ACTUAL LUNAR SURFACE COOLING RATE REFUTES THEORY OF GREENHOUSE EFFECT

By Alberto Miatello, 5 November 2012
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Before reading this article, I heartily recommend the reader studies the excellent analysis, 'A Greenhouse Effect on the Moon?' (2010), by Hertzberg, Siddons and Schreuder (often referred to as the "Moon Paper").

In the "Moon Paper" the authors showed, very straightforwardly, the misuse of the Stefan-Boltzmann (SB) formula ($W/m^2 = \sigma * T^4$), as normally suggested by the supporters of the "theory" of greenhouse gas effect (GHE). Climatologists sought to back their claims for the GHE on Earth by calculating the heat transmission for three-dimensional spherical rotating bodies (eg. our Moon or Earth), in which the ground surface (Moon) or ground surface + water (Earth) store the heat from our Sun (irradiance), and then release such heat during the night. It is here where there have been several miscalculations. For example, climatologists over-estimated the Moon's heating during the day (the "Moon Paper" authors showed that the Moon is 20° C colder in the day) plus the over-estimation of cooling on the Moon during the night (but shown to be 60° C warmer at night).

The aforesaid miscalculations would lead anyone who relied on them to believe that even a satellite without an atmosphere, just like our Moon, is under a "greenhouse effect," that is, warmer than what the SB formula foresees.

Subsequent studies (by Postma, Nahle and Miatello: see under 'Publications' at Principia Scientific International) affirm the above miscalculations are monumental errors for the GHE. Principia Scientific International papers prove that not only was the SB formula misapplied but so were crude calculations of heat transmission that over-simplified our three-dimensional planet into a flat two-dimensional surface (lacking account of the critical phase changes of night and day).

However, some defenders of the GHE have recently resorted to another "argument" in support of their discredited "theory." Among them is the blog, 'Skepticalscience'.

'Skepticalscience' (like others) claimed, in the "argument n° 63" (i.e.: "Has the Greenhouse effect been falsified?" http://www.skepticalscience.com/does-greenhouse-effect-exist.htm

Empirical Evidence for the Greenhouse Effect

We only have to look to our moon for evidence of what the Earth might be like without an atmosphere that sustained the greenhouse effect. While the moon's surface reaches 130 degrees C in direct sunlight at the equator (266 degrees F), when the sun 'goes down' on the moon, ***the temperature drops almost immediately, and plunges in several hours down to minus 110 degrees C (-166F).***

Since the moon is virtually the same distance from the sun as we are, it is reasonable to ask why at night the Earth doesn't get as cold as the moon. The answer is that, unlike the Earth, the moon has no water vapour or other greenhouse gases, because of course it has no atmosphere at all. Without our protective atmosphere and the greenhouse effect, the Earth would be as barren as our lifeless moon; without the heat trapped overnight in the atmosphere (and in the ground and oceans) our nights would be so cold that few plants or animals could survive even a single one.”

With assertions like that above, GHE defenders are hoping to persuade us that at the Moon’s equator the temperature “drops almost immediately…in several hours” from 130° C to minus 110 degrees C, due to the lack of atmosphere (as here on Earth) which (in their opinion) should “protect” the surface from the “cold” outer space. But is it really so?

Evidence Proves Reality is Opposite to Skeptical Science Claims

Let’s start with a very simple experiment that any of us can perform at home and without any complicated or expensive equipment. All that is required is heating a cup of water to boiling point. (For this I used a microwave oven). I took a small ceramic bowl and I added 170 grams of water. Then I placed the water for around four or five minutes in a microwave oven, until I saw the water boiling (reaching 100°C). I then allowed the bowl to cool at the window on what had been a hot 2012 summer's day (August 10, 2012). At the time I performed this experiment (10:07pm) the outside temperature was still warm (21.7° C).

After less than 30 minutes (10:34 pm) I took the temperature of the water. It had fallen to just 36° C. Therefore, my boiling water, in contact with the outside air of a hot summer night, had lost nearly 64° C in half an hour, from 100° C (boiling point of water) down to 36° C (warm water). I am sure, like me, you are not surprised by this.

