Basic Climate Physics #1

One fact at a time

This short essay is the first 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.

The first topic pertains to thermal equilibrium, meaning equilibrium with sunlight. At the orbit, sunlight has a certain intensity I_{sun}—often called *solar flux*—measured in (thermal) watts per square meter. Some fraction α (albedo, the reflectivity) of that is reflected, and the remaining fraction (1 – α) is absorbed. Averaged over the $4\pi R^2$ surface area, then, $I_{in} = \frac{I_{sun}}{4}(1-\alpha)$ is absorbed by the planet.

Jupiter seems to have a modicum of nuclear fusion taking place at its core, and some moons of the large planets receive a significant amount of energy from tidal forces, but with those exceptions, all of the planets (and their satellites) are in equilibrium with sunlight. That is, the emit just as much heat radiation as they receive from the sun: $I_{out} = I_{in}$. Of course, the heat radiated from the planet is in the infrared (IR) range, whereas the sunlight is mostly in the visible range. This equality leads to a very important equation that applies to all planets (even around all suns) that are in equilibrium with sunlight:

Planetary Heat Balance

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

There is nothing new or unique about the Planetary Heat Balance equation. What I want readers to see and understand is that **the radiation to space I_{out} depends on exactly two variables, the intensity of sunlight and the albedo**. Of course, I_{out} can change, but only if either sunlight changes or the albedo changes.

Again, we are talking about equilibrium conditions. Disequilibrium can occur. If, for example, I_{in} exceeds I_{out}, then the planet warms up until a new equilibrium is achieved. My motivation is (in future short discussions) to address the *Equilibrium* Climate Sensitivity (ECS), the term used by the IPCC and others for the temperature rise of the surface of the earth due to a doubling of CO_2 concentration.

Some numbers

At 149.6 million kilometers from the sun, our planet is exposed to sunlight at about 1,366 W/m^2 (give or take a little), and our albedo is 0.3, so we absorb and radiate about 239 W/m^2. (Published numbers vary between 239 W/m^2 and 244 W/m^2).

By contrast, the solar flux at Venus, at 108.2 million km from the sun, is a bit over 2,600 W/m^2. The planet reflects 75% of that light, so that the planet absorbs and radiates about 162 W/m^2. Venus, which is very hot at its surface, emits less IR to space than does the earth.

An important Rule of Measurement

Measure the distance from your feet to the moon. Then measure the distance from your head to the moon. Now determine your height by subtraction. You might find out that you are negative 477 meters tall.

The general rule is that whenever possible measure differences directly, rather than obtaining them by subtraction.

In the case of an imbalance between heat absorbed from the sun and IR radiated to outer space, there is no direct way to measure the difference between the two numbers. The small imbalance must be obtained by subtraction of two large numbers, both subject to uncertainties. IPCC finds (in its *Fifth Assessment Report, AR5*) that the earth absorbs more from the sun than it emits. The amount they come up with is 0.6 ± 0.4 W/m^2. The uncertainty is almost as big as the quantity itself. In any case, the imbalance is a very small fraction of the 239 W/m^2 absorbed and emitted.

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