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Testing a Flat-Earth Prediction: Is the Moon's Light Cooling?

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Abstract

Flat-earthers often claim that moonlight has a cooling property. I present the results of three independent experiments that test this claim. The results of all three experiments disprove the claim that moonlight cools objects exposed to it. Not only is this claim not supported by carefully conducted experiments, it defies all that we know about the nature of light and energy. Furthermore, this claim has nothing to do with flat-earth cosmology, and easily could be jettisoned by flat-earthers without jeopardizing their model.

Keywords: Flat earth, moonlight, heat

Introduction

The flat-earth phenomenon has grown tremendously over the past five years, and it has made serious inroads in the Christian community. The claim that the Bible teaches the earth is flat first was made by skeptics in the nineteenth century in an attempt to discredit Scripture. This amounts to a straw man argument, leading to the wrong conclusion that the Bible is false. Furthermore, the assumptions and the approach to Scripture of many flat earthers superficially resembles that of the creation science movement. Therefore, the flat-earth movement is a threat to Christianity and the authority of Scripture, as well as the creation science movement. To counter this threat, I have criticized the flat earth movement (Faulkner 2016a, 2016b, 2016c, 2017a, 2017b, 2017c, 2017d, 2017e, 2018a, 2018b, 2018c, 2018d, 2018e). In some of these articles I reported the results of experiments that I had performed to test predictions of the flat-earth model. For instance, in one article (Faulkner 2016c), I showed that the flat-earth model predicts that the sun's apparent size ought to change throughout the day as the sun's distance from us changes, but observations show that this is not the case. In another article (Faulkner 2017a), I showed that ships disappear hull first if atmospheric refraction due to a temperature inversion is not present.

Here I will investigate one of the more peculiar claims made by many flat earthers, that the moon's light is cooling. That is, objects that are exposed to moonlight at night supposedly are cooler than objects that are shaded from the moon's light. I devised and carried out three independent experiments to test this claim. The results of all three experiments disprove that moonlight is cooling.

Cool Light of the Moon

Where did this odd idea come from? Eric Dubay (2014, 79), who probably is most responsible for unleashing the flat-earth myth into the twenty-first century, has written about moonlight's unusual properties:

> The Sun's light is golden, warm, drying, preservative and antiseptic, while the Moon's light is silver, cool, damp, putrefying and septic. The Sun's rays decrease the combustion of a bonfire, while the Moon's rays increase combustion. Plant and animal substances exposed to sunlight quickly dry, shrink, coagulate, and lose the tendency to decompose and putrify; grapes and other fruits become solid, partially candied and preserved like raisins, dates, and prunes; animal flesh coagulates, loses its volatile gaseous constituents, becomes firm, dry, and slow to decay. When exposed to moonlight, however, plant and animal substances, tend to show symptoms of putrefaction and decay.

This sounds very mystical and superstitious. Where did he get such an idea? It probably came from David Wardlaw Scott's book on the flat earth because its wording is very similar:

> The light which is reflected must necessarily be of the *same character* as that which causes the reflection, but the light of the Moon is *altogether different* from the light of the Sun, therefore the light of the Moon is not reflected from the Sun. The Sun's light is red and hot, the Moon's pale and cold—the Sun's dries and preserves certain kinds of fish and fruit, such as cod and grapes, for the table, but the Moon's turns such to putrefaction—the Sun's will often put out a coal fire, while the Moon's will cause it to burn more brightly—the rays of the Sun, focused through a burning-glass, will set wood on fire, and even fuse

> metals, while the rays of the Moon, concentrated to the strongest power, do not exhibit the very slightest signs of heat. I have myself long thought that the light of the Moon is *Electric* but, be that as it may, even a Board School child can perceive that its light is totally unlike that of the Sun. (Emphasis in the original) (Scott 1901, 151–152)

