Planetary temperatures

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Abstract

This is a refutation of the greenhouse effect based on a quote from Planck´s book “the theory of heat radiation”. Then follows a simple alternative energy balance based on an equation from Planck´s book, which correctly produces the surface temperature of Earth. Lastly, I present a surprising result involving solar irradiation and gravity, somewhat based on Einsteins $\frac{L}{c^2} = m$ and the same equation as I use for the energy balance. The relationship shown between luminosity and gravity may be just an illusion.

Planck and the greenhouse effect

Let´s see what Planck has to say about emission from bodies. In the link you´ll find this quote on page 8.

> **7.** The coefficient of emission ϵ depends, not only on the frequency ν, but also on the condition of the emitting substance contained in the volume-element $d\tau$, and, generally speaking, in a very complicated way, according to the physical and chemical processes which take place in the elements of time and volume in question. But the empirical law that the emission of any volume-element depends entirely on what takes place inside of this element holds true in all cases (*Prevost's* principle).

He refers to Prevost´s principle.

Prevost´s principle:

Prevost showed that the emission from a body is logically determined solely by its own internal state.

When talking about the surface temperature of Earth we´re also talking about the emission from the surface. Planck and Prevost states clearly that, without exceptions, the emission depends entirely on the *internal* state of the emitting body. The atmosphere isn´t part of the internal state of the Earth surface, is it? It´s per definition the external state, and that means that surface emission/temperature can´t depend on the atmosphere. Yet, Sabine Hossenfelder claims in this video the exact opposite, that emission by the atmosphere at high altitude and low temperature, way outside the emitting volume element, determines the emission intensity from the volume element which is below the Earth surface. This is a common explanation by climate scientists, but it has no basis in physics. Both climate scientists and Planck can´t be right, so who is right? Do we have any reason to think that our planet is an exception? No, Planck says that this principle *always* holds. There can´t be an exception for our planet.

Planck is very clear when he´s saying that the emission from any volume element depends entirely on what takes place inside it. The emitting volume element in this case is the entire solid surface of the solid volume, or just a piece of the surface and the slice under it that goes all the way to the core. The atmosphere is not included in the internal state which determines surface temperature. There´s no room for the claim that the emission from the surface depends on the atmosphere, because it´s not inside the emitting volume element. The idea that the surface must compensate for the cold atmosphere doesn´t make sense. Our own bodies doesn´t compensate for cold air surrounding us by heating up, we instead cool down. I don´t know of any examples where a heat source with constant power supply heats up to compensate for dropping temperature in its surroundings. It doesn´t exist.

What Planck and Prevost says about emission, that it only depends on the internal state, almost sounds like nothing can affect emission from a body, but we know that´s not the case.

If we raise the question of how anything could affect the surface emission it has to be something that can change the internal state. There´s a law for this, the first law of thermodynamics, $\Delta U=Q-W$. Where ΔU is the internal energy which in this case is equal to the internal state, and the right side, Q-W, is the heat and the work being done on the surroundings. This means that an increase in the internal energy can only be caused by heat or by work. So, if the quantity of heat, Q, is added to a system which performs work W on its surroundings, the internal energy change will be Q-W because heat converted to work will be "lost" to the surroundings. In the case of both external heat and work being added, when the surroundings perform work on the system, you get a change in internal energy which is Q+W. An example of work that could increase the internal energy and raise temperature of a system would be external pressure.

When the first law is mentioned in this context it´s often a mumbling of "conservation of energy". Which is true, but the simple equation above gives the first law a very different meaning in my opinion. It has it´s origin in the physics of heat engines, and Earth is a heat engine. When looking at the equation it becomes clear that only heat and work can raise temperature and then the definition of heat and work becomes very important. Can the atmosphere fulfill the definition for heat or work in the context of warming the Earth surface? Let´s see.

The definition of heat according to Britannica:

"heat, energy that is transferred from one body to another as the result of a difference in temperature. If two bodies at different temperatures are brought together, energy is transferred—i.e., heat flows—from the hotter body to the colder."

Heat | Definition & Facts | Britannica

The definition of work according to Britannica:

"work, in physics, measure of energy transfer that occurs when an object is moved over a distance by an external force at least part of which is applied in the direction of the displacement."

Work | Definition, Formula, & Units | Britannica

Both definitions are clear cut with no room for doubt.

