Correspondence to corkhayden@comcast.net

Vol. 2.1 (2022)
pp. 34-37

Some Climate Simplicities

Howard "Cork" Hayden

Prof. Emeritus of Physics, University of Connecticut, USA

Submitted 02-01-2022, Accepted 14-02-2022. https://doi.org/10.53234/scc202203/11

Question: If I add heat to something, how much does the temperature rise? Answer: It depends.

If you add heat to ice water, you melt ice, but the temperature remains constant until all the ice is gone. The same amount of heat that would raise the temperature of a kilogram of water by 1ºC would, if delivered rapidly, easily be enough to set a tree leaf on fire. If heat were added to a rocky surface, the surface temperature would depend on how much heat would be re-radiated and how much heat would be conducted through the rock to the cooler ground beneath it. Heat added to a square meter of a puddle would have an entirely different effect than the same amount of heat added to a square meter of ocean water.

Therein lies the problem with climate models that attempt to estimate temperature rise due to increases in CO_2 and H_2O, or more specifically to increases in heat retention due to those greenhouse gases. You can get anything you want.

There are, however, some unambiguous simplifications that arise from simply asking answerable questions.

Question 1: How much IR does the earth radiate to outer space?

There is an equation known as the Planetary Heat Balance equation which asserts that the heat absorbed from the sun equals the heat radiated to outer space: $I_{in} = I_{out}$, both variables representing average fluxes over the surface of the planet. There can be imbalances, due to orbital eccentricity or changing conditions, of course. For the earth at present, there is a net imbalance: $I_{in} - I_{out} = 0.6\text{-}0.7\ \text{W/m}^2$ (Figure 2.11 from IPCC's *Fifth Assessment Report*) amounting to less than 0.3 % of I_{in}. At equilibrium—defined as equality of the two quantities—$I_{in} = I_{out}$. This simplicity becomes, with α representing the albedo,

$$I_{out} = \frac{I_{sun}}{4}\left(1-\alpha\right) \tag{1}$$

This simple equation tells us that at equilibrium I_{out} is calculable from exactly two variables: the solar intensity at orbit and the planetary albedo. To calculate I_{out} specifically does not require knowledge of the amounts of greenhouse gases, polar vortices, winds, the lapse rate, or any other phenomena normally associated with weather and/or climate. For the earth I_{out} = 239 W/m^2.

Another conclusion that can be drawn from Equation (1) is that if infrared radiation to outer space (I_{out}) changes, it can happen only if the solar flux I_{sun} changes, the albedo changes, or both. If, for example, a climate model says that I_{out} increases, but does not acknowledge (and explain) how the solar flux and/or the albedo changes, the model is faulty.

Question 2: How much IR is emitted from the surface?

The Stefan-Boltzmann law tells us how much IR the surface emits. Assuming an emissivity of 1.0, climate scientists are in agreement that approximately 398 W/m^2 (averaged over the surface[1]) is emitted from the surface, whose average temperature is ca. 289 K. The numbers vary slightly, depending on the source of the data, but those minor differences are not of importance in this discussion; nor would a few percent decrease in assumed emissivity have an appreciable effect on the results.

The 159 W/m^2 difference between the surface emission (398 W/m^2) and the emission to space (239 W/m^2) is—*finally*, in IPCC's *Sixth Assessment Report*—assigned a name and a variable: the greenhouse effect *G*. Thus

$$I_{out} = \sigma T_{surf}^4 - G \tag{2}$$

The processes by which the atmosphere causes the reduction in IR are many and complicated. If IR is absorbed by a GHG, the molecule can radiate IR or it can shed the excess energy by collisions with atmospheric molecules. Molecular collisions can cause excitation in GHGs that can radiate IR in random directions. The absorption cross-sections and emission rates are dependent on both temperature and pressure. Reflection of IR from the bottoms of clouds can send IR back to the surface. Refraction of IR through water droplets can change the direction, and multiple events can send IR back to the surface. Winds can move the absorbed energy around. It takes real expertise to keep track of all the complications.