What we may agree is that my water was subjected to a normal convective cooling mechanism. That is, the water cooled off by convective contact with the cooler outside air, according to the Second Law of thermodynamics (heat is flowing from hotter to colder bodies). We know this as per the formula:

q” = h*A* (Tsur – Tair) , where:
q” = heat flux/sec.
h = convective coefficient of still air
A = area of the bowl = R^2 * π = 0.06 m ^2 * 3.14 = 0.018 m^2
Tsur = temperature of water surface (100° C)
Tair = temperature of air (21.7° C)
As we have two unknown quantities (q”, h), it is easier to find the first (q”), and then the second, by remembering that
q” = ΔT *m* Cp/1800 sec. (1/2 hour)
q” = 64(°C) * 0.17kg * 1007 J/kg/1800
q” = 10,956/1800 = 6.08
and then
6.08 = h * 0.018 * (100 – 21.7)
h = 4.34 W/m^2.K

It is important to keep in mind this cooling convective coefficient h (4.34 W/m^2.K), because it cannot exist on the surface of the Moon, because, as we known, the Moon has no gas and no atmosphere.

Also, at this point, the most important thing to bear in mind is that my little experiment shows that, even on a hot summer's night, boiling water in open air quickly cools off. This may be shown to be at a rate of around 128° C/hour. Of course, the cooling rate of my small bowl was very fast, because it is small and will cool much faster than one cubic meter of boiling water.

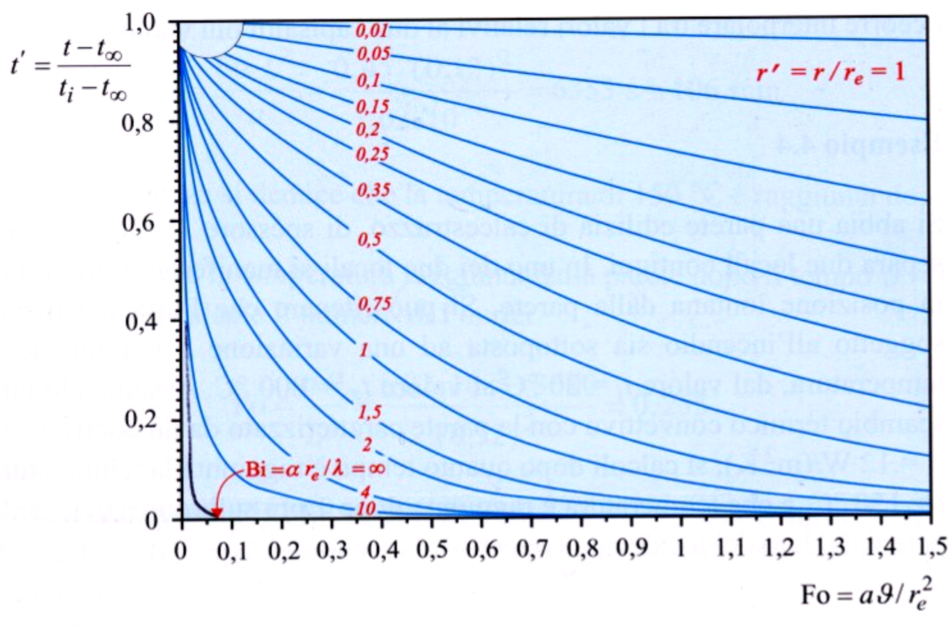
If we take a sphere (having everywhere in its surface the same cooling rate) of 1 cubic meter of boiling water , where radius is, 0.62 m., to calculate its cooling rate in contact with a surrounding atmosphere whose temperature is 21.7° C, then we can use the algorithms for transient (i.e. changing with time) heat transmission, namely Biot's and Fourier's numbers.

http://en.wikipedia.org/wiki/Biot_number
http://en.wikipedia.org/wiki/Fourier_number

Biot number is an a-dimensional number commonly used in technical physics and engineering, making reference to the relationship between the internal (R"i) and external (R"e) resistance of heat transmission in a body, as follows:
Bi = R"i/R"e

Fourier number , in its turn, is an a-dimensional number making reference to the time, as follows:
$\mathbf{Fo = a*\vartheta/L^2}$
Where a = heat diffusivity
ϑ = time (in seconds)
L = length/thickness of the body (or radius of the sphere, in our case)
To solve problems of transient heat transmission, in technical physics, technical diagrams and charts, like the Heisler Chart as the one of fig. 1, are normally being used.