So, does the atmosphere fulfill the definition of either of those two definitions? The atmosphere is always much colder than the surface, and, by definition heat is only transferred from high to low temperature, so no heat can be transferred from the atmosphere to the surface. When it comes to thermodynamic work, the greenhouse hypothesis doesn´t say that the atmosphere does work on the surface to add energy. If the greenhouse hypothesis did claim that the atmosphere did work by pressure you´d have energy creation by gravity, because surface pressure is a consequence of gravity. This means that the greenhouse hypothesis is a dead end, it provides neither heat or work. A greenhouse effect must therefore be impossible.

But he surface, on the other hand, does work on its surroundings, the atmosphere. Which causes global currents of air and water against gravitational resistance. Heat flow both from the sun and the surface is converted to work. Since the surface does work on its surroundings, the first law says that there will be a subtraction of the heat flow coming from the sun, Q-W.

A sphere with two shells in space.

I found this equation in Planck´s book "The theory of heat radiation".

$Q = \frac{4}{3}\sigma T^4 (V' - V)$

67. If, on raising the piston, the temperature of the black body forming the bottom is kept constant by a corresponding addition of heat from the heat reservoir, the process takes place isothermally. Then, along with the temperature T of the black body, the energy density u, the radiation pressure p, and the density of the entropy s also remain constant; hence the total energy of radiation increases from $U = uV$ to $U' = uV'$, the entropy from $S = sV$ to $S' = sV'$ and the heat supplied from the heat reservoir is obtained by integrating (72) at constant T,

$$Q = T(S' - S) = Ts(V' - V)$$

or, according to (81) and (75),

$$Q = \frac{4}{3}aT^4(V' - V) = \frac{4}{3}(U' - U).$$

Thus it is seen that the heat furnished from the outside exceeds the increase in energy of radiation $(U' - U)$ by $\frac{1}{3}(U' - U)$. This excess in the added heat is necessary to do the external work accompanying the increase in the volume of radiation.

Planck describes a system with blackbody at the bottom of a cylinder that has a piston on the opposite end of the blackbody. The system is at rest, the blackbody emits radiation at σT^4, and the wall of the cylinder is perfectly reflective. This means that the blackbody at the bottom is at thermal equilibrium with its surroundings, the walls reflect back the exact same amount of heat as the blackbody emits, so it can stay this way indefinitely. The system is also in mechanical equilibrium:

"An immediate consequence of this is that the pressure of the radiation on the black bottom is just as large as the oppositely directed pressure of the radiation on the reflecting piston."

Then he wants to raise the piston while keeping the temperature of the blackbody constant.

"If, on raising the piston, the temperature of the black body forming the bottom is kept constant by a corresponding addition of heat from the heat reservoir, the process takes place isothermally.."

To keep the heat emission by the blackbody constant the energy supplied to the system needs to be

$$Q = \frac{4}{3}\sigma T^4(V' - V)$$

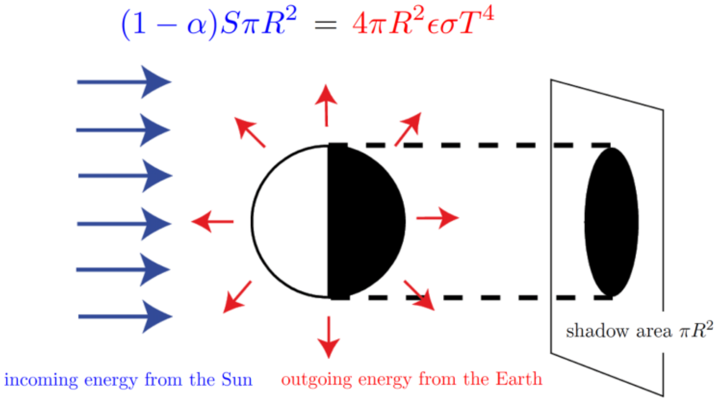
since radiation pressure, energy density and entropy must be constant.

In the case of Earth we have a steady state with constant heat flow and constant volume, but the system still does continuous work against the force of gravity, the atmosphere circulates like a fountain. The work is all the atmospheric currents of mass, convection, evaporation etc, i.e. work that the surface does on its surroundings. I´m going to assume that the first law of thermodynamics applies to the system, like all systems. Which means that solar heating results in work being performed along with heat emission from the surface, and that we can use Planck´s equation for an energy balance at the Earth surface. With constant volume the term V´-V disappears, and at the surface there must be a continuous heat supply which is $\frac{4}{3}\sigma T^4$ to keep temperature at σT^4, because this system loses all the energy at the same rate as it´s absorbed. The amount of solar radiation going in at the surface must in turn be balanced to what is received at the top of the atmosphere in space, so we have two shells which the heat must flow through before it´s absorbed and emitted, so $\left(\frac{4}{3}\right)^2 \sigma T^4$ should be what enters at the top of the atmosphere. This equation starting at the surface, and following the heat flow backwards to the boundary, produces exactly the solar constant irradiating the hemisphere at $1360.9W/m^2$.

