Basic Climate Physics #7

One fact at a time

This short essay is the seventh 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.

Introduction

The Climate Constraint Equation relates the surface temperature to the albedo, the greenhouse effect, and the solar intensity. Accordingly, if the IPCC provides the albedo, the greenhouse effect, the solar intensity, and the surface temperature for at least one of its hundreds of scenarios, we can test to see whether the equation is balanced. As it happens, they seem to have done so, and they will not like the result.

IPCC's Predictions for Future Climate

Broadly speaking, IPCC makes two kinds of scenarios. First, they make models for how much CO_2 will be released as time progresses, thereby laying out the prediction of how much CO_2 will be in the atmosphere at any given date. Second, they make various assumptions about how that amount of CO_2 will affect things like evaporation rates, glacial melt, permafrost melt, and so forth.

They identify their models by the Shared Socio-economic Pathway (SSP) with two identifiers (SSP*x*-*y*): *x* for the chosen pathway, and *y* for the approximate level of "radiative forcing" (in W/m^2) expected in the year 2100 (compared to "pre-industrial values, ca. 1750). We will examine SSP3-7.0 (see Fig. **Error! Reference source not found.**) simply because it is one where CO_2 doubling takes place by 2100. We need data for temperature rise, albedo, and CO_2 concentration for some given time. The model SSP5-8.5, for example, has CO_2 doubling take place by 2050, but has the expected temperature rise in 2100, so it cannot be used.

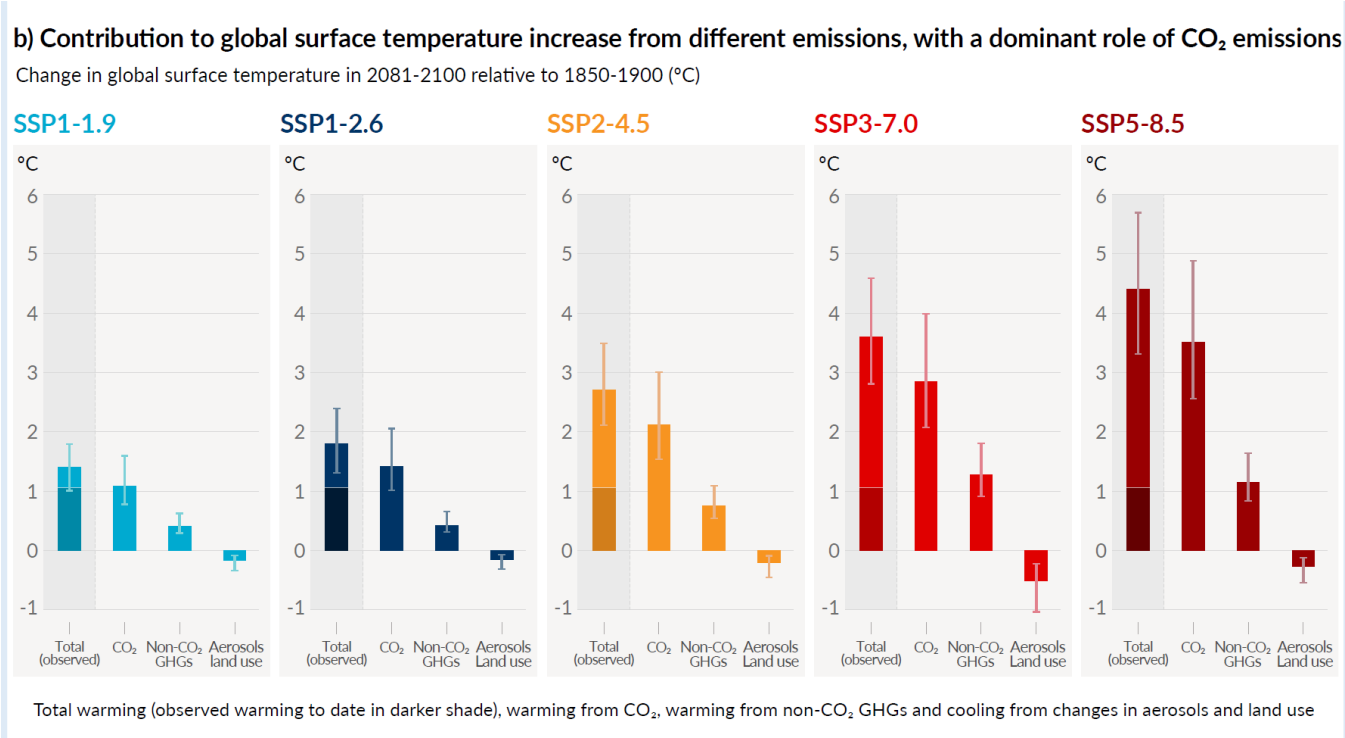
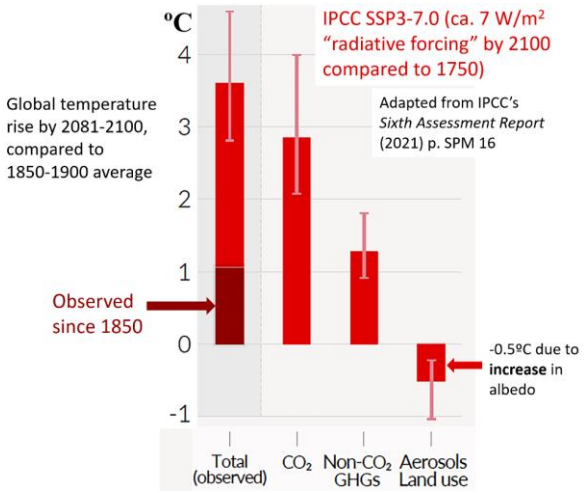


