A Simple Model of Global Warming

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The heat balance of the biosphere is given by:

\[
\begin{bmatrix}
\text{coefficient for the increase of heat content of the biosphere per degree rise of its temperature}
\end{bmatrix}
\times \begin{bmatrix}
\text{the time rate of increase of the temperature difference (from an initial reference temperature)}
\end{bmatrix}
\]

\[= \begin{bmatrix}
\text{net solar energy received per unit time (a rate)}
\end{bmatrix} +
\begin{bmatrix}
\text{net Earth heat lost to space per unit time (a rate)}
\end{bmatrix}
\]
\[
\frac{Cd(T-T_0)}{dt} = S'(1-A) - Q'(1-F)
\]

\[A = A_0 + a_{\text{cloud}}(T-T_0) - a_{\text{ice}}(T-T_0) + A_{\text{pollution}}(t-t_0)\]

\[A_{\text{pollution}} = A_{P0} + a_P(t-t_0)\]

\[F = F_0 + f_{\text{pollution}}(t-t_0)\]

Let \(T_1 = T-T_0\), \(T_0 = \text{constant}\)

\(t_1 = t-t_0\), \(t_0 = \text{constant}\)

Also constant: \(A_0, a_{\text{cloud}}, a_{\text{ice}}, A_{P0}, a_P, F_0, f_p\)

\(f_p = f_{\text{pollution}}\)

\(S' = \text{insolation at the edge of the atmosphere; a constant}\)

\(Q' = \text{thermal radiation from Earth's surface at temperature } T, \text{ given by the Stefan-Boltzmann law, } Q' = \sigma A_E \cdot T^4\)

Stefan-Boltzmann constant
\[ C = \text{the heat capacity of the biosphere,} \]

\[ \frac{dC}{dt} = \alpha' (1 - \alpha) - \alpha' (1 - F) \]

\[ A = A_0 + (a_{\text{cloud}} - a_{\text{ice}})T_1 + A_{\text{pollution}} \]

\[ A_{\text{pollution}} = A_p + a_p t. \]

\[ F = F_0 + f_p t, \quad f_p = f_{\text{pollution}} \]
As $\sigma$ is very small, $Q'$ will vary very little over the temperature range of interest, so $Q'$ will be treated as a constant.

For an Earth in heat balance:

$$\frac{dC_{\text{t,1}}}{dt} = 0 \quad \Rightarrow \quad S'(1-A) = Q'(1-F)$$

The Earth's Biosphere (EB) is warming because $F$ is increasing with time (primarily) and $A$ is also slightly increasing with time.

$A = \text{albedo}$, the Earth's reflection coefficient of sunlight (back into space) \(0 \leq A \leq 1\)

$F = \text{thermal (infrared) absorptivity of the atmosphere, which prevents some of Earth's escaping heat from being emitted into space, decreasing Earth's cooling rate. The increase in thermal absorptivity is due to the increasing load of greenhouse gases + pollution.}$
Let \[ A_i = A_0 + A_{p0} \]
\[ a_i = a_{\text{cloud}} - a_{\text{ice}} \]
then
\[
\frac{dT_i}{dt} = s' \left[ 1 - A_i - a_i T_i - a_{p} T_i \right] + \nonumber \\
- Q' \left[ 1 - F_0 - f_{p} T_i \right] 
\]

\( C, S', \) and \( Q' \) are very large numbers, so:
\[
\frac{dT_i}{dt} = \left( \frac{s'}{C} \right) \left[ 1 - A_i - a_i T_i - a_{p} T_i \right] + \nonumber \\
- \left( \frac{Q'}{C} \right) \left[ 1 - F_0 - f_{p} T_i \right] 
\]

Let \( \sigma = s' / C \)
\[ \chi = a' / C \]
then
\[
\frac{dT_i}{dt} = \sigma \left[ 1 - A_i - a_i T_i - a_{p} T_i \right] + \nonumber \\
- \chi \left[ 1 - F_0 - f_{p} T_i \right] 
\]
\[
\frac{dT_i}{dt} = \sigma [1-A_i] - \sigma a_i T_i - \sigma a_p t_i + \\
- \chi [1-F_o] + \chi f_p t_i
\]

\[
\frac{dT_i}{dt} = \left\{ \sigma [1-A_o] - \chi [1-F_o] \right\} + \\
- \sigma a_i T_i + \\
- [\sigma a_p - \chi f_p] t_i.
\]

Let \[\alpha = \left\{ \sigma [1-A_o] - \chi [1-F_o] \right\}\]
\[\beta = \sigma a_i\]
\[\gamma = \chi f_p - \sigma a_p\]

\[\alpha, \beta, \gamma \text{ are constants}\]
\[
\frac{dT_i}{dt} = \alpha - \beta T_i + \delta t,
\]

\(\alpha\) represents the natural or intrinsic degree of heat balance, without human influences.

