Temperature Sensitivity of a Basic Climate Model

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Abstract

We use a simple climate model to assess climate sensitivity as temperature response to heat forcing.

How wonderful that we have met with a paradox. Now we have some hope of making progress. (Nils Bohr)

Some aspects of climate have not been observed to change. (IPCC Summary for Policymakers 2007)

1 IPCC Climate Sensitivity and Global Warming

Climate science as presented by IPCC [2] is based on a postulate of basic climate sensitivity or global warming, without feed back, of about 1 degree Celsius C upon doubling of the concentration of CO_2 in the atmosphere corresponding to a 1% perturbation of heat forcing, as a consequence of Stefan-Boltzmann's Black Body Radiation Law. In this note we argue that the postulate is based on a fundamentally incorrect application of Stefan-Boltzmann's Radiation Law. We present a model study showing that basic climate sensitivity (without feed back) can be estimated to instead 0.15 C, in accordance to Fourier's Law. We start with the model and then show in what sense the application of the Radiation Law is incorrect.

The basic physics of global warming is presented by IPCC as follows [2]:

- *The Sun powers Earths climate, radiating energy at very short wavelengths, predominately in the visible or near-visible (e.g., ultraviolet) part of the spectrum. Roughly one-third of the solar energy that reaches the top of Earths atmosphere is reflected directly back to space. The remaining two-thirds is absorbed by the surface and, to a lesser extent, by the atmosphere. To balance the absorbed incoming energy, the Earth must, on average, radiate the same amount of energy back to space. Because the Earth is much colder than the Sun, it radiates at much longer wavelengths, primarily in the infrared part of the spectrum. Much of this thermal radiation emitted by the land and ocean is absorbed by the atmosphere, including clouds, and reradiated back to Earth. This is called the greenhouse effect.*

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- *The glass walls in a greenhouse reduce airflow and increase the temperature of the air inside. Analogously, but through a different physical process, the Earths greenhouse effect warms the surface of the planet. Without the natural greenhouse effect, the average temperature at Earths surface would be below the freezing point of water. Thus, Earths natural greenhouse effect makes life as we know it possible. However, human activities, primarily the burning of fossil fuels and clearing of forests, have greatly intensified the natural greenhouse effect, causing global warming*.

We note that IPCC claims that the "greenhouse effect" of the atmosphere comes from "thermal radiation emitted by the land and ocean absorbed by the atmosphere, including clouds, and reradiated back to Earth".

IPCC suggests that the atmosphere with its socalled GreenHouse Gasses GHG, mainly water vapour and CO2, acts like the window of a conventional greenhouse, "but through a different physical process". IPCC concludes that since a greenhouse gets very hot inside, because the window prevents convective heat transfer, the Earth will warm from a marginal increase of GHG, "through a different physical process".

In this note we consider a model of this "different physical process" and question its capacity of generating global warming of 1 C from doubled CO_2. Similar criticism is exposed in [1].

2 Observational Facts

The Sun shows a black body radiation spectrum at an effective temperature of 5578 Kelvin K heating the Earth by about 280 Watts/m^2, and the Earth with atmosphere (troposphere plus stratosphere), radiates back the same amount from the stratopause (top of the stratosphere) at about 273 K $=$ 0 C, all in accordance to Stefan-Boltzmann's Radiation Law. The mean Earth surface temperature is about 15 C, drops linearly to -50 to -70 C in the tropopause and then increases linearly to the stratopause at 0 C, as shown in Fig. 2. The thickness of the troposphere is about 17 km in middle latitudes and 7 km at the poles in summertime and indistinct in winter.

The heat absorbed by the Earth including atmosphere is transported to the stratopause by a coupled process of convection with evaporation/condensation, conduction and radiation, and is then radiated to outer space.

The vertical heat transport in the troposphere is dominated by convection along with a negative temperature gradient with temperature decreasing with increasng height, which allows also some heat transfer by conduction and radiation. The vertical convection in the stratosphere is small and the temperature gradient is positive, and so a mechanism for direct vertical heat transfer is lacking. Instead the heat mostly accumulated at the Equator and vertically convected under cooling to the top of a thick troposphere, is convected horisontally towards the Poles while warming in a stratosphere on top of a thin Polar troposhere, and then radiates out into space from a stratopause at 0 C.

