Responses to “Why does the stratosphere cool when the troposphere warms?”

1. *John M Rutt* Says:
   10 December 2004 at 9:24 AM

   Why not just say that the absorption of the suns UV energy creates heat and with the dissipation of the ozone layer in the stratosphere, this is now occuring closer to the earth in the troposphere rather than up in the stratosphere.

   Response: This is indeed an effect, but it has not been the dominant cause of the current trend. Now that ozone depletion is likely to stabilise, the changes in the future will also likely be dominated by the CO_2 (and possibly stratospheric H_2O) changes. - gavin

2. *Roy W. Spencer* Says:
   10 December 2004 at 1:53 PM

   1. The stratosphere does NOT have a positive lapse rate…it is negative. A positive lapse rate is one in which temperature decreases with height. That’s why it’s called a “lapse” rate.

   Response: Thanks for pointing out the slip. Fixed it. - gavin

   2. The answer to the original question depends on time and space scales involved…if it is referring to global trends in recent decades, then you didn’t really answer the question: the lower stratosphere has cooled in recent decades primarily due to ozone depletion, while the troposphere has warmed (presumably) from the enhanced greenhouse effect.

   Response: Fair point. The observed lower stratosphere trend is mainly due to decreasing ozone. Further up, and over the longer term, greenhouse gas changes are likely to be dominant. - gavin

3. *James B. Shearer* Says:
   11 December 2004 at 9:36 PM

   I believe the explanantion given in paragraph 2 is incorrect. Since radiation is absorbed and emitted both up and down there is no justification for just considering temperatures in the layers below the layer in question.

   It appears to me that a more correct analysis would note in equilibrium for a given layer energy out must equal energy in. Also long wave and short wave radiation should be considered separately. The stratosphere absorbs short wave (UV) radiation from the sun but is not hot enough to radiate much at short wavelengths. So to maintain energy balance the stratosphere must be losing energy via long wavelength radiation which means long wavelength emitters like CO2 must be radiating more than they are absorbing. So naively adding more CO_2 will have a cooling effect moving the equilibrium temperature lower. However it appears to me that lower layers of the atmosphere must also be losing energy via long wavelength radiation since they are gaining energy via convection from below. So here too CO_2 must be radiating more than it absorbs. So naively adding CO_2 to a lower layer would (ignoring feedbacks) also cause it to cool. Presumedly this means the neglected factors (feedback and the fact that CO_2 is added to all layers at once not just the layer being considered) dominate for lower levels but not for upper levels. Perhaps there is a simple explanation for this but I do not see it at the moment.

Response: As CO_2 increases, both absorbtion and re-radiation increase. Re-radiation also depends on the local temperature, while absorbtion does not. In the lower atmopshere, there is a large amount of LW up from the surface, part of which is absorbed. The total long wave going up from any layer must remain constant, and so any extra absorbtion must be balanced by increased re-radiation. Since the local temperature is lower than at the surface, the increased re-radiation purely from the extra CO_2 emissivity is not sufficient and so you need to increase the local temperature. - gavin

Response #2: A different (probably equivalent, but I find it easier to understand) explanation is that the stratosphere is heated by absorbing solar/uv by ozone; increasing the amount of CO_2 (which is only significantly active in the IR) increases the ability of the stratosphere to lose heat, so it does. - William.

4. *Ferdinand Engelbeen* Says:
   12 December 2004 at 6:20 AM

   There is a lapse rate discrepancy in the tropics, according to the latest radiosonde quality control by Peter Thorne, Simon Tett and David Parker from the Hadley Center (see: http://www.ncdc.noaa.gov/oa/ncdc_vtt_pwt.ppt)

   The lapse rate ‘discrepancy’
   Since 1979 observations imply that the troposphere in the tropics has cooled whereas the surface has warmed.
   This contradicts climate model projections, which predict greater warming aloft.
   It is also a reversal of an earlier global-mean trend according to the longer radiosonde analyses.
   It casts doubt upon our understanding of the climate system and ability to predict future climate changes.”>

   How can that be explained by the GHG theory?

5. *James B. Shearer* Says:
   20 December 2004 at 4:59 PM

I believe Gavin's response to my comment is incorrect. The increase in radiation emitted from the increase in emissivity can (more than) balance the increase in radiation absorbed even if the temperature of the layer is less than the temperature below because the increase in radiation is in two directions (both up and down) while the radiation absorbed is only coming from below.