Figure 1: Five scenarios from the *Summary for Policy Makers* in the *Sixth Assessment Report* (*AR6*) in 2021.

Figure 1 shows measured temperature rises since 1850 (up to 2015) as the dark bars at the lower left in each case, and the temperature rises expected in each scenario by the year 2100 at Total (left bar), the amounts due to CO_2, other GHGs, and that due to changing albedo (via aerosols and land use) respectively. In all cases, of course, the temperature rise since 1850 is close to 1ºC. In all cases, an eyeball estimate shows that IPCC holds CO_2 responsible for close to 80% of the temperature rise, so our choice of the SSP3-7.0 case is not cherry-picking. The differences in the scenarios are primarily due to the choice of how fast society puts CO_2 into the atmosphere.



An annotated version of the SSP3-7.0 scenario is shown at the right. It shows a 3.6º temperature rise from 1850 until the last two decades of the present century, with 2.8ºC ascribed to CO_2, 1.25ºC ascribed to other GHGs, and –0.5ºC ascribed to an increase in albedo. That is the projected temperature rise due to GHGs is 4.1ºC, and that due to aerosols (reflecting more sunlight to space, hence to albedo) is –0.5ºC.

Given the assumption that the temperature in 1850 was 288 K, and the end-of-century temperature would be 291.6 K, the increase in surface IR should be 19.9 W/m^2. (Note that IPCC includes the change in reflected incoming sunlight with changes in net absorption of outgoing IR by GHGs in the dramatic term "radiative forcing.")

In 1850, the atmospheric CO_2 concentration was 285 ppmv. *AR6* asserts that the "radiative forcing" due to CO_2 from 1750 to 2019 is 2.72 [1.96 to 3.48] W/m^2, as says that the "effective radiative forcing" due to doubling is 3.93 W/m^2 (an increase from their previous estimate of 3.71 W/m^2.

Let us put these numbers together. IPCC says that the *total human-caused* "radiative forcing" from CO_2 from 1750 to 2000 (in SSP3-7.0) is 2.72 + 3.93 = 6.65 W/m^2. If we further recognize that CO_2 accounts for 80% of the greenhouse effect, the total human-caused GH effect is 6.65/0.8 = 8.3 W/m^2.

IPCC Data Meet the Constraint Equation

To review: at equilibrium, the heat radiated to space equals the heat absorbed from the sun: $I_{\text{out}} = \left(\frac{I_{\text{sun}}}{4}\right)(1-\alpha)$, where α is the albedo. Also, the IR flux to outer space equals the surface radiation minus the net absorption by the atmosphere (the greenhouse effect) G: $I_{\text{out}} = I_{\text{surf}} - G$. Let us equate these two values of I_{out}, and the find the differential, assuming a constant sun:

$$I_{\text{surf}} - G = \left(\frac{I_{\text{sun}}}{4}\right)(1-\alpha)$$
$$dI_{\text{surf}} - dG_{\text{CO2}} - dG_{\text{other}} = -\left(\frac{I_{\text{sun}}}{4}\right)d\alpha \qquad (1)$$

As we saw above for SSP3-7.0 the increase in surface radiation (dI_{surf}, 1750-2100) due to GHGs should be 22.7 W/m^2, and the "radiative forcing" (increment dG to the greenhouse effect G) for the same period is 8.3 W/m^2.

Let us now use IPCC's numbers in Equation 1:

IPCC says for 2100: $$19.9 - 8.3 - dG_{\text{non-human-caused}} = \left(\frac{I_{\text{sun}}}{4}\right)d\alpha = 0 \quad \frac{\text{W}}{\text{m}^2} \qquad (2)$$

In equation 2, the zero enters because IPCC has included their notion of albedo change in the surface temperature change. Somehow, non-human-caused changes in the greenhouse effect (but not identified by the IPCC) must amount for 11.6 W/m^2 needed to balance Eq. 2. (Note that if we used the temperature rise since 1750 instead of 1850, the increase in surface radiation would be even higher.)

Obviously, IPCC's analysis of climate is woefully incomplete, if not egregiously in error.

The next lesson will address the adiabatic lapse rate—the drop in temperature versus altitude.