Both vertical and horisontal convective heat transport thus are essential, which shows that any attempt to explain the surface temperature of the Earth by radiation alone, will be based on grossly incorrect physics and thus cannot give meaningful results. But this is precisely what IPCC does when referring to a "greenhouse effect from thermal radiation emitted by the land and ocean absorbed by the atmosphere, including clouds, and reradiated back to Earth", that is a greenhouse effect without physical basis. It remains to explain how an effect of global warming without physical basis has come to dominate both scientific academies, politics and media, not in the Dark Ages but in our Information Age.

3 Heat Transfer

For the discussion we consider the following model for vertical heat transfer in an atmosphere including effects of convection-conduction-radiation coupled with evaporation-condensation:

$$\begin{aligned} \dot{T} + \beta T' + \alpha T - \epsilon T'' = q \quad \text{for } t > 0,\ 0 < x < 1, \\ -\epsilon T'(0,t) = Q(t), \quad T(1,t) = 0 \quad \text{for } t > 0, \end{aligned} \tag{1}$$

where $x \in [0,1]$ is a vertical coordinate with $[0,0.5]$ representing the troposophere and $[0.5,1]$ the stratosphere, $T(x,t)$ is atmosphere temperature at x at time t, $\alpha(x,t)$ is a coefficient of net outgoing radiation, $\beta(x,t)$ a convection velocity, $\epsilon(x,t)$ a heat conduction coefficient, $Q(t)$ is incoming heat flux from the ocean (originating from insolation), and $q(x,t)$ is an internal heat source from evaporation/condensation-radiation. Further, $\dot{T} = \frac{\partial T}{\partial t}$ and $T' = \frac{\partial T}{\partial x}$. In this one dimensional model we "compress" global climate horisontally, which by the above argument motivates that the convection coefficient β can be assumed to be positive not only in the troposphere $[0,0.5]$, but also in the stratopshere $[0.5,1]$.

4 With Conduction-Radiation Only

The basic stationary case with $\dot{T} = 0$ is $Q(t) = Q$ constant, $\alpha = \beta = 0$, $q = 0$ and ϵ constant, which gives $T(x) = \frac{Q}{\epsilon}(1-x)$, with corresponding temperature sensitivity $T(0) = \frac{Q}{\epsilon}$, as displayed to the right in Fig. 1. This is a case of potentially high temperature sensitivity (if ϵ is small) connected to conduction-only driven by a consistent negative temperature gradient. If we add radiation with say $\alpha = \epsilon$, then then $T(x) = \frac{Q}{\epsilon}\exp(-x)$ with similar high sensitivity. We observe that a consistent negative temperature gradient is not in accordance with observation.

5 With Convection-Evaporation-Condensation

Consider now the stationary case $\beta = 1$, $\alpha = 0$, $q = -1$ for $0 < x < 0.5$ (evaporation) and $q = 1$ for $0.5 < x < 1$ (condensation), ϵ small, which gives $T(x) \approx -x$ for $0 < x < 0.5$ and $T(x) \approx x - 1$ for $0.5 < x < 1$, with corresponding temperature sensitivity $T(0) = 0$, as displayed to the left in Fig. 1. This is a case of small temperature sensitivity connected to convection combined with evaporation/condensation with temperature gradients of varying sign, in accordance with observation.

6 Conclusion

We have in a model case seen that (i) radiative/conductive heat transport can show high temperature sensitivity, but is incompatible with observation, (ii) heat transport by convection-evaporation-condensation can show low temperature sensitivity, and is compatible with observation.

Basic climate sensitivity as global warming from a 1% perturbation of heat forcing, can be estimated to 1% of the temperature drop from 15 C from the Earth surface to the stratopause at 0, by Fourier's Law, that is to 0.15 C, almost a factor 10 smaller than that by IPCC.

We compare with a common greenhouse, which has high temperature sensitivity because convection is prevented by the glass enclosure. It is also relevant to compare to a boiling pot where increasing the forcing results in more vigorous boiling, while the temperature stays the same, resulting in low temperature sensitivity.

7 Climate Sensitivity by Black Body Radition

The climate alarmism of IPPC is summarized in [2] as follows:

- *An albedo decrease of only* 1%*, bringing the Earths albedo from* 30% *to* 29%*, would cause an increase in the black-body radiative equilibrium temperature of about 1 degree Celsius, a highly significant value, roughly equivalent to the direct radiative effect of a doubling of the atmospheric CO2 concentration.*

This result comes out of the Stefan-Boltmann Black Body Radiation Law, which states that

$$Q = cT^4 \tag{2}$$

where Q is heat radiated from a black body at surface temperature T Kelvin, and c is a constant. Differentiation gives

$$dQ = 4cT^3 = 4\frac{Q}{T}\,dT. \tag{3}$$

Using that for the Earth with atmosphere, $Q \approx 273$ Watts/m^2 and $T \approx 273$ K, one obtains

$$dQ = 4dT, \tag{4}$$

which is the scientfic basis of the IPCC prediction of global warming of 1 C upon a radiative forcing of 4 Watts/m^2, about 1% of total forcing of 273 Watts/m^2.