Notice that while these two quotes describe some rather bizarre properties of moonlight, neither one explicitly states that moonlight cools. Rather, they say that moonlight is "cool" or "cold," while sunlight is "warm" or "hot." So, where does this idea come from? Dubay (2015, 25–26) included discussion of the cooling property of moonlight as "proof" numbers 132 and 133 (out of 200). This alleged cooling property of moonlight supposedly proves that the moon does not reflect the sun's light but rather has its own light. Where did Dubay get this idea? Dubay's "proof" number 133 mentions an article from the March 14, 1856 issue of *The Lancet*, the British medical journal that purportedly gave experimental results that moonlight has a cooling effect. Dubay apparently is repeating this claim about *The Lancet* from Rowbotham (1881, 112):

> In the "Lancet" (Medical Journal), for March 14th, 1856, particulars are given of several experiments which proved that the moon's rays when concentrated, actually reduced the temperature upon a thermometer more than eight degrees.

However, there was no March 14, 1856 issue of *The Lancet*. *The Lancet* is a weekly publication and the closest issue to this date was the one on March 15, 1856. The table of contents of that issue does not remotely suggest a paper of that type in it. However, I am indebted to a reviewer who found and provided me with what likely is the article that Rowbotham intended. Winslow (1856) wrote on the possibility of lunar effects on disease in which he discussed reports of the influence of lunar light. He included statements from Pliny (first century), the seventeenth century astronomer Geminiano Montanari, the eighteenth century botanist Jean-Baptiste Thibault of Chanvalon, the eighteenth century botanist and physician Henri-Louis Duhamel du Monceau, as well as three of his contemporaries, the botanist Augustin Satin-Hilaire, the astronomer François Arago, and the scientific writer Dionysius Lardner. From Winslow's discussion, it seems that most of these sources attributed some interesting powers to moonlight, though none them explicitly mentioned any cooling of the moon's light, though one (Montanari) alluded to "the warmth of its [the moon's] light." To which Winslow had this to say:

> This explanation does not satisfy Dr. Lardner, who remarks, that if it be admitted that the lunar rays possess any sensible calorific power, this reasoning might hold good, but it will have very little force when it is considered that the extreme change of temperature which can be produced by the lunar light does not amount to the thousandth part of a degree of the thermometer! Upon this point, however, philosophers are at variance. The lunar rays have, according to the experience of practical men, a decided calorific agency. The gardeners of Paris assured Arago that in the months of April and May they found the leaves and buds of their plants, when exposed to the full moon in a clear night, *actually frozen, when the thermometer in the atmosphere was many degrees above the freezing-point*. He mentions these facts as proving that the moon's rays have a frigorific power, but that the largest speculums directed to the moon produced no such indications on a thermometer placed in their focus. Dr. Howard, of Baltimore, has affirmed that, on placing a blackened upper ball of his differential thermometer in the focus of a thirteen-inch reflecting mirror, opposed to the light of the full moon, the liquor sunk, in half a minute, eight degrees!

It is unknown who Dr. Howard of Baltimore was. Almost none of the things claimed here are referenced, so it is impossible to find the original sources. However, notice that the conclusions on the question of whether the moon's light is cooling are contradictory.

The one sentence quoted from Rowbotham above seems to be the source for the claim among flat earthers that moonlight cools. For instance, Carpenter (1885), the third major flat-earth source from more than a century ago that modern flat earthers often cite (besides Rowbotham 1881 and Scott 1901), doesn't mention this at all. And this statement by Rowbotham is strange because it was preceded by several statements that said something very different, that the light of the moon has no effect on changing the temperature of things exposed to it. For instance, immediately prior to the above quote from Rowbotham, Rowbotham (1881, 112) quoted from Noad (1843, 334):

