Basic Climate Physics #5

One fact at a time

This short essay is the fifth 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 Energy Constraint on Climate (and models)

In Climate Physics Lesson 4, we summarized the basic physics of absorbed sunlight, surface IR emission, IR emitted to space in one equation with $\sigma = 5.67 \times 10^{-8}$ W/(m^{2}K^4)

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

There are precisely four variables in Eq. 1: the surface temperature T_{surf}, the solar intensity at orbit (often called the Total Solar Irradiance, *TSI*) I_{sun}, the albedo of Earth α, and the greenhouse effect G, which, despite the complicated physics involved, turns out to be the numerical difference between I_{surf} and the radiation to space I_{out}. The equation is sufficiently general that it applies to any planet or moon with any type of atmosphere, orbiting any sun, providing that the planet or moon has its sun as the only energy source, and a surface. In particular, it must apply to Earth however much fossil fuel we burn.

For example, at https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html we find that the solar irradiance at Venus is 2601 W/m^2, and that the planet has an albedo of 76%. The rightmost term in Eq. 1, which represents the absorbed heat from the sun and the amount of IR emitted to space is 156 W/m^2. The surface temperature is 737 K, so the surface emission is 16,729 W/m^2, from which we conclude that the greenhouse effect on Venus is 16,573 W/m^2.

> As an aside, IPCC says, in the *Sixth Assessment Report* (*AR6*, 2021), "a warmer planet radiates more energy to space." Perhaps they never heard of Venus, or that is why they say **Do Not Cite, Quote or Distribute** on every page.

We are concerned, however, with Earth, for which the IPCC gives these numbers: G = 159 W/m^2; T_{surf} = 289 K; I_{sun} = 1366 W/m^2, and α = 0.3.

> (These numbers vary somewhat depending on source—I am inclined to have higher trust in van Wijngaarden and Happer—but the overall conclusions are insensitive to the choice. At least IPCC cannot complain that I have used somebody's unapproved numbers.)

Lousy Nomenclature

Decades ago, climate modelers (& IPCC) adopted the term *radiative forcing*, with the symbology $\boldsymbol{\Delta F}$, to represent any increase or decrease in net IR blockage (stopping, reduction, …) due to changes in greenhouse gas concentrations in the atmosphere. Finally, in the **Do Not Cite, Quote or Distribute** *AR6*, the IPCC has made illusion to the *total* radiative greenhouse effect, and assigned the symbol G, and acknowledged that G is the difference between surface radiation and radiation to space. Clearly, then, the dramatic term *radiative forcing* is nothing more and nothing less than a positive or negative undramatic increment to G. That is, $\boldsymbol{\Delta F} = \Delta G$ or dG.

Equilibrium climate sensitivity (ECS)

The term *equilibrium* in this case refers to the time when everything has settled down, and that happens when the planet emits just as much heat energy to space as it receives from the sun—precisely the conditions under which Equation 1 is derived. The term *equilibrium climate sensitivity* refers to the equilibriium temperature rise to be expected from a doubling of CO_2 concentration. Various climate models are based on guesses about how fast society will be increasing atmospheric concentration, most suggesting that doubling will take about a century.

But what the models have in common is the estimate of the "radiative forcing $\boldsymbol{\Delta F_{2XCO2}}$," due to changing CO_2 concentration, usually calculated from

$$\Delta F = 5.35 \ln(C/C_0) \quad \left(\text{W/m}^2\right). \tag{2}$$

For a CO_2 doubling ($C/C_0 = 2$), the value is 3.7 W/m^2. (This may well be an overestimate, but we will continue to use IPCC values.)