\(\beta\) represents the effect of "solar dimming", which is due to the increase of cloud cover, and the decrease of reflective ice cover, as temperature increases.

\(\delta\) represents the effect of heating over time because of the presence of greenhouse gases and pollution particles in the atmosphere.
\[
\frac{dT_i}{dt} + \beta T_i - \alpha = \delta t_i
\]

\[
e^{-\beta t_i} \left[ e^{\beta t_i} \frac{dT_i}{dt} + e^{\beta t_i} \alpha \right] = \alpha + \delta t_i
\]

\[
e^{-\beta t_i} \frac{d}{dt} \left[ e^{\beta t_i} T_i \right] = \alpha + \delta t_i
\]

\[
\frac{d}{dt} \left[ e^{\beta t_i} T_i \right] = \left( \alpha + \delta t_i \right) e^{\beta t_i}
\]

\[\int_{t_i}^{t_i + \delta t_i} \frac{d}{dt} \left[ e^{\beta t_i} T_i \right] dt_i = \int_{t_i}^{t_i + \delta t_i} \left( \alpha + \delta t_i \right) e^{\beta t_i} dt_i\]

\[
\left[ e^{\beta t_i} T_i - e^{\beta t_i - \delta t_i} T_{i_0} \right] = \alpha \int_{t_i}^{t_i + \delta t_i} e^{\beta t_i} dt_i = \delta t_i \frac{\beta}{e^{\beta t_i}}
\]

\[
\left[ e^{\beta t_i} T_i - e^{\beta t_i - \delta t_i} T_{i_0} \right] = \frac{\alpha}{\beta} \int_{t_i}^{t_i + \delta t_i} e^{\beta t_i} dt_i
\]

\[
+ \frac{\delta t_i}{\beta^2} \int_{t_i}^{t_i + \delta t_i} (\beta t_i) e^{\beta t_i} dt_i
\]
\[ [e^{\beta t_1} - e^{\beta t_0}] = \frac{\alpha}{\beta} [e^{\beta t_1} - e^{\beta t_0}] + \frac{1}{\beta^2} \int_{t_0}^{t_1} (\beta t') e^{\beta t'} d(\beta t') \]

use form:

\[ \int u dv = uv - \int v du \]

with \( u = \beta t_1 \), \( du = \beta dt_1 \),
\( v = e^{\beta t_1} \), \( dv = e^{\beta t_1} d(\beta t_1) \)

\[ = \frac{1}{\beta^2} \int_{t_0}^{t_1} (\beta t') e^{\beta t'} d(\beta t') \]

\[ = \left( [\beta t_e^{\beta t_1} - \beta t_0^{\beta t_1}] - \int_{t_0}^{t_1} e^{\beta t'} d(\beta t') \right) \]

\[ = \frac{1}{\beta^2} [\beta t_1 e^{\beta t_1} - \beta t_0 e^{\beta t_0}] - \frac{1}{\beta^2} \left[ e^{\beta t_1} - e^{\beta t_0} \right] \]
\[ e^{\beta t_i} T_i - e^{\beta t_{i0}} T_{i0} = \]

\[ + \frac{\delta}{\beta} \left[ e^{\beta t_i} - e^{\beta t_{i0}} \right] + \]

\[ + \frac{\delta}{\beta^2} \left[ \beta t_i e^{\beta t_i} - \beta t_{i0} e^{\beta t_{i0}} \right] - \frac{\delta}{\beta^2} \left[ e^{\beta t_i} - e^{\beta t_{i0}} \right] \]