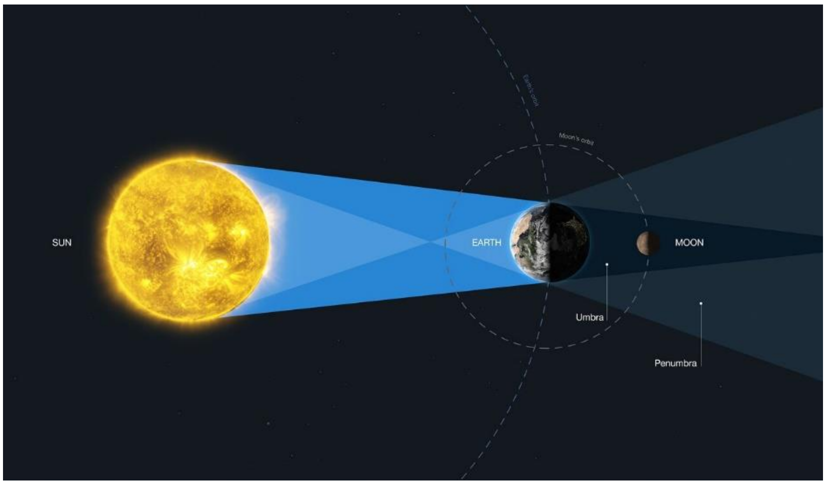
$$\left(\frac{4}{3}\right)^2 4\pi r^2\sigma T^4 = 2\pi r^2 TSI$$

As you see surface emission is balanced to irradiation on the whole hemisphere and some will oppose this because the greenhouse model uses only $\pi r^2 TSI$. I will not question $2\pi r^2 TSI$, it works. Both emission and absorption depends on the internal state. The reduction of the heat flow with this equation is much more aggressive than what the greenhouse model uses(albedo), but for other reasons.

In a simple energy balance which the greenhouse model uses, the intercepting area of a sphere in the solar system is assumed to always be πr^2, with an explanation like this:



But the shadow of Earth isn´t a cylinder like portrayed above, it´s a cone.



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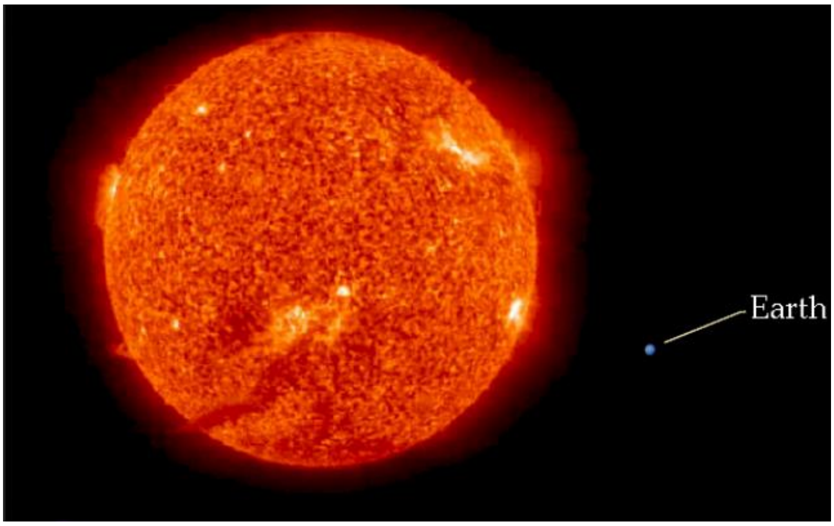


And Earth is very small compared to the sun

This means that the intercepting area of a sphere at Earth´s orbit is larger than πr^2since light is coming in at angles from a much larger surface area than Earth has. The angles are very small but it makes a difference. A funny detail about this is that the greenhouse model per definition is a flat Earth hypothesis because it calculates the Earth as a disc.

