A heuristic analysis of global warming leading to a new understanding of climate change

David M. Bower[1]

[1]Independent researcher

Email address: wpd.hbt777@gmail.com

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Abstract

In this paper I present a heuristic approach to understanding the temperature of a planet in orbit around a star. To simplify the discussion, I begin by introducing the concept of the planet's mean temperature. I proceed to discuss the effect of any atmosphere that might be present and also consider the effect of so- called ”greenhouse gases” present in this atmosphere. In contrast to the usual discussion of the importance of the effect of the ”trapping” of electromagnetic radiation by the greenhouse gases, I present the opposing idea that it is the reflection of electromagnetic radiation from the sun that is of overwhelming importance. No concepts more advanced than those of basic thermodynamics as presented in a high school physics class are used. While the conclusions pertain to any planet in a radiation flux from a star, the obvious application is to the so-called global warming experienced by the earth. The conclusions in this brief analysis are not presented as final, but rather open to debate. It is hoped that this analysis will serve as the basis for a detailed understanding of the climate change – if any – that the earth is experiencing. Comments and corrections are welcomed.

1 Introduction

The discussions of global warming on the internet and in textbooks and publications world-wide are too numerous to count. Many – if not the vast majority – of these discussions present complicated energy flow diagrams which attempt to show the flux of radiation from and to various components of the earth-atmosphere system. Also, many of the discussions appeal to the capacity of so-called ”greenhouse gases” – i.e., water, carbon dioxide, etc – to absorb radiation from the sun and/or the earth. At least some of the discussions ignore the release of radiation from these same gases. That is, they ignore the fact that these molecules release previously stored up energy as radiation and therefore cannot act as long- term reservoirs of thermal energy as can, for example, a large rock formation. Some of the discussions include an analysis of the importance of ozone in cooling the earth.

In this paper, I attempt to bypass the logic of these arguments (whether the logic is faulty or incomplete or both) and to bring clarity and simplicity to analysis of global warming / climate change. I ignore the fact that to attribute to certain gases (such as carbon dioxide and water vapor) a ”greenhouse effect” is to misunderstand how glass windows in a greenhouse cause the greenhouse to be warmer than its surrounding environment. (The glass windows raise the temperature inside the greenhouse by preventing convection of warm air from inside of the greenhouse to the outside environment. This mechanism is not operating in the atmosphere in the absence of solids like glass.) Thus, in the remainder of this paper, no mention will be made of any possible ”greenhouse effect”. However, carbon dioxide and water vapor will still be referred to as ”greenhouse gases” for ease of communication.

I employ only basic thermodynamics considerations typical of those presented in an (American) high school physics class. Hence, the lack of references to other papers and articles relevant to this subject.

To simplify the discussion, I will introduce the concept of a planet’s mean temperature. I define this average temperature to be a numerical quantity that represents in some way the totality of the planet’s internal heat energy. I will ignore local and temporal temperature variations due to atmospheric convection, the water cycle, etc. I will also ignore heat generation due to radioactive decay, contraction of the earth, tilt of the earth’s axis, etc. Throughout the discussion, I will consider the incoming solar radiation flux to be constant. If in fact the solar radiation flux increases, this will cause an increase in the mean temperature of the planet and vice versa.

2 Heat

Heat is a form of energy which can be transferred through at least three methods: Conduction, convection and radiation. For the purpose of this short argument, heat transfer by convection will be ignored.

2.1 Heat conduction

Consider a metal strip being heated at one end by a blowtorch. Imagine that the other end is submerged in a water bath maintained at constant cold temperature.

Eventually, a temperature gradient will be established along the strip with the temperature highest at the heated end and lowest at the end submerged in the cold water bath. This temperature gradient is maintained by heat conduction. The temperature gradient is due to the fact that heat flows from hotter regions to colder regions and also to the fact that the rate of heat loss is proportional to the magnitude of the temperature difference between the material and its environment.

2.2 Heat transfer by radiation

Consider a spherical object suspended in space that is being heated by a blowtorch. Imagine that the sphere is rotating so that the heat is distributed uniformly in the radial direction (i.e., the temperature gradient is a function of distance from the sphere center only). As the sphere heats up, heat will leave the sphere through radiation. The hotter the sphere, the faster the heat will radiate away. Eventually the temperature of the outer surface of the sphere will reach a point where the rate of heat loss will equal the rate of heat entering the sphere from the blowtorch.

Now consider two spheres which are identical except for the fact that one has a perfectly absorbing surface and one has a perfectly reflecting surface. Again imagine these spheres to be suspended in space and heated by incoming radiation (and not by a blowtorch as in the example just considered). The sphere covered with the perfectly reflecting surface will not absorb any radiation. Its temperature will be that of space, which we will assume to be absolute zero. (In fact, if it were really perfectly reflecting, we would not be able to see it.) The sphere covered with the perfectly absorbing surface will absorb all incoming radiation and will eventually heat up to an equilibrium temperature at which incoming energy gain from the incoming absorbed radiation will match outgoing energy loss from energy radiation.

Now consider two additional spheres whose surfaces have properties intermediate between perfect absorption and perfect reflection. We can assign values for R and A to the surfaces as shown in below. These four spheres are shown in figure 1. In this figure, R represents the fraction of incoming radiation reflected, while A represents the fraction of radiation absorbed by the surface. The composition of the bodies is irrelevant except for the composition of the sphere's surface.

