Basic Climate Physics #6

One fact at a time

This short essay is the sixth 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.

We begin with a section from Basic Climate Physics #5:

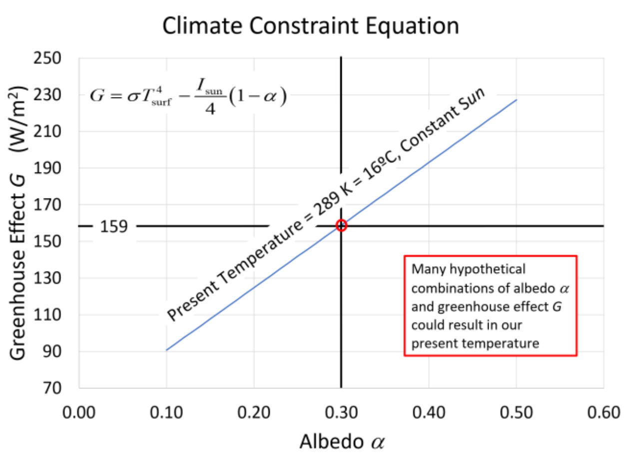
The Energy Constraint on Climate: graphical version

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)

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

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}. Assuming, as IPCC does, that the *TSI* remains constant, Eq. 1 has three variables which can be graphed in various ways.

The figure to the right shows a graphical representation of Equation 1, with the red dot showing the present trilogy of albedo (α = 0.3); greenhouse effect G = 398 W/m^2, and surface temperature T_{surf} = 289 K. Assuming that the sun remains constant, the slanting T = 289 K line represents the possible combinations of α and G that could produce the same surface temperature.



The Differential Form

The greenhouse effect in Eq. 1 is mostly due to H_2O, secondarily due to CO_2 (20%), and in small part to other GHGs. As we are interested in the "changing climate," let us find the differential of Equation 1.

$$dG = 4\sigma T_{\text{surf}}^3 dT_{\text{surf}} - \frac{dI_{\text{sun}}}{4}(1-\alpha) + \frac{I_{\text{sun}}}{4} d\alpha \tag{2}$$

Climate models try to predict future surface temperature increases due to increases in CO_2 concentration. Equation 2 *could* be used to calculate it, providing that the changes in the greenhouse effect, the solar intensity and the albedo were known. This is very unlikely.

Alternatively, if the models predict the surface temperature rise, the equation can—and *should*— be used to check whether the model is correct or incorrect; complete or incomplete. It is common in climate modeling to assume that sunlight remains constant. For simplicity, let us assume (as does the IPCC) that the TSI (I_{sun}) remains constant, and then rewrite Equation 2:

$$dG = 4\sigma T_{\text{surf}}^3 dT_{\text{surf}} + \frac{I_{\text{sun}}}{4} d\alpha \tag{3}$$

We can make a further simplification by using known present values: $\sigma = 5.67 \times 10^{-8}$ W/(m^{2}K^4), T_{surf} =289 K and I_{sun} = 1366 W/m^2:

$$dG = 5.47 dT_{\text{surf}} + 342 d\alpha \quad \left(\frac{\text{W}}{\text{m}^2}\right) \tag{4}$$

Equation 4 has three variables: dG, dT_{surf}, and $d\alpha$, all representing changes from the present. We can now construct a graph of dG (ΔG, ΔF, "radiative forcing") on the vertical axis versus the albedo α on the horizontal axis, for various temperature changes, as shown in Figure 1.