> The light of the moon, though concentrated by the most powerful burning glass, is incapable of raising the temperature of the most delicate thermometer. M. De La Hire collected the rays of the full Moon when on the meridian, by means of a burning glass thirty-five inches in diameter, and made them fall on the bulb of a delicate air thermometer. *No effect was produced* though the lunar rays by this glass were concentrated 300 times. Professor Forbes concentrated the Moon's light by a lens thirty inches in diameter, its focal distance being about forty-one inches, and having a power of concentration exceeding 6,000 times. The image of the Moon, which was only eighteen hours past full, and less than two

> hours from the meridian, was brilliantly thrown by this lens on the extremity of a commodious thermopile. Although the observations were made in the most unexceptional manner, and (supposing that half the rays were reflected, dispersed, and absorbed), though the light of the Moon was concentrated 3000 *times, not the slightest thermo-effect was produced.* (Emphasis in original)

Clearly, this issue in the original flat-earth literature of the late nineteenth and early twentieth century is muddled at best. However, the twenty-first century incarnation of the flat earth seems to have embraced this one statement by Rowbotham that moonlight is cooling while ignoring his statements to the contrary.

The moon's spectrum is a good match to the solar spectrum, strongly indicating that the moon does reflect the sun's light.[1] Therefore, it may seem reasonable that since objects exposed to the sun's light are warmed, the same ought to be true of the moon's light. Let us explore this question. Astronomers express brightness of objects in magnitudes.[2] The apparent magnitude of the sun is –27.4, while the full moon's apparent magnitude is –12.7. That is a difference of 14 magnitudes, which corresponds to a difference in brightness of 400,000 times. Hence, an object illuminated by the full moon will receive $^1/_{400,000}$ the radiant energy that it would receive from the sun during the day. At any other phase, the moon's light will be additionally reduced. With such a large disparity in brightness, any heating from the moon's light at night would be very small compared to the sun's heating during the day and thus would be difficult to detect. Therefore, I would expect that experiments would not reveal any significant temperature change in objects exposed to moonlight, in agreement with some of the statements by Rowbotham.

Due to a misunderstanding of Genesis 1:14–19, flat earthers believe that the moon doesn't reflect the sun's light, but rather that the moon has its own source of light. To maintain this belief may be the motivation of many flat earthers who claim that the moon's light has the strange property of cooling objects exposed to it. But this contradicts everything we know about heat and light. Light contains energy that objects can absorb. Therefore, any moonlight that falls on an object will heat that object, though the amount of heat is so small that it may not be easy to detect a temperature increase as a result. Furthermore, heat can radiate from an object, but nothing sucks heat from objects as this mythical belief of flat earthers would require. Nevertheless, flat earthers are unperturbed by this, for there are many videos on the internet that promote this idea that moonlight is cooler than shade. Most of these videos feature people using infrared (IR) thermometers to measure the temperature of objects in moonlight and in shadow. They seem always to find that objects in moonlight are cooler than objects in shadow, thus supporting their claims.

How Not to Do the Experiment

I have conducted this experiment myself many times. I can reproduce the results that flat earthers obtain; objects in moonlight indeed are cooler than objects that aren't in moonlight. But a moment later, I can produce the opposite result, objects in moonlight are warmer. How can I do this? Most people have no idea how IR thermometers work.[3] They apparently think that simply pointing the device at an object will give "the temperature" of the object. This is not a bad approach for objects that are significantly warmer or cooler than their surroundings or for objects that are made of the same substances. However, IR thermometers work by measuring the IR emission from objects. When objects are close to ambient temperature, the IR emission is more of a function of the *emissivity* of the objects than anything else. Emissivity is an expression of how well an object radiates energy. Emissivity depends upon color, with darker objects emitting better than lighter objects. But emissivity also depends on composition and texture. Consequently, different objects at the same temperature will produce slightly different, albeit noticeable, temperature measurements with IR thermometers.