The initial time difference, \( t_{i0} = 0 \)

\[ \Rightarrow \quad \text{temperature} \quad t_i = t_{i0} = 0 \]

\[ e^{\beta t_i} T_i = \frac{\delta}{\beta} \left[ e^{\beta t_i} - 1 \right] + \frac{\delta}{\beta} t_i e^{\beta t_i} + \]

\[ - \frac{\delta}{\beta^2} \left[ e^{\beta t_i} - 1 \right] \]

\[ e^{\beta t_i} T_i = \left( \frac{\alpha \beta - \delta}{\beta^2} \right) \left[ e^{\beta t_i} - 1 \right] + \frac{\delta}{\beta} t_i e^{\beta t_i} \]

\[ T_i = \left( \frac{\alpha \beta - \delta}{\beta^2} \right) \left[ 1 - e^{-\beta t_i} \right] + \frac{\delta}{\beta} t_i \]
$\beta$ is positive, and $[1 - e^{-\beta t}]$ is a "solar dimming" factor, gradually "reducing" the Earth's albedo;

if $\frac{\Delta \beta - t}{\beta^2} > 0$, this is a warming effect

if $\frac{\Delta \beta - t}{\beta^2} < 0$, this is a cooling effect

In either case the effects increase over the course of time (at a diminishing rate)

For $(\Delta \beta - t) > 0$, natural processes of albedo reduction dominate pollution-induced albedo increase (by pollution particles scattering sunlight back into space)

For $(\Delta \beta - t) < 0$, the combined effects of natural processes and pollution increase albedo, and thus cooling by "solar dimming"
$$T_i = \left( \frac{2\beta - r}{\beta^2} \right) \left[ 1 - e^{-\beta t_i} \right] + \frac{r}{\beta} t_i \tag{12}$$

$$\frac{dT_i}{dt_i} = \left( \frac{2\beta - r}{\beta^2} \right) \beta e^{-\beta t_i} + \frac{r}{\beta}$$

$$\beta \frac{dT_i}{dt_i} = (2\beta - r) e^{-\beta t_i} + r$$

$$\frac{dT_i}{dt_i} > 0 \text{ for } (2\beta - r) \text{ and } r \text{ both } > 0$$

$$\frac{dT_i}{dt_i} \text{ can be negative, and have a minimum value for } (2\beta - r) \leq 0$$

In that case, \( \frac{dT_i}{dt_i} = 0 \) (at minimum point) for \((2\beta - r)e^{-\beta t_i} = -r\)

\( e^{-\beta t_i} = \frac{-r}{|2\beta - r|} = \frac{1}{|2\beta - r|} \) at minimum point
\[
\frac{1}{e^{\beta t_1}} = \frac{1}{e^{\beta T_1}}, \quad \text{at minimum point}
\]

\[
e^{\beta t_1} = e^{\beta T_1}
\]

\[
\beta t_1 = \ln \left[ \frac{1}{e^{\beta T_1}} \right]
\]

\[
t_1 \quad \text{at minimum point} = \frac{1}{\beta} \ln \left[ \frac{1}{e^{\beta T_1}} \right]
\]

If \((d\beta - \tau) < 0\), then \(T_1\) has a minimum at time \(t_1\), where

\[
t_1 \quad \text{at minimum} = \frac{1}{\beta} \ln \left[ \frac{1}{e^{\beta T_1}} \right]
\]

Recall that both \(t_1\) and \(T_1\) are differences.
\[
\frac{\alpha \beta - \gamma}{\beta^2} > 0
\]

1. Rising temperature difference because of albedo reduction and pollution heating.

2. Variable temperature difference because of albedo increase and pollution heating.
Example #5

See page 10 for the equation $T(t)$.