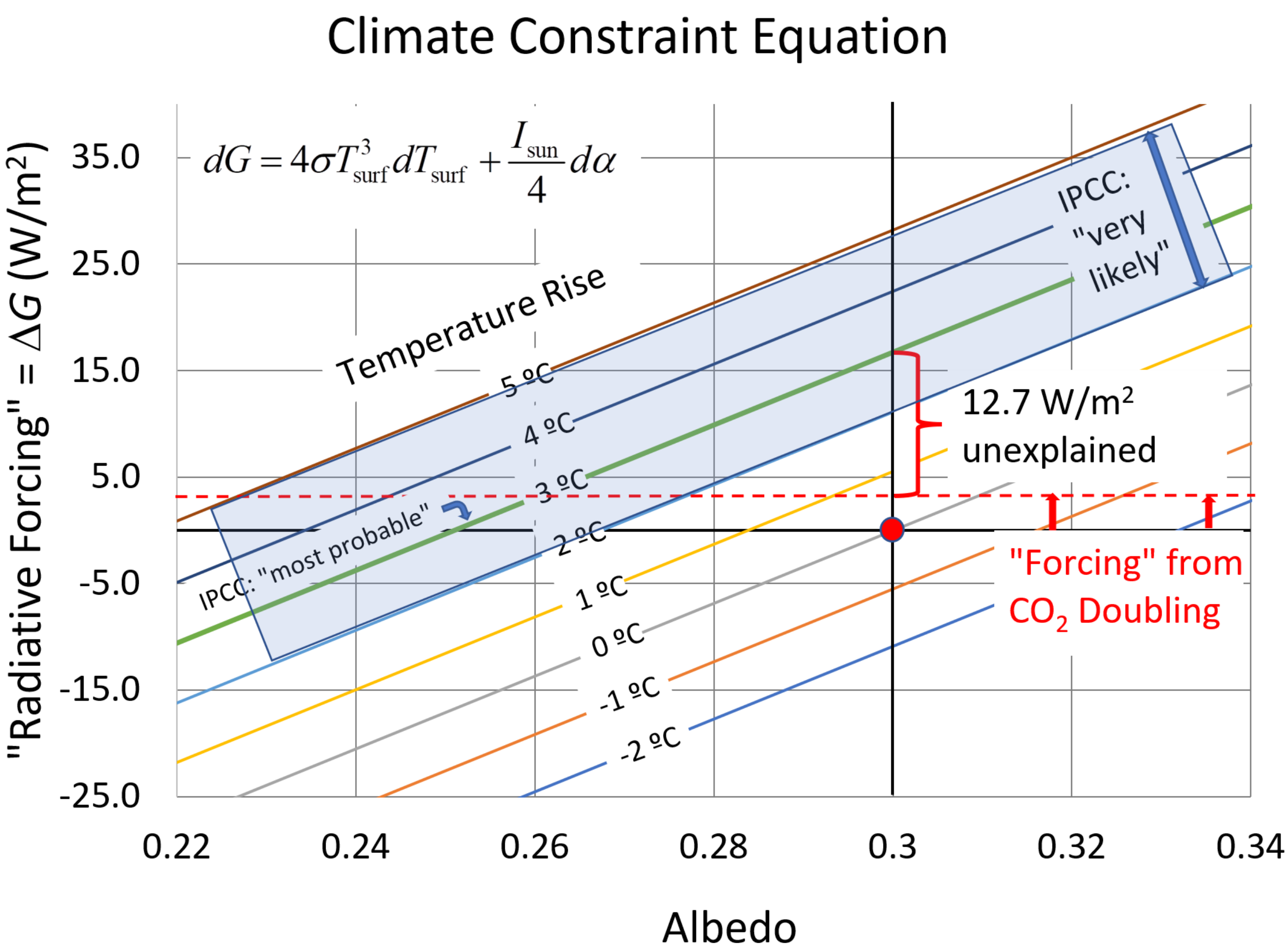


Figure 1: The differential form of the climate constraint equation. The red dot shows the current situation. The dashed red line shows the "radiative forcing" (=3.47 W/m^2, IPCC) due to doubling CO_2 concentration, and the green slanted line shows IPCC's "most probable" temperature rise of 3ºC. IPCC says that the rise due to doubling is "very likely" to be between 2ºC and 5ºC. A temperature rise dT_{surf} of 3ºC will increase surface radiation by 16.5 W/m^2. IPCC has no explanation and no description of how 3.47 W/m^2 can cause 16.5 W/m^2 of increased surface radiation.

In Figure 1, the dashed red line represents IPCC's "radiative forcing" due to CO_2 doubling. The slanted green line represents all possible combinations of albedo and "radiative forcing" that can result in a 3ºC temperature rise (IPCC's "most probable" temperature increase due to CO_2 doubling). The slanted gray area represents IPCC's "very likely" range of temperature increase due to CO_2 doubling.

By the Stefan-Boltzmann radiation law, the surface radiation must increase as shown as the first term to the right of the equals sign in Equation 4. The results are in the table below.

Temperature increase (ºC)	**Increase in IR from surface (W/m^2)**	**Increase in *G* due to** CO_2 **(W/m^2)**	**Difference unaccounted for (W/m^2)**
2	10.9	3.7	7.2
3	16.4	3.7	12.7
4	21.9	3.7	18.2
5	27.4	3.7	23.7

If Equations 3 and 4 are to be balanced, it is clear that some combination of *increased* greenhouse effect from other GHGs and a *decrease* in albedo might—in principle—balance the equation. Climate models, however, all predict an *increase* in albedo with increased CO_2, and all show a totally inadequate increase in G from other GHGs to account for the increased surface emission. We will discuss that matter in the next Climate Physics lesson. We will uses IPCC's own data in *AR6* to prove that their models *cannot* balance the Climate Constraint Equation, and are therefore wrong.

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