Furthermore while the increased radiation down from the layer will eventually (in equilibrium) warm the layers below enough to cause a matching increase in radiation upward from below, it is not true that this radiation will all be absorbed by (and warm) the layer. If the emissivity of the layer is low most of the additional upward radiation can pass right through the layer without warming it. The net effect is increased emissivity can cause a cooling effect even if the layer is already cooler than the layers below.

6. *Eli Rabett* Says:
   23 December 2004 at 9:43 PM

   James Shearer's comment about "If the emissivity of the layer is low, most of the additional upward radiation can pass right through the layer without warming it" is one of those it depends things. Mosly what it depends on is that the two layers have different composition. If we are talking about clear atmosphere, then no, because the radiation will be ONLY at exactly those frequencies where the greenhouse gases above and below absorb/emit. If you are talking about clouds and aerosols, then maybe, but maybe not if the layer above is also cloud/aerosol. Trapping of radiation in clouds can be significant.

7. *James B. Shearer* Says:
   26 December 2004 at 10:05 PM

   Eli Rabett, I don't understand your point. If we consider a thin enough layer most radiation will pass right through the layer even at the most absorbant frequencies.

8. *Eli Rabett* Says:
   28 December 2004 at 12:19 AM

   You have to integrate my answer. As you say, in the limit everything is thin, but irrelevant.

9. *James B. Shearer* Says:
   28 December 2004 at 10:10 PM

   Let me present a model illustrating my point. Consider a slab atmosphere modeled as a gray body (at long wavelengths) with emissivity "e". Suppose further that a fraction "a" of the incoming shortwave radiation is absorbed in the atmosphere (with the remainder being absorbed by the ground). Let T1 be the temperature of the atmosphere, T2 be the temperature of the ground and TB be the black body temperature of the ground (with no atmosphere). Then I believe we have

T1**4 = (TB**4)*(a+e-a*e)/(e*(2-e))
T2**4 = (TB**4)*(2-a)/(2-e)

Then for certain values of a and e the atmosphere will be cooler than the ground but increasing e will cool the atmosphere further. For example a=.05, e=.1. I think this shows gavin's argument that this cannot occur is incorrect.

10. *Nobuki Matsui* Says:
    [30 December 2004 at 6:32 PM]()

    I found those web site below. Are they really non-sense? If so, how? Could anybody explain to us?
    http://people.freenet.de/klima/indexe.htm
    http://www.geocities.com/atmosco2/backrad.htm
    http://www.geocities.com/atmosco2/Influence.htm

    Response: Yes. These arguments are nonsense. If I have time, I'll try and see what the major error is and report back.- gavin

11. *James B. Shearer* Says:
    [15 January 2005 at 6:46 PM]()

    Unfortunately I believe the updated post is still incorrect.

    First as the temperature gradient in the atmosphere increases, at a certain point the atmosphere becomes unstable (because rising (falling) packets of air do not cool (warm) fast enough by expansion (compression) to stop rising (falling)). When this point is reached convection starts and effectively prevents the temperature gradient from increasing further. This point has already been reached in the lower atmosphere (otherwise the surface would be much warmer than it actually is). As far as I know there is no reason to expect greenhouse warming to increase the lapse rate near the surface.

    Second even if we ignore convection (and assume all warming of the atmosphere is from below, ie no incoming solar radiation is absorbed in the atmosphere) it is not the case that the atmosphere temperatures will "pivot" around some fixed level (increasing below it and falling above it). Instead it is reasonably easy to see that in this case the temperature of the top of the atmosphere will remain fixed at .84*TB (where TB is the black body temperature of the earth) and the rest of the atmosphere will warm with the greatest warming near the ground. This means the effective radiating level will rise which makes sense as it is harder to "see" into the atmosphere.

Finally if I am not mistaken the temperature of the top layer of an atmosphere consisting of n blackbody shells should be Tg/((n+1)**.25) not Tg/(2.**(n/4)) as stated.

