Basic Climate Physics #10

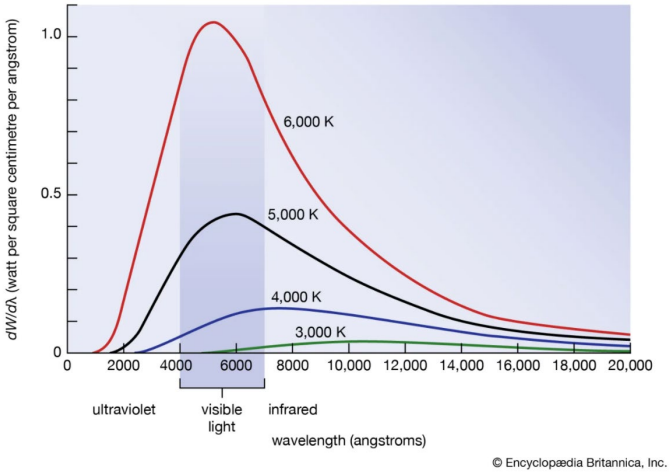
One fact at a time

This short essay is the tenth in a series about basic (meaning all-inclusive) physics that pertains to the subject of climate.

Bear in mind that my purpose is not to engage in details about wind, rain, snow, storms, historical climatology, Milankovitch cycles, or any of the common topics discussed about climate. What I will discuss is some simple physics.

The Absence of Stefan-Boltzmann

The Stefan-Boltzmann radiation law says that the radiation emitted out through a small hole in a cavity, summed up over the entire spectrum, is equal to $\sigma T^4 = 5.67\times10^{-8}\ \frac{\mathrm{W}}{\mathrm{m^2K^4}}\bullet T^4$, where T is the Kelvin temperature. The equation has been around since 1884, and put on a solid theoretical foundation by Max Planck in 1900. Curiously, it also applies to solids as diverse as stars, hot pokers, the surface of the earth, including the oceans and the background radiation of the universe. It is the principle upon which non-contact thermometers work.



One would therefore expect to see reference to the Stefan-Boltzmann radiation law, and the Planck curve in every IPCC report. A search of IPCC *Assessment Reports* reveals that not a single one had the words *Stefan* or *Boltzmann* until *AR6*, (published in **Do Not Cite, Quote or Distribute** form) in 2021. The number 5.67 appears nowhere except for some table entries that have nothing to do with the Stefan-Boltzmann constant. The name *Planck* occurs only in reference to the Max-Planck Institute in the first four *Assessment Reports*. In *AR5* (2014), we are introduced to the jargon *Planck Response* (to be discussed) but nowhere—repeat **NOWHERE**—is there any mention that the Stefan-Boltzmann law always applies to the surface. Nor, more importantly, is the law actually applied to the model-predicted surface temperatures.

The Planck Response (a.k.a. Planck Feedback)

Look up *Planck Response* on the internet and you find this line repeated *ad nauseum*: "The Planck feedback is the most basic and universal climate feedback, and is present in every climate model. It is simply an expression of the fact that a warm planet radiates more to space than a cold planet." In Lesson #3, we proved that statement false with two examples. (1) The earth with the same albedo but with either the presence or absence of the greenhouse effect (*i.e.,* warmer of colder) emits exactly the same IR to outer space. (2) Venus, with lead-melting surface temperature emits less IR to space than does the earth.

The Planck Response, however, does have some validity. Imagine that somebody sprinkles the right kind of Pixie Dust all over the earth so that the surface warms up. It will radiate more IR and set up an imbalance so that the heat emitted to space (ca. 60% of the surface radiation) will exceed the absorbed solar heat ($I_{\mathrm{out}} > I_{\mathrm{in}}$). The imbalance will continue (and diminish) until the earth cools down to the condition before the Pixie

dust was applied. This is indeed a negative feedback mechanism that tends to hold the surface temperature constant, but it most assuredly does not determine what that temperature is. In particular, it is of no use in calculating the *Equilibrium* Climate Sensitivity (*ECS*, the temperature rise due to CO_2 doubling when $I_{out} = I_{in}$).

More Greenhouse Effect!

If the greenhouse effect increases, such as by increasing atmospheric CO_2 or H_2O, then the IR emission to outer space is decreased. That imbalance ($I_{out} < I_{in}$) warms the surface until the equality between incoming solar heat and outgoing heat radiation is re-established. (Climate modelers take note: **During this time, the warming planet radiates less IR to space than when it was cooler.**) In this realistic case, the increase in the greenhouse effect occurs before the temperature increase, unlike the Pixie-Dust scenario. It is important to remember that the sole source of heat to the earth is sunlight.

Importantly, when the Planetary Heat Balance is restored—that is, when $I_{out} = I_{in} = (I_{sun}/4)(1-\alpha)$—*the additional greenhouse effect ("radiative forcing") must equal the additional surface radiation* unless there is a change in either I_{sun} or albedo α. Recall the Climate Constraint Equation from Lesson #4:

$$G = \sigma T_{surf}^4 - \frac{I_{sun}}{4}(1-\alpha)$$

If the greenhouse effect G increases by (say) 2 W/m^2 and sunlight and albedo remain constant, then the surface radiation σT_{surf}^4 must increase by the same 2 W/m^2, and that fact tells us exactly what the temperature rise would be: 0.36ºC for this numerical example.

Asking the Wrong Question

Suppose we have a warehouse containing all kinds of stuff, and that the warehouse is perfectly insulated. Let us ask how much the temperature of the warehouse would rise if we added a certain amount of heat to it. We could calculate the temperature rise if we knew the masses and heat capacities of everything within the warehouse.

Now ask what the temperature rise of the earth would be if we added a certain heat flux in so-many watts per square meter all over the planet. The heat flux (I_{add}) would have entirely different effects on a square meter of ocean, a square meter of desert, a square meter of a puddle, a square meter of rock or a square meter of grass. Presumably with an encyclopedic knowledge of the materials on every square meter of the surface of our planet, we could use a supercomputer to figure it out, but it is fundamentally a fool's errand.

Solution: Ask an Answerable Question

Turn that unanswerable question around and ask: "If the temperature rises by some amount (ΔT), how much more heat flux (ΔI) does it radiate? The Stefan-Boltzmann law provides the unambiguous answer, and does so with a slide rule instead of a supercomputer. (N.B.: If you include emissivities, the numbers change a little, but not enough to balance the Climate Constraint Equation in Lesson 4.)

IPCC's goal (aside from frightening the public) is to determine the *ECS*, the Equilibrium Climate Sensitivity, which is the surface temperature rise (ΔT_{surf}) due to a doubling of CO_2 concentration. They are free to speculate, of course, but they are intellectually obligated to see whether their *ECS* makes sense. All they have to do is to apply the Stefan-Boltzmann law to their predicted temperature rise.

If they do so, they will find out that 16.4 W/m^2 (for a 3ºC) rise in radiative flux is violently in contradiction to the 3.71 W/m^2 of "radiative forcing" that their models say causes that 3ºC temperature rise. They are free to come up with an explanation, but they first have to apply the Stefan-Boltzmann law to their *ECS*. Maybe in a few more decades, IPCC will make this discovery.

Howard "Cork" Hayden, Prof. Emeritus of Physics, UConn, corkhayden@comcast.net