Fig. 1 (transient heat transmission in a sphere. Diagram adapted from : "Fondamenti di trasmissione del calore" [Basics on Heat Transmission], p. 143, by Prof. G. Comini and Prof. G. Cortella" 2008)



In 1 cubic meter sphere of boiling water, where convective coefficients are very high, and external resistance is very low, we can suppose a Biot's number $\rightarrow \infty$

So, we have, to calculate the time:
$t' = t - t\infty/ti - t\infty$, namely
$t' = 36 – 21.7/100 – 21.7 = 14.3/78.3 = 0.182$

In the diagram of fig. 1, we have that, for a $Bi = \infty$, and $t' = 0.182$,

We can find a $Fo = 0.02$.

Therefore, we have:
$\vartheta = Fo^* r^2/a$
$\vartheta = 0.02^* 0.62^2/ 1.68 * 10$ ^ -7 (=diffusivity of 100° C water)
ϑ = 45,761 sec. = 12.7 hours

Therefore, it will take 12.7 hours, for 1 cubic meter of boiling water, to lose 64° C in contact with a hot summer night (21.7° C)

But, as we can easily see, this means that even in such a situation, the cooling rate on a hot summer night is much faster than the one on the Moon, as 64° C in 12.7 hours means nearly 5° C/hour cooling, whereas on the Moon surface the average cooling rate of regolith at sun set is 0.67° C/hour, namely 7.5 times slower!

Furthermore, we must not forget that, here on Earth, we can find much higher convective coefficients, ranging from 30 W/m^2K for natural convection of air, up to 1,000/5,000 W/m^2K for water vapor in condensation (forming clouds).

Therefore, as we will see, there is no comparison between the very slow cooling rate of the moon's surface and the much faster cooling rates here on Earth.

Real Cooling Rate of the Moon's Surface

We will focus on the cooling of the Moon at the equator, where NASA tells us the duration of daytime is equal to that of the night, namely 14.75 terrestrial days, for a total day (day + night) of 29.5 days (708.7 hours). The highest temperature at the Moon's equator is 390K (117 ° C), whereas the mean (at setting) is 220K (- 53° C), and the lowest is 100K (-173° C). For more on this see:
A.R. Vasavada, D.A. Paige, and S.E. Wood (1999),'Near-Surface Temperatures on Mercury and the Moon and the Stability of Polar Ice Deposits.'

The above verifiable data is sufficient to prove that *Skepticalscience* erred. We may say that because if - on the Moon's surface - it takes 708/2 = 354 hours to cool the surface from 390K to 100K, this means that the cooling rate is very, very slow, being just 290/354 = 0.8K (0.8° C)/hour. And the situation is not very different if we analyze the cooling at lunar sun set (when solar irradiance ceases): from 220K (- 53° C) to 100 K (-173° C). Even there, the cooling rate is just 120/177(=354/2), namely 0.67K (°C)/hour.

But this means that on the Moon the cooling rate of the surface is – on average – 5/0.8 = 6 times slower than the cooling rate of 1 cubic meter of boiling water, as somehow envisaged by our demonstration of a small pot of boiled water in contact with atmospheric gases on a summer's night. We may say it is even slower, 5/0.67 = 7.5 times slower if we consider the cooling of the lunar surface after the sun's setting and there is no "drop" of temperatures at all, as incorrectly asserted by *Skepticalscience.*

And now to evaluate the behavior of the lunar regolith up to 50 cm depth. For this let us turn again to the "Moon Paper" cited at the beginning of this article. That paper quotes the following NASA statement:

"During lunar day, the lunar regolith absorbs the radiation from the sun and transports it inward and is stored in a layer approximately 50cm thick. As the moon passes into night, the radiation from the sun quickly approaches zero (there is still a bit of radiation from the earth) and, in contrast with a precipitous drop in temperature if it was a simple black body, the regolith then proceeds to transport the stored heat back onto the surface, thus warming it up significantly over the black body approximation."