Sphere A has a perfectly reflecting surface with no ability to absorb radiation. (R = 100%, A = 0%) Sphere D has a perfectly absorbing surface. (R = 0%, A = 100%) Spheres B and C have surfaces which are intermediate between those of spheres A and D. The surfaces of spheres B and C partially reflect and partially absorb radiation. Sphere B has greater reflection and poorer absorption than sphere C. This reality is reflected in the values of R and A shown below these two spheres.

Then I maintain that at after the equilibrium temperature of the spheres has been reached, the following relationship among the temperatures of the spheres will be true:

$$T_D > T_C > T_B > T_A. \qquad (1)$$

That is, the equilibrium temperature of sphere D will be greatest, while the equilibrium temperature of sphere A will be least. The equilibrium temperatures of spheres B and C will be intermediate between the equilibrium temperatures of A and D with $T_C > T_B$.

NOTE: The composition of the sphere below the surface will not affect the equilibrium temperature. The only discernable effect will be on the length of time required to reach thermal equilibrium; the length of time required for thermal equilibrium will be a function of the material's specific heat.

2.3 Application to planets

Planets can be considered to be spheres covered by non- ideal surfaces which act in a manner intermediate between perfectly absorbing and perfectly reflecting surfaces. In planets with atmospheres, the atmosphere will function as a surface with both absorptive and reflective properties. In planets without atmospheres, the land of the planet will function as the corresponding surface.

Each planet type – i.e., those with and without atmospheres – will achieve an equilibrium temperature which ensures that heat gain from incoming radiation equals heat loss from outgoing radiation.

If the radiation flux surrounding the planet remains unchanged, the only way that the planet's temperature can increase is if the surface coating – i.e., the planet´s atmosphere or the planets land– becomes less reflective and more absorbing.

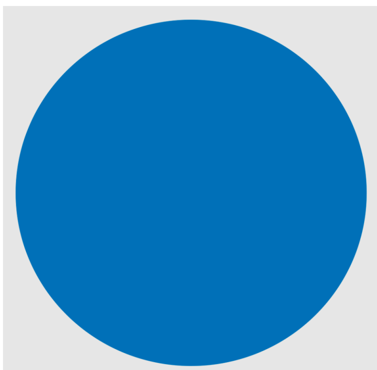
3 Conclusion and Discussion

As has been clearly shown, the equilibrium temperature of a spherical object in a (constant, unchanging) flux of radiation depends only on the magnitude of the reflectivity of its surface coating. The composition of the object below the surface affects only the length of time required to reach temperature equilibrium. Objects whose inner composition has a higher heat capacity will take longer to reach equilibrium temperature than will objects whose inner composition has a lower heat capacity. The ”surface coating” of planets with atmospheres is primarily the atmosphere.

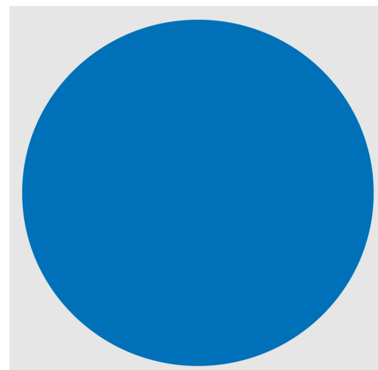
Those who maintain that increasing the content of ”greenhouse gases” in the atmosphere (of planets with atmospheres) results in a temperature increase in the planet (in the absence of increased radiation flux) must provide proof that such an increase in greenhouse gases increases the absorption coefficient of the atmosphere.

The presence in the atmosphere of so- called greenhouse gases (e.g., carbon dioxide, water vapor and methane, etc.) cannot increase the temperature of a planet unless the gases increase the absorption of solar radiation (or conversely, decrease the reflection of solar radiation) when compared to the atmosphere of the planet without the gases. These so- called greenhouse gases can absorb radiation, but they can also reradiate this energy. When they re- radiate the absorbed energy, they radiate the energy isotropically, i.e., in all directions. Therefore, it is difficult to understand how these gases can contribute to a net increase in energy stored in the earth or the earth's atmosphere. It is this fact that makes it also difficult to understand how they can contribute to global warming.

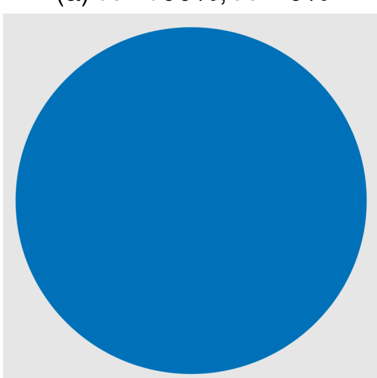
Even if these so- called greenhouse gases contribute substantially to global warming, it seems inevitable that their presence in the earth's atmosphere will certainly decline in the decades ahead as fossil fuel depletion becomes a reality as part of the "peak oil" scenario. Thus fossil fuel depletion seems to be a much more dire threat to the existence of humanity than the threat of uncontrolled global warming.



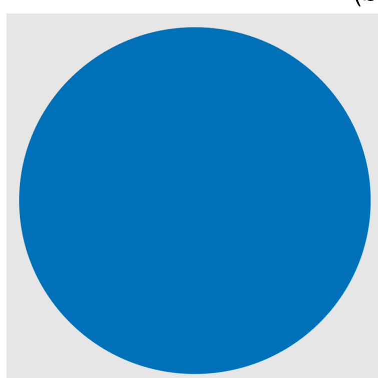
(a) R= 100%, A = 0%



(b) R= 75%, A = 25%



(c) R= 25%, A = 75%



(d) R= 0%, A = 100%

Figure (1) Four spherical objects each having a different surface composition. The internal composition of each sphere below the surface may also differ. The reflection coefficient is represented by the letter R and the absorption coefficient is represented by the letter A.