So IPCC alarmism claims that we live in a highly unstable surface climate in which human civilization can get destroyed by a 1% change of albedo, or doubling of CO_2.

But the climate does not seem that unstable, certainly the albedo has changed 1% by human activities without catastrophical effects.

So the relation $dQ = 4dT$ is questionable. What can be wrong? It not Stefan-Boltzmann's Radiation Law per se, which gives the observed temperature of 0 C at the stratopause, but it is not correct to use it as IPCC does to predict changes of the temperature of surface of the Earth. This is because the surface at 15 C interacts with

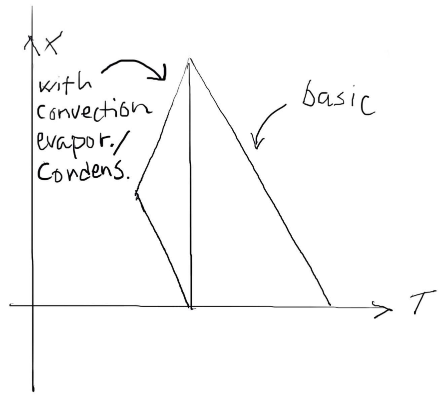

Figure 1: Model temperature distribution in the atmosphere without and with convection and evaporation/condensation.

the stratopause at 0 C by convection-condensation-evaporation and it is the physics of this process which determines the surface temperature, not any Radiation Law. Similarly the inside temperature of a room is determined by the outside temperature and a a process of convection-diffusion through walls and windows, not by and Radiation Law.

No engineer would attempt to compute the inside temperature of a house relying only of Stefan-Boltzmann's Law.

It thus appears that the entire basis of IPCC alarmism rests on a fundamenatlly incorrect application of Stefan-Boltmann's Radiation Law. A new approach to understanding black body radition is presented in [4]. It is possible that the incorrect application of the Radiation Law comes from the fact that its derivation is based on some mysterious statistics of quanta not understood by many. If the derivation of a mathematical result is obscured, it may easily be misinterpreted and applied incorrectly.

8 Is Climate Simulation Possible?

The above model is simple, yet much better than the basis current IPCC predictions. The above model can be seen as a simple version of a full model based on the Navier-Stokes equations for the coupled ocean-atmopshere system which possibly can be used for useful predictions of e.g. climate sensitivity [3].

References

[1] G. Gerlich and R. Tscheuschner, Falsification of the atmospheric greenhouse effect within the frame of physics, International Journal of Modern Physics B, Vol 23, Issue 3(2009) pp. 275-364, http://arxiv.org/abs/0707.1161.

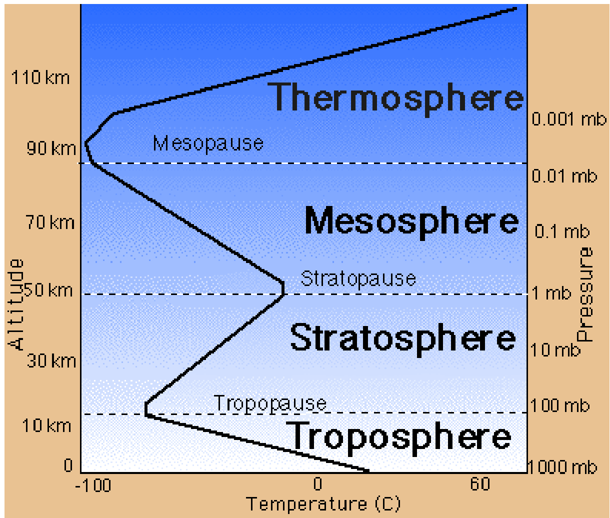

Figure 2: Real temperature distribution in the atmosphere. Notice similarity in troposphere-stratosphere with model.

[2] IPCC AR4 2007, Working Group I: The Physical Science Basis.

[3] J. Hoffman and C. Johnson, *Computational Turbulent Incompressible Flow*, Springer, 2007.

[4] C. Johnson, *Computational Black Body Radiation*, http://www.nada.kth.se/ cgjoh/ambsblack.pdf