Basic Climate Physics #4

One fact at a time

This short essay is the third in a short 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.

Review of first three lessons

Lesson 1: All planets radiate the same amount of heat that they get from the sun.

Planetary Heat Balance

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

This equation applies to any planet going around any star (sun), so long as the only heat source is the star. The albedo (reflectivity) is represented by α.

Lesson 2: The greenhouse effect is the difference between the surface radiation and the radiation to space.

$$G = I_{\text{surf}} - I_{\text{out}} \tag{2}$$

This equation applies to any planet that has a surface and any atmosphere of any kind whatsoever (including none).

Lesson 3: The surface radiation is given by the Stefan-Boltzmann radiation law.

$$I_{\text{surf}} = \varepsilon\sigma T^4 \tag{3}$$

Here, the emissivity ε is usually taken to be 1.0, although a more correct value is 0.95. We will stick with the IPCC's traditional 1.0 for simplicity. The Stefan-Boltzmann radiation constant is 5.67×10^{-8} W/(m^{2}K^4).

Simple algebra

It is a simple matter to combine Equations 1, 2, and 3 into one. Begin with Equation 2 and insert Equations 3 and 1 in sequence, and assume that the emissivity ε is 1.0:

Lesson 4:

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

Equation 4 is just as all-inclusive as the other equations. It applies to Mercury, Venus, the Earth, and Mars, but not to the gaseous planets (no surface). It applies to most moons in the solar system, but not to a few that are heated by tidal forces owing to the proximity to massive planets.

Equation 4 has no capability of predicting the climate, but it can and does tell us what cannot happen.

At present, IPCC uses the following numbers for our planet: T_{surf} = 289K; I_{sun} = 1366 W/m^2; and α = 0.3. With these numbers, the first term to the right of the equation is 398 W/m^2, and the second is 239 W/m^2, so that G = 159 W/m^2.

Now imagine a future IPCC (in 2322, for example) constructing a heat-flow diagram for the earth, akin to the type found in IPCC's *Fifth Assessment Report* (*AR5,* 2014). (*AR6* 2021remains incomplete as of February 2022.) Figure 1 shows the heat flow diagram from *AR5*, with external markings showing where the present numbers come from and how they would be determined at that future date. In other words, everything is now in accord with Equation 4, and will be at that time and all other times.

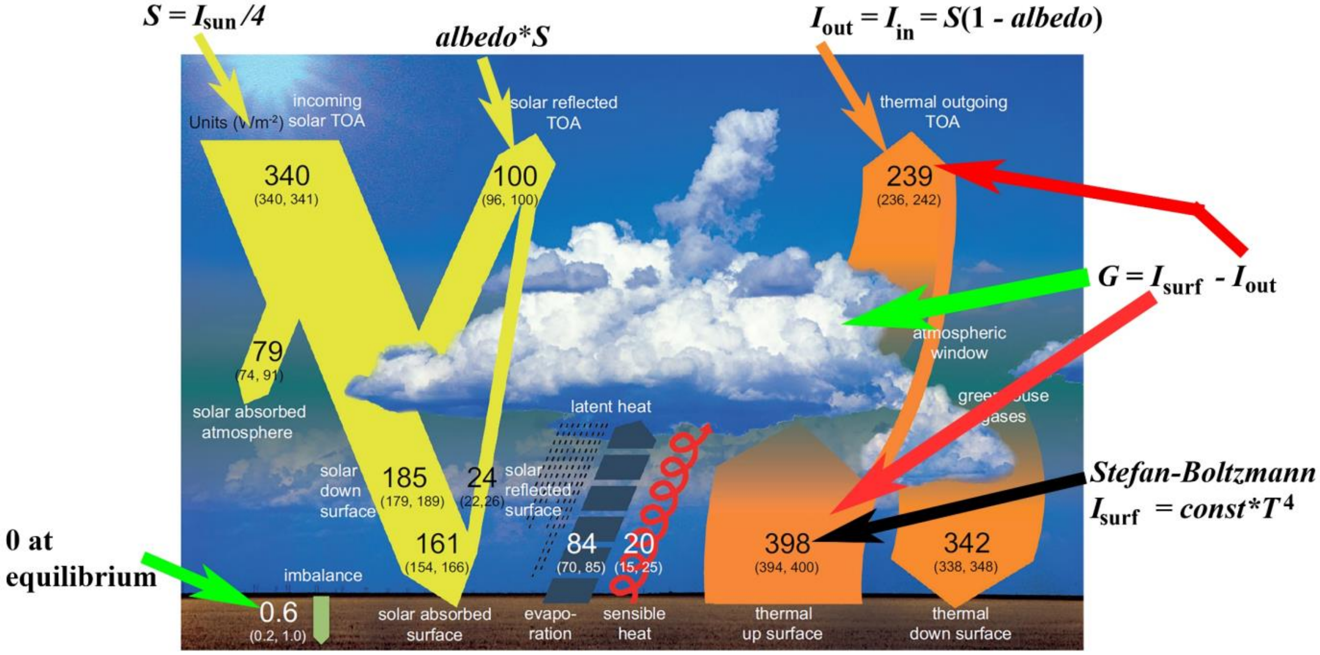

Figure 1: The heat-flow drawing from *AR5*, showing how the drawing comports with Eq. 4.

Now imagine that something changes. The greenhouse effect changes for some reason, the albedo changes for some reason, and/or the solar intensity changes. What does your climate model say the new temperature will be?

If your model gives a different temperature than you get from Equation 4, you'd better revise your model, because your model violates the law of conservation of energy. If your model does not produce values for all four variables— G, T_{surf}, I_{sun} , and α— it is woefully incomplete.

The next Climate Physics lesson will discuss examples.