This is most important because it immediately introduces the heat transmission on the Moon (a revolving planet/satellite devoid of atmosphere and surrounded by a vacuum space) as a slow cooling process, with heat exchanges from the depth to the surface. With reference to the lunar regolith here are the main physical features:

ρ (density) = 3,000 Kg/m^3
λ (thermal conductivity) = 1.0 W/m.K
c (specific heat) = 1,000 J/Kg.K
L (thickness/depth) = 0.5 meters

So, we have for a single half cubic meter, when the temperature reaches the highest level, i.e. 390 K (117 °C), the total amount of thermal energy stored, (Q), according to the equation of calorimetry, as:

$Q = \rho * c * \lambda * L * T$
Q = 3,000*1,000*1.0*0.5*390
Q = 585 million joule

Now, to evaluate the rate of cooling of this thermal energy stored by the lunar regolith the end of the cooling process, when the temperature is just 100K:

Q = 3,000*1,000*1.0*0.5*100
Q= 150 million joule

So, we see that on the lunar surface it takes 354 hours to cool off 435 (= 585 – 150) million joules of energy. i.e 435/354 = 1.2 million joule/hour = 341 j/sec.

We can make the same calculation, considering one cubic meter volume (instead of 0.5) and we would need 870 million joule (1170 – 300). This equates to 682 j/sec. to cool off a cubic meter of regolith in 354 hours (14.5 days) in the lunar vacuum space, just by radiation and with no cooling through convection with gases.

These results accord with my previous findings – as shown in the article: 'Roy Spencer and the Vacuum Bottle Flask' (February 2012). There I calculated how long it would take to freeze one cubic meter of copper surrounded by one cubic meter of an insulating PVC, at a lower temperature (338K = 65°C for copper, 310K = 37° C for PVC, in a vacuum space, after reaching an equilibrating temperature of nearly 58° C (331K). We saw there the temperature fall very slowly, at a rate around 363 j/sec. or even lower (i.e. it would take weeks to freeze).

In a vacuum space – as that surrounding our moon's surface – the hot regolith (390K), which is not an insulating material, is cooling at a 682j/sec. rate, whereas an insulator such as PVC, starting from a lower temperature (331K), would lose thermal energy just by radiation, with a cooling rate around 383j/sec.

Again, the cooling rate of the lunar surface is very, very slow. This is because the vacuum of space is not at all "cold" - as wrongly maintained by GHE supporters. In fact, outer space has no temperature - it works like a perfect insulator, making the lunar surface lose thermal energy very, very slowly. It has a cooling rate almost 5 to 7.5 times slower than that of the atmosphere of Earth during a summer night with still air (never mind what would occur on a cold winter's night with strong winds!).

Bluntly, the vacuum of outer space has no temperature and as such cannot be regarded as "cold." From these facts we may adduce that there is no "greenhouse effect" at all, because our terrestrial atmosphere does not "protect" the Earth's surface against an alleged "cold" outer space.

> Temperature is defined as the average internal kinetic energy of a body and $e_k = ½ mv^2$ but a true vacuum has no mass and therefore no kinetic energy and no temperature. The only temperature measurement that can be made in a vacuum is a measurement of how close to a complete vacuum the chamber is so theoretically there is no temperature in the vacuum chamber. (Norm Kalmanovitch)

The Sinusoidal Heat Transmission of the Lunar Regolith Layer

It is very interesting to investigate still further the mechanism of heat transmission in a 0.5 meters regolith layer, as introduced in the NASA's quotation above, because it is no different from any other heat transmission in thick materials, such as house walls, brick kiln walls, or thermal shields. For instance, consider thermal shields of space vehicles/capsules undergoing huge heating entering our atmosphere at high speed before the final splashdown, where precision engineering is the difference between life and death for the astronauts.