$C = 5.725 \times 10^{24} \text{ J/K}$

$S' = 1.775 \times 10^{17} \text{ Watts}$

$Q' = 1.9941 \times 10^{17} \text{ Watts (at 15°C)}$

$A_0 = 0.3$

$a_{\text{cloud}} = 5.715 \times 10^{-3} \frac{\text{W}}{\text{m}^2}$

$a_{\text{ice}} = 1.429 \times 10^{-3} \frac{\text{W}}{\text{m}^2}$

$a_i = 4.286 \times 10^{-3} \frac{\text{W}}{\text{m}^2}$

$A_{P0} = 0$

$F_0 = 0.3769$

$a_{P} = 5 \times 10^{-11} \frac{1}{\text{s}}$

$f_P = 5 \times 10^{-11} \frac{1}{\text{s}}$

$\sigma = 3.101 \times 10^{-8} \text{ °C/s}$

$\chi = 3.483 \times 10^{-8} \text{ °C/s}$

$\alpha = 0 \text{ °C/s}$

$\beta = 1.329 \times 10^{-10} \frac{1}{\text{s}}$

$\gamma = 1.910 \times 10^{-19} \text{ °C/s}^2$

$t = \left(31,557,600\right) t_{\text{yr}}$

in seconds \(\longrightarrow\) in years
\[ T_i = -10.8139 \left[ 1 - e^{-\left(1.329 \times 10^{-10} \right) t_i} \right] + \left( \frac{1.437 \times 10^{-9}}{\gamma^{1/3}} \right) r_i \]

above for \( t_i \) in seconds.

\[ T_i = -10.8139 \left[ 1 - e^{-\left(0.004194 \right) t_{yr}} \right] + \left( 0.04535 \right) t_{yr} \]

above for \( t_{yr} \) in years.

Example #5 is a type (2) curve (see page 14) where the minimum \( T_i \) is zero, and it occurs at \( t_i = 0 \).
Global Warming Model, example #5

\[ T = -10.8139(1 - \exp[-0.004194t]) + 0.04535t \]

- \( T \) = temperature rise in °C (y axis)
- \( t \) = time span in years (x axis)
- \( t = 0 \) in year 1910
Global Warming Model, example #5

\[ F = 0.3769 + 0.001578t \]

\[ A = 0.3 + 0.004286T + 0.001578t \]
Global Warming Model, example #5

\[ T = -10.8139(1 - \exp[-0.004194t]) + 0.04535t \]

- **T** = temperature rise in °C (y axis)
- **t** = time span in years (x axis)
- **t** = 0 in year 1910
How much monthly temperatures were above or below normal

Last year was the hottest on the historical record, scientists say. Of the 17 hottest years recorded, 16 have occurred since 2000.

Source: NASA GISS Surface Temperature Analysis
## Comparison to Data for 1910-2020

\[ t_{yr} = \text{time span with respect to 1910 (years)} \]
\[ T_i = \text{temperature rise since 1910 (°C)} \]

<table>
<thead>
<tr>
<th>Year</th>
<th>( t_{yr} ) (years)</th>
<th>previous interval (years)</th>
<th>Temperature rise during last interval (°C)</th>
<th>( T_i ) relative to temperature in 1910, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1960</td>
<td>50</td>
<td>50</td>
<td>+0.25</td>
<td>+0.25</td>
</tr>
<tr>
<td>1985</td>
<td>75</td>
<td>25</td>
<td>+0.25</td>
<td>+0.50</td>
</tr>
<tr>
<td>2005</td>
<td>95</td>
<td>20</td>
<td>+0.25</td>
<td>+0.75</td>
</tr>
<tr>
<td>2020</td>
<td>110</td>
<td>15</td>
<td>+0.25</td>
<td>+1.00</td>
</tr>
</tbody>
</table>

"average"
**Data for the Earth**

Mass = $5.983 \times 10^{24}$ kg

Mean surface density of continents = $2670 \text{ kg/m}^3$

Radius of sphere of same volume = 6,371.22 km

Surface area = $510.1 \times 10^6 \text{ km}^2 = 510.1 \times 10^{12} \text{ m}^2$

"Disc" area = $12752 \times 10^6 \text{ km}^2 = 12752 \times 10^{12} \text{ m}^2$

Land area = $148.847 \times 10^6 \text{ km}^2$

Ocean area = $361.254 \times 10^6 \text{ km}^2$

Deepest point in ocean = 10,430 m = 10.43 km

% of surface, ocean = 70.82 %

% of surface, land = 29.18 %

Total mass of atmosphere = $5.2 \times 10^{18}$ kg
Mean surface temperature = 288.16 °K
Solar constant (edge of atmosphere) = 1392 W/m²
Albedo (50% cloud cover) = 0.3
Cloud albedo = 0.5

Variations of this is the cause of all our problems

Atmosphere heat (infrared) absorptivity = 0.377

Stefan-Boltzmann constant, \(\sigma = 5.6697 \times 10^{-8}\) W/m² °K⁻⁴

Specific heat at constant pressure for dry air
\[ C_{\text{air}} = 1005 \frac{J}{\text{kg} \cdot \text{°K}} \]