Here is where the lousy nomenclature comes to the fore: the use of *radiative forcing* $\boldsymbol{\Delta F}$ leads the non-technical person to fail to see that the 3.7 W/m^2 "radiative forcing" is a mere 2.3% addition to the greenhouse effect G of 159 W/m^2. Also, according to the IPCC, the surface is 33-34ºC warmer than it would be with the same albedo but no greenhouse effect. In other words, 159 W/m^2 raised the surface temperature by 33-34ºC. With CO_2 doubling, 162.7 W/m^2 is going to do *what?*

Examples

Most probable ECS?

The IPCC finds that the most probable temperature rise due to doubling CO_2 concentration is 3ºC. If we use IPCC's "radiative forcing" for doubled CO_2, and assume that the intensity of sunlight at orbit remains constant, we get

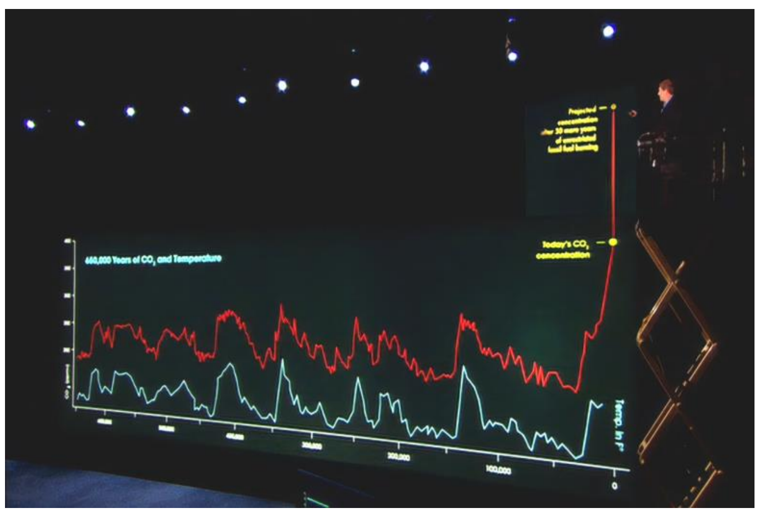
$$G + 3.7 = \sigma\left(T_{\text{surf}} + 3\right)^4 - \frac{I_{\text{sun}}}{4}(1-\alpha) \quad \left(\frac{\text{W}}{\text{m}^2}\right)$$

or

$$G + 3.7 = \sigma T_{\text{surf}}^4 + 16.5 - \frac{I_{\text{sun}}}{4}(1-\alpha) \quad \left(\frac{\text{W}}{\text{m}^2}\right) \tag{3}$$

If IPCC's prediction is correct, then somehow the –12.8 W/m^2 needed to balance Eq. 3 must be accounted for by a decrease in albedo and an increase in greenhouse effect from other gases. If anybody can find the details of how this is accomplished, please let me know. The experts to whom I have posed this conundrum have suddenly gone AWOL.

Glacial-Interglacial Transitions



If there is an iconic picture of the correlation between CO_2 concentration and surface temperature measured in ice cores at the Vostok site in Antarctica, it is surely that of Al Gore on a scissor lift showing how high CO_2 might get on his zero-suppressed graph. In approximate numbers, the temperature difference between the glacial periods and the interglacials is 10ºC, and the CO_2 concentration ranged from 180 ppmv to 280 ppmv.

Equation 2 tells us that the "radiative forcing" (a.k.a. dG) for CO_2 is 2.4 W/m^2. The increase in surface radiation (Eq. 1) is about 55 W/m^2. Suffice it to say that Mr. Gore does not tell us how 2.4 W/m^2 of "radiative forcing" can cause the surface to increase its radiation by 55 W/m^2. For that matter, no climate modeler has provided an explanation either, but it strains the imagination to believe that they would give any credence to Mr. Gore.

Beyond the problem of trying to get the arithmetic to balance, there are the questions of where the CO_2 came from if it caused the temperature to rise and where it went if its decrease caused the temperature to fall. There is, of course, no quarrel with either the temperature rise or the increase in CO_2. It's about causality, and Mr. Gore has it all backwards.

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