[**Response:** I concur with your correction of the n-shell problem (I should have worked it out for myself instead of trusting what someone told me) and the post is amended accordingly. While your other two points are valid, they are not strictly 'corrections'. I specifically state that I'm ignoring convection (and other atmospheric mixing processes) in order to simplify the discussion. They are clearly important in the troposphere, but it doesn't help understand the stratospheric part. As part of the final response to a change in GHGs, the effective radiating level will indeed move up, but above that level the tendency will be to cool. Possibly a more complete statement would have been that you can think of the temperature profile pivoting around the radiative level, and having that pivot move up a bit. There will still be cooling in the upper atmosphere. -gavin]

12. *John Davis* Says:
    18 January 2005 at 5:25 AM

    I see that Steve Milloy has posted some graphs on junkscience.com which purport to show that the stratosphere has in fact NOT cooled over the past 10 years or so. Can you debunk, please?

    [**Response**: There is too much junk on junkscience to take it seriously. A better reference is http://www.ghcc.msfc.nasa.gov/MSU/msusci.html, though the graph there is substantially the same as SM's. Fitting a curve through 10 years of data isn't a very good idea - if you use the full set you obviously get a very different answer. Given that CFC concentrations in the atmos have largely stabalised, I would suppose that ozone too should stabalise. SM seems to reject that, but for no very clear reason - William]

    [**Response**: This is bad even by Milloy's own standards. While the basic physics is sometimes difficult to explain (see above!), the basic issue is that stratospheric temperatures change in response to local effects, they do not change because the troposphere does (i.e. troposphere warming does NOT imply stratosphere cooling). Thus the changes in the stratosphere are basically a function of the greenhouse gases, ozone levels and volcanic aerosols there. The changes seen in the MSU 4 data (as even Roy Spencer has pointed out), are mainly due to ozone depletion (cooling) and volcanic eruptions (which warm the stratopshere because the extra aerosols absorb more heat locally). As William points out, ozone depletion is levelling out since the Montreal Protocol, and so lower stratospheric cooling will start to attenuate, but then Milloy doesn't appear to think that ozone depletion was a real phenomena either. - gavin]

13. *Eli Rabett* Says:
    26 February 2005 at 8:47 PM

I don't know if this is still open, but one point to keep in mind is that the temperature increases with altitude in the stratosphere. James Shearer seems to be saying that it decreases with altitude.

14. *James B. Shearer* Says:
    26 February 2005 at 9:12 PM

    I don't agree that temperatures will pivot around the effective radiating level. Instead the entire atmosphere will get warmer (assuming no atmospheric absorption of incoming solar radiation). Consider the case of n black body shells. Adding shells makes the ground hotter but the temperature of the top shell remains at TB, the blackbody temperature of the earth. More generally assume the top shell is a graybody shell with emissivity e. Then its temperature will be ((1/(2-e))**.25)*TB. Note this is an increasing function of e so even for the top layer increasing e causes the layer to warm. As we let this layer get thinner e will go to 0 and the temperature of the top layer will go to .84*TB. So as I said in my previous comment the temperature at the top of the atmosphere is effectively fixed at .84*TB.

    Still more generally consider n graybody shells (emissivity e) numbered from the top. Then if I calculated correctly the temperature of the jth shell is TB*((1+(j-1)*e)/(2-e))**.25 and the temperature of the ground is TB*((2+(n-1)*e)/(2-e))**.25. All of these are increasing in e. Also note the discontinuity at the ground. If we let e=1/n and let n go to infinity the temperature of the bottom layer is TB but the temperature of the ground is 1.1*TB.

    [**Response:** You can only understand the strat cooling by knowing the atmos is non-grey. In a grey atmos it all warms. The stratosphere exists because it is non-grey (ozone abs of UV). Adding CO2 increases its ability to cool but less its ability to warm (since most comes from UV) so it cools. I think this means I'm agreeing with JBS… - William]

    [**Response:** Et tu William? Take a step back here. I am not saying the atmosphere is like the n-blackbody shell atmosphere. This example is given as an end member for the extreme GHG effect, which is to be compared to the no GHG case. It is the difference between them that tells you what increasing GHGs do (not what happens when you increase the number of shells). In the real world we are in between the two cases, but increasing GHGs pushes us towards an n-shell case. Since that case has a much steeper temperature gradient, the basic effect of increasing GHG is to increase that gradient. Given that the effective blackbody emission must be constant (and allowing for a small movement in the effective radiating level), an increasing gradient must therefore lead to cooling far above this level. UV absorbtion by O3 is irrelevant for this point (as is convection in the troposphere) although it is key in setting the actual temperature profile. - gavin]

15. *James B. Shearer* Says:
    27 February 2005 at 6:51 PM

Eli, Gavin is arguing above that adding greenhouse gasses would cause the stratosphere to cool even if the stratosphere was not being warmed by the adsorption of UV and that this is the explanantion of stratosphere cooling. I am arguing that this is incorrect if all warming was from below there would be no cooling.