Using πr^2 isn´t necessarily wrong for all planets, it can produce interesting results which we´ll see when the equation is applied to Mars.

When we have a single heat source like the sun, the natural course would be to assume that heat emission by the surface of the sphere is fully supplied by the heat flow from the sun, not that it gets extra heat in some magical way from cold air. Then we need about $4\pi r^2\sigma 287^4$ for a temperature of 14°C. Using $\pi r^2$for received energy in the calculation won´t cover that, and that´s how we know it´s the wrong approach in this case.

We should assume from the start that the system is in balance at the surface, not that the surface is hotter than it should be thanks to a greenhouse effect. It´s much more likely that the estimation of absorbed heat is wrong than that the idea that cold air warms the hot surface is true. Once heat passes through the boundary at TOA it´s regarded as added to the system, all energy will either heat the solid surface or be transformed into work. Any fraction being converted to work will not add to σT^4 of the surface. From only the solar constant we can get the surface temperature of a system of two concentric shells:

$$\frac{2\pi r^2 TSI}{\left(\frac{4}{3}\right)^2} = 4\pi r^2\sigma 286.6^4$$

This gives a surface temperature at 286.6K=13.48°C, this is why I think the average temperature given by temperature.global and P.Jones & C.Harpham is closer to the truth than the 16°C Sabine Hossenfelder mentions in her video. I think the result is remarkably good for such a simple energy balance. I find it funny that the greenhouse model of starts with $\pi r^2 TSI$, reduce it with albedo and then complain about the surface being "too hot". My conclusion would be that there´s an error in the calculation of absorbed heat, not that a planet is too hot.

Both stages of the heat flow, from the top to the surface, into the surface and out, have many components of thermodynamic work, biological life included.

With this hypothetical system I don´t care about the details of that work, I just accept that a part of the heat flow is consumed according to the ratio Planck gave. It´s unavailable for heating the surface just like in the first law where the internal energy is equal to the heat supplied minus the work done by the system, $\Delta U = Q - W$.

Since radiation entropy is $\frac{4}{3}\sigma T^3$, so for surface emission $\frac{4}{3}\sigma 286.6^3 = 1.78\ W/m^2/K$, doesn´t that make the maximum energy available for work : $\frac{4}{3}\sigma 286.6^3 * 286.6 - \sigma 286.6^4 = 127.6 W/m^2$? This seems connected to σT^4 at the tropopause which is just that.

It seems like Earth behaves perfectly according to thermodynamic principles. With the annual variation of solar irradiation between $\sim 1300 - 1400 W/m^2$ we then should have fixed limits for a temperature range of 11-15°C. According to the average temperature from raw data presented at temperature.global, which sits at this moment at $\sim$14°C, we have a bit to go to reach the maximum.

So, what about Venus which is claimed to have a massive greenhouse effect? With solar irradiation at $2601.3 W/m^2$, we get:

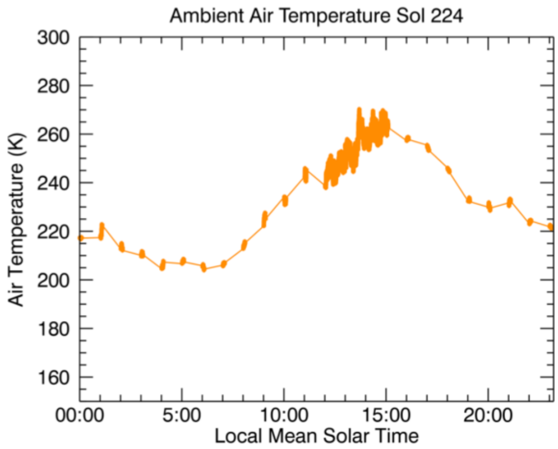
$$\frac{2\pi r^2 TSI}{\left(\frac{4}{3}\right)^2} = 4\pi r^2\sigma 337^4$$

340 kelvin is the average temperature at 50km at 1 bar pressure. I think what this equation gives us is the balance point of a system, where the inflow of heat is balanced to the outflow, and on Earth this happens to be at the surface. On venus almost no sunlight reaches the surface, so it can´t be balanced there.