Specific heat of liquid water (at 273 °K)
\[ C_{\text{water}} = 4.218 \times 10^3 \frac{J}{\text{kg} \cdot \text{°K}} \]

Specific heat of ice (at 273 °K)
\[ C_{\text{ice}} = 2.106 \times 10^3 \frac{J}{\text{kg} \cdot \text{°K}} \]

Density of seawater = 1025 kg/m³
Density of dry air @ 273 °K = 1.293 kg/m³
Heat capacity of Aluminum
(used as a surrogate for material of "land surface"
since it has same density)

\[ C_{Al} = C_{land} = 901.3 \text{ J/kg} \cdot \text{K} \]

Seconds in 1 averaged year = 31,557,600.

Average depth of the oceans = 3689 m
(12,100 feet)
Heat Balanced Earth

One example

The insolation into the disc area of the Earth is:

\[ S' = 1392 \text{ W/m}^2 \times 127.52 \times 10^{12} \text{ m}^2 \]

\[ S' = 1.7751 \times 10^{17} \text{ Watts} \]

The amount of this insolation absorbed by the surface (biosphere) is

\[ S'(1-A) = 1.2426 \times 10^{17} \text{ Watts} \]

The thermal ("black body") radiation emitted by the surface at 288.16 °K is given by the Stefan-Boltzmann law

\[ Q' = \sigma \text{ Area_{sphere} T_{surface}^4} \]

\[ = \left( 5.670 \times 10^{-8} \text{ W/m}^2 \text{K}^4 \right) \left( 510.1 \times 10^{12} \text{ m}^2 \right) (288.16 \text{ °K})^4 \]

\[ = 1.9941 \times 10^{17} \text{ Watts} \]
The amount of thermal radiation, \( Q' \) that escapes into space is

\[ Q'(1-F) = 1.2423 \times 10^{17} \text{ Watts} \]

This heat loss balances the captured insolation to 3 decimal places (choosing \( F = 0.3769 \) makes it exact).

From space, the thermal radiation that escapes from the Earth is equivalent to the thermal radiation from an Earth-sized "black body" (no atmosphere) at a temperature of 256 K.

The mean surface temperature is:

\[ 288.16 \, ^\circ\text{K} = 15 \, ^\circ\text{C} = 59 \, ^\circ\text{F} \]

The black body temperature seen from space is:

\[ 256 \, ^\circ\text{K} = -17.16 \, ^\circ\text{C} = 1.11 \, ^\circ\text{F} \]
Heat Capacity of Biosphere

I will consider the mass of the Biosphere to consist of:

1. the atmosphere
2. the oceans
3. land to a depth of 10 m.

The atmosphere:

At sea level and "normal" temperatures the density of air is 1.293 kg/m³. Air density decreases with height, and the atmosphere thins down into the void of space by 300 km. Most of the mass of the atmosphere is in its lowest layer (where weather happens), the troposphere. The mass of the atmosphere is estimated (C.R.S. 1967-1968) at $5.2 \times 10^{18}$ kg. If we were to imagine this mass confined to a layer of uniform density at 1.293 kg/m³, that layer would be 7.884 km thick, (4.928 miles).
The oceans:

The oceans cover 70.82% of the surface of the Earth, and have an average depth of 3,689 m. The density of seawater is 1025 kg/m$^3$. From these data, and given a radius of 6,371.22 km for the Earth's mass averaged volumetrically into a sphere, the mass of the oceans can be calculated:

\[ M_{\text{ocean}} = 0.7082 \cdot 4 \cdot \pi \cdot \left( \frac{3.689 \times 10^3 \text{ m}}{(6.371.22 \times 10^3 \text{ m}) \cdot (1025 \text{ kg/m}^3)} \right)^2 \]

\[ M_{\text{ocean}} = 1.366 \times 10^{21} \text{ kg} \]

The land:

The mass of land surface down to 10 m is:

\[ M_{\text{land}} = 0.2918 \cdot 4 \cdot \pi \cdot (6.371.22 \times 10^3 \text{ m})^2 \cdot (10 \text{ m}) \cdot (2670 \text{ kg/m}^3) \]

\[ M_{\text{land}} = 3.974 \times 10^{18} \text{ kg} \]
The total mass of the Earth's Biosphere (EB, as defined here) is

\[ M_{EB} = \left( 1.366 \times 10^{21} + 3.974 \times 10^{18} + 5.2 \times 10^{18} \right) \text{kg} \]

\[ M_{EB} = 1.375 \times 10^{21} \text{ kg} \]

The mass fractions are:

\[ M_{\text{ocean}} = 0.9936 \]
\[ M_{\text{air}} = 0.00382 \]
\[ M_{\text{land}} = 0.00289 \]

(10 m deep)

Heat capacity is the material property of how much heat a given mass (kg will be used) can absorb and store, for a rise in temperature of one degree (in units of Kelvin, or absolute Centigrade degrees).