Gavin, the gradient increases but the fixed point is the top of the atmosphere not the effective radiating level. As a result all layers warm with the amount of warming increasing as you move towards the surface. This means the effective radiating level rises.

Consider the top of the atmosphere as an arbitrarily thin gray body. Looking down from this layer we see the earth radiating at its black body temperature, TB. Looking up we see space at near absolute zero. So this layer will have temperature ((TB**4)+0**4)/2)**.25 or (.5**.25)*TB or .84*TB as claimed above. If the top layer is not arbitrarily thin but instead has emissivity e then its temperature will be TB*(2-e)**(-.25). In either case the temperature is independent of the details of the temperature structure below, the key point is that the total outgoing radiation must balance the incoming solar radiation.

[**Response:** Obviously radiaitve balance must be maintained, and I am not disputing that the effective radiative level will rise. Possibly, the solution to this is that in the real atmopshere the movement of this level is severely constrained (mainly by adiabatic cooling) and so cannot rise enough to produce your solution. I'll think about this a little more…- gavin]

16. *James B. Shearer* Says:
28 February 2005 at 7:17 PM

Suppose we add absorption of incoming solar radiation to our model of the top of the atmosphere. Let the top layer be a gray body with emissivity e and suppose it also absorbs a fraction f of the incoming solar radiation. Then if I have calculated correctly it will have temperature T = ((e+f-ef)/(e*(2-e)))**.25*TB where as before TB is the black body temperature of the earth. Note for e>f, T < TB (so the temperature decreases from the effective radiating level to the top of the atmosphere). On the otherhand for e < f, T > TB (so the temperature increases from the effective radiating level to the top of the atmosphere). Now let f=a*e for some constant, a, and let e go to zero (ie let the top layer become arbitrarily thin). Then in the limit T=((1+a)/2)**.25*TB. Now if adding greenhouse gasses increases e but not f then a will decrease as will the temperature at the top of the atmosphere. We can check this by computing the dT/de and comparing it to zero. By my calculation the derivative will be negative for f > (e*e/(1+(1-e)**2)). So if f=a*e for some fixed a>0 the derivative will become negative as e goes to zero as expected. This is true even if a<1 and the temperature of the top of the atmosphere is less than the black body temperature of the earth. So I agree with William, the cooling effect at the top of the atmosphere requires that the atmosphere be absorbing some incoming radiation (and that this absorption be (mostly) by non-greenhouse gasses).

[**Response:** You have simply restated the problem as being the same as for a single atmospheric layer (read Tg for your new TB). This doesn't help ascertain why different layers react differently… And it doesn't explain why the mesosphere (with very few absorbers) also cools. - gavin]

17. *Andy Lacis* Says:
2 March 2005 at 12:56 PM

The question of why the stratosphere cools when the troposphere warms addresses an important validation point for the CO_2 greenhouse effect, but the question as stated is ill posed in that the correct answer depends on the proverbial details.

Climate forcing perturbations such as increasing the solar constant, increasing black carbon aerosols (tropospheric), and decreasing surface albedo, low cloud cover, sea salt aerosol, will (on global average) warm the ground and troposphere and will also warm the stratosphere. For these types of radiative climate forcings the atmospheric temperature profile will be shifted basically unchanged to its new equilibrium position. On the other hand, decreasing stratospheric ozone (above 25 km), increasing stratospheric water vapor, and increasing atmospheric CO_2 uniformly with height) will produce global surface and tropospheric warming along with stratospheric cooling. These results are described in considerable detail in Hansen, Sato and Ruedy (1997) "Radiative forcing and climate response" in JGR 102, 6831-6864 (see their Plate 2 for $2xCO_2$, Plate 3 for +2% So, Plate 5 for ozone). The radiative effects of increased stratospheric water vapor act to cool the stratosphere and warm the troposphere and are described by Oinas et al (2001) "Radiative cooling by stratospheric water vapor: big differences in GCM results" GRL 28, 2791-2794. That holds for the global mean temperatures. Oinas et al also show that stratospheric dynamics make their contribution in the polar vortex regions to produce local warming in the 1 mb region for the uniformly applied increase in stratospheric water vapor. (This just shows that while the stratosphere as a whole may be in radiative equilibrium, i.e., energy transfer is primarily by radiative means, there are some locations in the stratosphere where dynamic energy transport is also significant.)