In these thick layers we can find a typical sinusoidal heat transmission with a surface curve of heating; and another curve of heating below overlapping the first curve and sometimes releasing heat when – at surface – the temperature is very low.

This explains why in the summer (in homes having thick walls) despite the outside wall temperatures reaching their highest levels at around 3:0 to 4:0 pm, you still feel comfortable inside. By contrast, during nighttime when the walls are slowly releasing the heat stored from the hottest hours, you will need to open the windows (unless you have air conditioning), to enjoy the chill of the evening.

It is interesting to explain what happens by mathematics and the typical formulas of technical physics. The main physical items to consider, in a sinusoidal heat transmission, are:

ω (angular frequency) 2 π/ϑ°
ϑ° = period of time
ϒ = smoothing constant = √(ω* ρ*c)/2λ
ϑr = time of delay (in heat transmission inside the layer) = ϒL/ ω
e ^ - ϒL = smoothing factor

So, we have for calculation of heat transmission in a lunar regolith layer 0.5 m. thickness, for a cooling period of time of 14.7 terrestrial days: ϑ° = 1,270,080 sec.
ω = 6.28/1,270,080 = 4.9446 ^ -6
now the smoothing constant is:
ϒ = √ 14.83/2 = 2.72 m ^-1
And the smoothing factor is:
e ^ - 2.72* 0.5 = 2.718 ^ -1.36 = 0.256 = 25.6% (reduction of temperature)
and finally, the time of delay in heat transmission inside the layer is:
ϑr = ϒL/ ω = (2.72*0.5)/4.9446^-6 = 275,047 sec. = 76.41 hours = 3.1 (terrestrial) days.

To summarize:

1) On the lunar surface there is no “almost immediate drop” of temperature when the Sun goes down – as falsely claimed by *Skepticalscience*. On the contrary, it takes 177 hours to cool the surface from 220K to 100K (= 0.67K/hour). In comparison, here on Earth, it takes more or less 30 minutes to cool a small cup of boiling water (100° C) to a warm 36° C on a hot summer’s night (21.7° C); 12.7 hours to cool off a sphere of one cubic meter of boiling water, with a cooling rate more than 6/7.5 times faster. This is without mention of the very fast cooling rates of water vapor forming clouds, or the cooling rates of cold winter winds.

2) At the lunar surface equator the cooling rate of one cubic meter of regolith is approx. 682 j/sec., to cool from 390K to 100K. This cooling rate accords with the one we showed for one cubic meter of copper surrounded by insulating PVC in a vacuum; namely 383 j/sec. to cool off from 331K (58° C). Therefore, as compared with earth, the cooling rate of the lunar surface is very, very slow.

3) With reference to the sinusoidal heat transmission, inside a 0.5 m. layer, we have a “smoothing factor” of 25.6%, and a delay of heat transmission for 3.1 days. This means that, inside a lunar regolith layer, the heat is transmitted at the lowest point inside (= 0.5 m depth) with a factor of temperature reduction of 25.6% and with a delay of 3.1 days. This means that when the temperature on the surface is 390K (117° C) and we dig down at the same point 3.1 days later, up to a 0.5 meters depth, we should see there a temperature of 290K (17° C) = 25.6% lower. But on the contrary, we see that when the temperature on the surface is just 100K (the lowest at the lunar equator), then the temperature of the regolith inside is higher. This is because it will take a further 3.1 days to reach the 100K temperature.

But the most important thing is that on the Moon the cooling rate is very slow, because there’s no “cold” outer space surrounding the moon’s surface. Our atmosphere is actually very much colder and that’s another conceptual issue that is easily misunderstood.

In conclusion then, the accurate study of the cooling rate on the moon surface brings another compelling evidence against the mistaken "theory" that our atmosphere acts as a "greenhouse" or a "blanket" "protecting" Earth's surface against a "cold" outer space.

On the contrary, our atmosphere is demonstrably cooling the surface of Earth because the vacuum of outer space is not at all cold, as the study of heat transmission on the Moon shows.

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