On Mars, with irradiation at $586{,}2W/m^2$, we get:

$$\frac{2\pi r^2 TSI}{\left(\frac{4}{3}\right)^2} = 4\pi r^2 \sigma 232.2^4$$

We don´t have good data on the average surface temperature of the whole globe of Mars, but I´m going to cherry pick an example from curiosity´s measurements, and it looks pretty good:



I mentioned that the disc for intercepting area would become useful on Mars. As distance from the sun increases the intercepting area approaches the disc more and more. Mars has a very thin atmosphere, about 1/100 density of Earth, and I thought it maybe can´t be treated like Earth and Venus. On Mars, with only one shell using the $\pi r^2 TSI$, it gives the blackbody temperature exactly:

$$\frac{\pi r^2 TSI}{\frac{4}{3}} = 4\pi r^2 \sigma 209.8^4$$

Some sources gives this as an average temperature of Mars, about -60°C.

What I want to show with this is that there are very easy and rational ways to do energy balances of planets without a greenhouse effect.

Isn´t it strange that the starting point of the greenhouse hypothesis is an energy balance where the heat flow is estimated by guessing the intercepting surface area, then subtract from the heat flow with a collection of assumptions about the reflectivity of the surface, and when it gives the wrong surface temperature the conclusion is that the surface is “too hot”? My conclusion would be that there are errors in the calculation.

This model provides a lot more information than the greenhouse model. If we for exampe look at the amount of heat arriving at the surface of Earth we find that:

$$\frac{TSI}{\frac{4}{3}} = 1020W/m^2$$

Which is the midday intensity of solar irradiation at the surface. There are many more correlations in the system which I may get back to, the point is that this approach seems to give a structure of the average heat flow with several balance points, almost like stratified energy levels.

Luminosity and gravity

> *If a body gives off the energy L in the form of radiation, its mass diminishes by* L/c^2. The fact that the energy withdrawn from the body becomes energy of radiation evidently makes no difference, so that we are led to the more general conclusion that
>
> The mass of a body is a measure of its energy-content; if the energy changes by L, the mass changes in the same sense by $L/9 \times 10^{20}$, the energy being measured in ergs, and the mass in grammes.
>
> It is not impossible that with bodies whose energy-content is variable to a high degree (e.g. with radium salts) the theory may be successfully put to the test.
>
> If the theory corresponds to the facts, radiation conveys inertia between the emitting and absorbing bodies.

When Einstein says that a body loses mass proportionally to heat emission it will be as $4\pi r^2 \sigma T^4/c^2$=m. He then says that radiation conveys inertia, so there must be a component of gravity in $4\pi r^2 \sigma T^4$. This wasn't so clear to me when I look at $E = mc^2$, but in Einsteins original form I see a different picture. Since L is a surface flux maybe it´s not so crazy if there´s an equality between solar irradiation and g^2? It probably is crazy, but if it´s not I shouldn´t keep it to myself. So:

g is surface acceleration

$TSI = 1360.9W/m^2$

$$\left(\frac{4}{3}\right)^2 16\pi r^2 g^2 = 2\pi r^2 TSI$$

Or as received flux per unit surface area:

$$TSI = \left(\frac{4}{3}\right)^2 8g^2$$

So surface emission is equal to:

$$\sigma 286.6^4 = 4g^2$$

That makes surface emission looks like the source strength of gravity.

Here I also found a relationship to σT^4 at TOA, the temperature at the tropopause, the outer boundary. It´s It happens to be equal to $\frac{4}{3}g^2 = \frac{1}{3}\sigma 286.6^4$, 217K.

This connects to radiation entropy $\frac{4}{3}\sigma T^3$ at the surface, $\frac{4}{3}\sigma 286.6^3 = 1.78\ W/m^2/K$:

$\frac{4}{3}\sigma 286.6^3 * 286.6 - \sigma 286.6^4 = \frac{4}{3}g^2$.

For Venus the relationship is $32\pi r^2 g^2 = 2\pi r^2 TSI$, but not as exactly as on Earth. On Mars it´s exactly $\frac{4}{3}32\pi r^2 g^2 = \pi r^2 TSI.$

I don´t make any claims of this being important or correct at all, it may be just a coincidence, an illusion. But what It looks like to me if I speculate, is that heat and gravitational energy is interchangeable, which is kind of what Einstein said. I don´t know what this means, or if it even means anything, but I like the idea of joining heat and force together on a planet.

Force and heat are intimately related companions in our universe, that´s what thermodynamics is. Is gravity and planetary heat flow an exception?

The previous parts about the impossibility of the greenhouse effect being real is what´s important if we want our kids to have a future in modern civilization. Modern civilization isn´t possible without fossil fuels at this moment and it won´t be in the foreseeable future.