The oversimplified analytic expressions that have been used to make the case pro and con a given explanation for why the atmosphere responds as it does are of limited validity. For example, the formula given by JBS that T = (e+f-ef)/(e*(2-e)))**.25*TB can't really be correct since setting the solar input fraction f to zero does not reproduce temperature of the earth TB unless the emissivity e is equal to unity. The 2-layer equilibrium relationship Ta=0.84Tg, which is valid for an isothermal gray absorbing layer above a Planck emitting ground, when applied to multiple layers is valid only when the layers are either totally transparent or totally opaque. Also, the T**4 dependence refers only to spectrally integrated radiation. Planck radiation is linear in T at microwave wavelengths and goes to an increasingly higher exponential dependence toward shorter wavelengths. Simple formulas can be useful, but they are a poor substitute for the physics involved. Radiative transfer in the earth's atmosphere is not particularly amenable to simple formulas because the atmosphere is semi-transparent to differing degree at different wavelengths, which allows radiation emitted locally to interact with the entire atmosphere. (Even for a relatively simple example of a gray medium, calculating the equilibrium temperature profile within a homogeneous slab involves a singular Fredholm integral equation of the second kind as described by M. N. Ozisik in Radiative Transfer (1973).) The radiative transfer problem is best addressed numerically with a sufficient number of vertical layers to resolve the atmospheric temperature and absorber distributions and with a sufficient number of spectral intervals to resolve the spectral dependence of the contributing gases - as is being done in most GCMs.

For radiative transfer, the vertical geometric scale is not relevant - only the optical depth distribution matters. From a semi-transparent atmosphere, radiation to space can come from virtually all parts of the atmosphere. But the bulk of it comes from the so-called TAU=1 level (looking down from space) where the opacity is near unity. This is because the fundamentals of thermal radiation from an isolated slab : emissivity, absorptivity, transmissivity, are related by emissivity = absorptivity = (1 - transmissivity) where transmissivity = exp(-TAU) (neglecting directionality). Thus radiation emitted from below the TAU=1 level gets mostly absorbed before it can get out to space. And radiation emitted from the uppermost levels of the atmosphere is small because the opacity there (hence the emissivity) is small, and little flux is emitted. Spectrally, the opacity of the atmospheric column ranges from a few tenths in the 10 micron window region to many thousands in the center of the 15 micron CO_2 band. As a result, the thermal radiation that is emitted to space comes from a wide range of points in the atmosphere ranging all the way from the ground to the top of the stratosphere. The spectrally averaged effective emission temperature of the earth is about 252 K, which corresponds to the physical temperature near the 6 km level. This is also then the approximate location of the spectrally averaged TAU = 1 level from which most of outgoing flux can be said to originate from. As the atmospheric opacity is increased (e.g., $2xCO_2$), the physical location of the TAU = 1 level will rise to a higher altitude, but the outgoing flux will still come from the TAU = 1 level since radiation doesn't care about the geometric scale), and the TAU = 1 level will still correspond to the same temperature (since the solar input energy is unchanged). The increased opacity will also act to increase the atmospheric temperature gradient between ground and the top layer of the atmosphere.