Specific heat is heat capacity per unit mass. The heat capacity of a given mass is calculated by multiplying its mass (say, in kg) times its specific heat (in J/kg·°C).
Heat capacity of the EB:

\[ C_{\text{ocean}} = \left( \frac{4218 \text{ J}}{\text{kg} \cdot ^\circ \text{K}} \right) \left( 1.366 \times 10^{21} \text{ kg} \right) \]
\[ = 5.762 \times 10^{24} \text{ J/} ^\circ \text{K} \]

\[ C_{\text{air}} = \left( \frac{1005 \text{ J}}{\text{kg} \cdot ^\circ \text{K}} \right) \left( 5.2 \times 10^{18} \text{ kg} \right) \]
\[ = 5.226 \times 10^{21} \text{ J/} ^\circ \text{K} \]

\[ C_{\text{land (10 m)}} = \left( \frac{901.3 \text{ J}}{\text{kg} \cdot ^\circ \text{K}} \right) \left( 3.974 \times 10^{18} \text{ kg} \right) \]
\[ = 3.582 \times 10^{21} \text{ J/} ^\circ \text{K} \]

The heat capacity of the EB is the weighted sum (average):

\[ C_{EB} = C_{\text{ocean}} \frac{m_{\text{ocean}}}{m_{\text{total}}} + C_{\text{air}} \frac{m_{\text{air}}}{m_{\text{total}}} + C_{\text{land (10 m)}} \frac{m_{\text{land (10 m)}}}{m_{\text{total}}} \]

\[ C_{EB} = \left( 5.725 \times 10^{24} \right) + \left( 1.996 \times 10^{19} \right) + \left( 1.035 \times 10^{19} \right) \frac{\text{J}}{^\circ \text{K}} \]

\[ C_{EB} = 5.725 \times 10^{24} \frac{\text{J}}{^\circ \text{K}} \text{; basically all ocean.} \]

The oceans are where the EB stores its accumulated heat.
For every degree (°K, 0° C) rise in the temperature of the biosphere (EB), it has absorbed and stored (mainly in the oceans) an additional $5.725 \times 10^{24}$ Joules of heat energy.

The energy yield of the Hiroshima atomic bomb was 12.5 kilotons equivalent of TNT, and 1 ton of TNT yields $4.2 \times 10^9$ Joules, so the yield of the Hiroshima bomb was $5.25 \times 10^{13}$ Joules.

A 1°K rise in the temperature of the EB is the equivalent of it absorbing the energy yield of: 109 billion Hiroshima bombs.

For that temperature rise to have taken 109 years, it is equivalent to the EB absorbing the energy yields of 1 billion Hiroshima bombs per year. (2.738 million per day)

For a 54.5 year span for the net 1°K rise, the EB absorbed the energy yield equivalents of 2 billion Hiroshima bombs per year. (5.476 million per day)

Global warming is serious!
A heating rate of the EB of \(1.664 \times 10^{15}\) Watts for 54.5 years accumulates the \(5.725 \times 10^{24}\) Joules for 1°K temperature rise. This heating rate is only 2.68% of the insolation that reaches the Earth’s surface (\(1.2426 \times 10^{17}\) W).

A heating rate of the EB of \(3.328 \times 10^{15}\) Watts for 109 years accumulates the \(5.725 \times 10^{24}\) Joules for the 1°K temperature rise. This heating rate is only 1.39% of the insolation that reaches the Earth’s surface (\(1.2926 \times 10^{17}\) W).

So, a 1% to 3% deficit of heat radiated out into space, because of infrared heat capture by greenhouse gases and pollution (which captured heat is ultimately stored in the oceans) can cause the EB to heat up by 1°K (1°C) within a half century to a century.