Despite all the complications, there remains the fact that the *net* effect of the atmosphere is the greenhouse effect *G*. Presently the net effect of the atmosphere is to reduce the surface radiation by 159 W/m^2.

A = B and A = C ⇒ B = C

Equations (1) and (2) can be combined simply, with the result

$$\sigma T_{surf}^4 - G = \frac{I_{sun}}{4}(1-\alpha) \tag{3}$$

Equation (3) is the summary of the two simplicities. It is not a predictor of future climate, but rather a general constraint that applies to all planets and moons that have a surface. Without atmosphere, G is zero. Alternatively, it may be regarded as an acid test

[1] 395,6 W/m^2

for climate models. Whatever future temperature the model predicts, Equation (3) must be balanced.

Question 3: If the surface warms up, how much more IR does it radiate?

We began this discussion by asking how much the temperature would change if we added some fixed amount of heat, and immediately ran into complications. However, if we turn the question around and ask how much more would the surface of the earth radiate if the temperature changed by (say) 1 ºC, the answer is simple and unambiguous.

Let us find the first differential of Equation (3):

$$4\sigma T_{\text{surf}}^{3} dT - \left(dG_{\text{CO2}} + dG_{\text{other}}\right) = \frac{dI_{\text{sun}}}{4} - \frac{I_{\text{sun}}}{4} d\alpha \qquad (4)$$

This equation relates changes in temperature to changes in the greenhouse effect (due to changing amounts of CO_2 or of other gases), changes in the solar flux and changes in the albedo.

Application to models

From the beginning, the IPCC has used the term *radiative forcing*, expressed as ΔF, to represent any changes in the greenhouse effect from any cause. The Δ indicates that there is a difference in net radiative blocking; however, the historical use of F is at odds with the use of G to represent the same thing. The radiative forcing should be expressed in the modern symbology as dG or ΔG. In any case, the amount of greenhouse effect attributable to 400 ppmv (G_{CO2}) of CO_2 is about 30 W/m^2 (van Wijngaarden and Happer, "Dependence of Earth's Thermal Radiation on Five Most Abundant Greenhouse Gases," arXiv:2006.03098v1 4 June 2020) and the increase due to doubling to 800 ppmv would be 3.7 W/m^2.

The IPCC's 2021 *Sixth Assessment Report* asserts that the most probable temperature rises due to doubling CO_2 concentration is 3 ºC, with any rise outside the range of 2 ºC to 5 ºC to be very improbable. We will only consider their most probable value, and we will assume their radiative forcing (dG_{CO2}) due to CO_2 doubling to be 3.7 W/m^2.

Using the Stefan-Bolzmann constant

$$5.6704 \cdot 10^{-8}\, Js^{-1}\, m^{-2}\, K^{-4}$$

the left hand side of Equation (4) becomes

$$4 \cdot 5.6704 \cdot 10^{-8} \cdot 289^{3} \cdot 3 - (3.7\ + dG_{other})$$

With these numbers, and IPCC's assumption of no change in solar intensity, Equation (4) becomes

$$16.5 - 3.7 - dG_{\text{other}} = -\frac{I_{\text{sun}}}{4} d\alpha \qquad \left(\frac{\text{W}}{\text{m}^2}\right) \tag{5}$$

If the IPCC's model is to be believed, then IPCC must account for 12.8 W/m^2 by an increase in dG_{other} or a decrease in albedo or both. They present no evidence whatsoever that they have done it.

It is also very interesting to observe the large negative Stefan-Bolzmann feedback effect, an increase of 3 degrees in surface temperature results in a 16.5 W/m^2 increase in emitted radiation, a value more than 4 times the effect of doubling CO_2. This means the Stefan-Bolzmann radiation is an important surface temperature regulator.

Reference

van Wijngaarden A and Happer W, Dependence of Earth's Thermal Radiation on Five Most Abundant Greenhouse Gases. ***https://arxiv.org/abs/2006.03098***, 4 June 2020