When measuring temperatures of surfaces on the ground, such as pavement, additional factors come into play. One factor is how well the surface absorbs energy from the sun during the day. This is a function of the physical properties of the surface, including the material's specific heat. Another factor is how well heat conducts down into the ground during the day and how well heat conducts up from the ground at night. How efficiently this heat is transmitted depends upon the conductivity of the materials involved, which varies for different substances. Similarly, bare soil, mulch, and other substances directly on the ground will produce different temperature measurements. Another factor is how much shade was on the pavement during the

[1] Technically, the moon doesn't reflect the sun's light, but rather scatters sunlight. However, that distinction isn't important in most discussions.

[2] For more information about magnitudes, please see Faulkner (2004, 117–118).

[3] This is evidenced in many videos on the internet, where flat earthers refer to IR thermometers as "laser thermometers." This confusion arises from the fact that most IR thermometers have a small red laser to indicate where the IR detector is pointing. Of course, the IR detector doesn't pick up the spot of the laser, so the laser spot has nothing to do with the temperature measurement.

day. I've found that when I measure the temperature of concrete in my driveway after dark, the portions of the driveway that were in full sun late in the day are significantly warmer than those portions that were shaded by trees late in the day.

On the other hand, grass is not affected much by heat from the ground. Thin grass blades do not conduct heat well, and the small air gap between the soil and the top of the grass provides insulation to reduce greatly the transfer of heat from the ground to the blade tops. On the other hand, grass efficiently emits radiation on clear nights, leading to its cooling. This is why dew and frost form so readily on grass. By selecting different surfaces in shadow and not in shadow, I can produce any result that I want. In many of the videos of these experiments, there is no indication what surfaces are sampled. It is like a magic trick, where the magician will distract the audience to look at one thing (shadow versus non-shadow and/or the temperature reading on the thermometer), while he subtly does a sleight of hand trick (changing surfaces, such as between grass and concrete). On some videos, one can see that the experimenter changes surfaces, but in many videos, one cannot see what surfaces are being sampled.

Another trick is to take the temperature on the ground under the canopy of a tree, often in shadow from the moon's light, and then take the temperature away from the canopy, in the moon's light. On a clear night with little wind, objects radiate IR energy, causing their temperatures to cool, almost always to temperatures less than the air temperature. However, any obstruction overhead, such as the canopy of a tree, will reduce greatly radiative loss of heat. Out from under a tree's canopy, radiative cooling will allow the ground or objects to cool more than under the canopy where leaves overhead block radiative losses from the ground. This is why automobiles parked under a carport or a tree with leaves usually won't develop dew or frost on a clear night, while an automobile parked with no cover overhead will. Therefore, it is possible to get a temperature difference of a few degrees this way. However, if one were to sample free of a tree's canopy overhead, there likely would be no temperature difference in objects in moonlight or shaded from moonlight. Many people who have done this experiment probably have taken temperature readings in moonlight with no tree canopy above, followed by taking temperature readings in the shade, under the canopy of a tree, not realizing that any temperature difference is due to the presence or lack of tree canopy rather than the presence or lack of the moon's light.

In one video on the internet that I watched, the person doing the video measured the temperature on the hood of an automobile that was bathed in moonlight. Then he measured the temperature on the side of a fender that was shaded from the moon's light by the car. The hood was several degrees cooler. The problem with this experiment is that horizontal surfaces of a car, such as the hood, fully radiate heat away to the clear sky above. On the other hand, a vertical surface, such as the side of a fender, cannot so easily radiate heat into the sky. If anything, vertical surfaces are exposed to the ground, allowing absorption of heat radiated from the ground. Therefore, vertical surfaces on automobiles tend to be warmer than horizontal surfaces. This is why dew and frost form so readily on horizontal surfaces on automobiles, such as the hood, trunk, and roof, while automobile vertical surfaces, such as the sides of fenders, have little or no dew or frost. To do this experiment properly, the maker of the video ought to have compared the temperature of the side of the fender that was in moonlight to the temperature of the fender in shadow, making sure to sample both fenders at the same height above the ground. Furthermore, it is important to make sure that the surfaces below the two fenders are the same as possible. My own experimentation confirms my expectation that if one fender is above grass while the other is above concrete, the fender above concrete will be warmer. Furthermore, I confirmed that temperatures of a fender measured lower to the ground are warmer.