In a purely greenhouse atmosphere, successive layers with height can only be colder than the layer below, i.e., the temperature must decrease monotonically. Thus the top most layer will cool to absolute zero, except that it is being warmed by energy coming from the layer below, and so on down the line. Accordingly, for an atmosphere initially in thermal equilibrium, increasing the atmospheric opacity will cause the outer layers of the atmosphere to cool by increasing their emissivity while reducing the upwelling flux that warms them from below. With increased opacity, the lower layers are less able to send energy upward because, although the layer's emissivity = absorptivity, the emissivity gets multiplied by the layer's local temperature while the absorptivity is multiplied by a higher temperature radiation from below - effectively, a fractional increment of a higher temperature Planck function (from below) is being replaced the same fractional increment of a lower temperature Planck function (local layer) for transfer in the upward direction, thus cooling the layers above. For the surface layers near the ground, warming occurs because the flux from the ground remains fixed. Thus the near-ground layer's increment in absorptivity is multiplied by a higher temperature than its increment in emissivity, for a net gain in energy. As the atmosphere approaches its new thermal equilibrium, the top of the atmosphere cools while the bottom warms. For a homogeneous spectrally gray slab over a ground surface, the equilibrium temperature profile that is established is approximately a linear function of T**4 in optical depth within the slab. As the optical depth of the slab is increased, the temperature difference between the top and bottom of the slab also increases. Since the solar input is being kept constant, the outgoing thermal radiation will have the same (constant) effective temperature, and the TAU = 1 level will continue to coincide with the same physical temperature equal to the effective temperature. As the outer atmospheric layers above this point continue to get colder as the column optical depth of the slab is increased, the temperature profile within the slab will appear to "pivot" about the TAU = 1 point.

The actual atmospheric temperature profile is more complicated, being roughly 290 K at the surface, 200 K at the tropopause (15 km), 270 K at the stratopause (50 km), 200 K at the mesopause (80 km), then increasing again to large values in the thermosphere. Thermal optical depths beyond the stratopause are negligibly small, so they make no contribution to the earth's energy balance. This increase in stratospheric temperature with height to the stratopause and the decrease beyond is due to UV solar heating by ozone, independent and unrelated to the greenhouse effect, but nevertheless superimposed on the monotonically decreasing greenhouse temperature profile. The two effects operate independently of each other.

Andy

18. *James B. Shearer* Says:
2 March 2005 at 6:05 PM

Andy Lacis,

… For example, the formula given by JBS that T = (e+f-ef)/(e(2-e)))**.25*TB can't really be correct since setting the solar input fraction f to zero does not reproduce temperature of the earth TB unless the emissivity e is equal to unity. …*

Since T is the temperature of the top layer of the atmosphere, why are you expecting it to be TB?

… As the atmosphere approaches its new thermal equilibrium, the top of the atmosphere cools while the bottom warms. …

This makes no sense. Why will the top of the atmosphere cool? In equilibrium to maintain the energy balance of the earth you must have just as much long wave radiation passing through (and warming) the top layer as before.

19. *Spencer Weart* Says:
21 March 2005 at 12:21 PM

Can't resist butting in - this thread has been a good example of how people can let simple physics get in the way of real physics. There are two ways to look at what the "real" physics is. One is to acknowledge that calculation of radiation transport through a partially opaque atmosphere is one of those problems that seems easy until you try to write down the equations, and then you find it's a monster - the great mathematical physicist S. Chandrasekhar spent years working on it and wrote a book full of equations on stellar atmospheres that I think hardly anyone in atmospheric physics even tries to read. In practice you can't figure out what's going on without plenty of computer time.

The other way of looking at "real" physics is to back off and see the overall process. The first scientist to report the carbon dioxide greenhouse effect was John Tyndall. In 1862 he wrote, "As a dam built across a river causes a local deepening of the stream, so our atmosphere, thrown as a barrier across the terrestrial [infrared] rays, produces a local heightening of the temperature at the Earth's surface." I don't think anyone's said it better since. To say it a bit worse but in modern lingo: to maintain radiative equilibrium, the planet has to put out a certain amount of heat, and if it can't radiate it out from the surface, the lower atmosphere *somehow* has to get warmer until there's some level that radiates the right amount. In practice a lot of the ferrying of energy up towards the right level is done by convection (S. Manabe was the first one to get this right in his computer calculations), so a lot of the radiative gymnastics doesn't even count for much.

As for the stratosphere above the level where the heat is radiated out, who cares? It's a very thin gas that doesn't contain much heat energy and is easily influenced by anything. The real heat energy that we need to worry about is in the lower atmosphere. (In fact, still more in the oceans, where most of the new heat energy is going over the decades. At present we're not radiating out quite as much as we take in, so there's heat energy building up in the system.)

[**Response:** Well, some people care! It may not be the most important factor in GW, but there are impacts for ozone, strat-trop exchange, and hypotheses concerning stratospheric influence on atmospheric dynamics. On a more general point, we should be able to explain easily reproducible phenomena in language accessible to the (relatively) lay public. This post and thread have not served this purpose unfortunately, and I will revist the issue again hopefully with a little more clarity (and prior consultation!). -gavin]