temperature at the pressure altitude of 1000mb of 338.6/1.176 or about 287.9^0K (about 14.7^0C). You will notice that, although I have ignored the difference in reflectivity (albedo) for the two planets, the small difference in the planet disc facing the sun, the fact that the Earth's rotation is fast compared to Venus and some other factors, this simple calculation appears explain the temperature difference without the need to call upon a greenhouse effect!

In case you think that this is all smoke and mirrors let's take a slightly different approach and only talk about Earth. You may know that generally as one goes higher the atmospheric temperature reduces. The rate at which this proceeds depends on whether the air is dry or contains water vapour. We call this reduction in temperature with height the lapse rate. The simplest lapse rate is the dry adiabatic lapse rate or the DALR. It can be expressed as a rate of change of temperature T with height h as: $dT/dh = -g/c_p$ where g is the acceleration due to gravity and c_p is the specific heat of air in the atmosphere at constant pressure. Although g changes slightly with h and c_p changes slightly with T to a first approximation one can regard both g and c_p as constants. So using integral calculus, we can generate the formula:

$$\mathbf{T_s - T_h = -g/Cp * (h_s - h)}$$

Where: Ts is the average temperature at the Earth's surface and T_h is the temperature at height h and h_s is height at sea level which by definition is zero. Now the moist lapse rate has many more terms in it but we are interested only in a rough calculation so I will insert the average moist lapse rate for $-g/c_p$ as -6.5^0K/km (or C) the equation simplifies to: $T_s = T_h + 6.5*(h)$. Now let us substitute two numbers for height and temperature at that height. Typically, at say 5km above sea level the air temperature is about 255^0K. So using this information let us calculate the surface temperature. It is 255+6.5*5, which is 222.5^0K or 287.5^0K (about 14.4^0C). So, again, without using any radiation formulae we have deduced the average surface temperature correct to within less than one degree Kelvin.

This leaves us with the thought that, if there is a greenhouse effect, it is likely to be small. It also follows that, a change in the amount of carbon dioxide in the atmosphere, is not likely to have very much effect on temperature. On the other hand, because the solubility of carbon dioxide in water (and sea water in particular) varies inversely with temperature one expects to see increasing levels of carbon dioxide in the atmosphere when, for whatever reason, the atmosphere heats up. Interestingly is what we have been seeing since we emerged from the little ice age. Nevertheless, if I was an English Literature graduate I may still be thinking that it is all smoke and mirrors.

Peter F Gill