Thus, there are many tricks that one can employ to get the desired results. Most people aren't aware of the many factors that can skew the results, so most people do not know about the nuances that can affect IR temperature measurements. Some of the people who post these videos promoting the false notion of moonlight being cooling probably know what they are doing, and so are blatantly dishonest. Other people who post these videos online probably do not know what they are doing, and so stumble onto the results that flat earthers claim. However, even a person who does not know what he is doing must occasionally stumble onto the opposite results. But these results never seem to appear on the internet. It seems that flat earthers post only the videos with results that conform to what they want to believe. This is dishonest and involves cherry picking data which supports their paradigm.

Experiment 1

As I previously stated, I have done this simple IR-thermometer experiment many times, and I have had difficulty repeating the results claimed by flat earthers. Some of my experiments have been informal, while others have been more carefully conceived. It is important to devise and carry out the experiment in a way that avoids the pitfalls that I discussed above. I will now explain the methodology that I developed to conduct properly the following experiment. Since grass absorbs sunlight during the day and radiates heat away on clear nights, it provides the possibility of conducting this experiment under controlled conditions. However, it is important to select stands of grass in and out of the shade of moonlight that are similar.

The display on my IR thermometer has both Celsius and Fahrenheit settings. In either mode, the temperature reads to 0.1°. While Celsius normally is the preferred scientific temperature scale, I chose to use Fahrenheit because Fahrenheit is $^9/_5$ finer scale than Celsius. When I pull the trigger on the thermometer, the output updates every second. When I release the trigger, the display holds the current reading. So that I would not bias the results, when I recorded temperature measurements, I pulled the trigger while not looking at the display, waited a couple of seconds, and then released the trigger and looked at the display to take the held reading. When I measured the temperature of the grass at one location, I took at least ten readings this way. I read the temperature readings aloud and recorded them on an audio recorder. I later played the recording and entered the first ten temperature readings into an Excel spreadsheet. This allowed me to form an average temperature measurement, as well as the standard deviation of each temperature average. Most such measurements were made on grass in the yard at my house. However, when on trips I took measurements on any grass that I could find. All runs of this experiment were conducted on nights with clear skies and a reasonable amount of moonlight, usually first quarter to third quarter phases. While the grass in my yard and other places that I conducted this experiment appeared to be uniform, there were slight variations in height, thickness, lushness, and other conditions. These variations in the grass at different locations could cause slight differences in temperature due to differences in emissivity. However, in repeating this experiment on later dates, I usually had to change locations where I measured the temperature of the grass, so the effects of any variations eventually ought to cancel.

To test whether moonlight cools objects, one obviously must measure the temperatures of similar objects (grass in this experiment) in moonlight and out of moonlight. However, there is the additional factor of radiative cooling that I already discussed. Since I am concerned that many of the results of flat earthers may be due to this affect, I took measurements under and not under the canopy of trees. Therefore, I made four different temperature measurements:

1. Temperature taken in moonlight with no canopy
2. Temperature taken in moonlight with a canopy
3. Temperature taken out of moonlight with a canopy
4. Temperature taken out of moonlight with no canopy

For each of the four cases, I took ten measurements to obtain the average temperature and standard deviation, for a total of 40 measurements each time that I did the experiment.

If the flat earth claim is correct, then the temperatures taken in 1 and 2 would be cooler than the temperature taken in cases 3 and 4. On the other hand, I would expect that radiative cooling would make the temperatures of cases 1 and 4 cooler than the temperatures taken in cases 2 and 3. If one believed that moonlight is cooling *and* accepted the reality of radiative cooling, then one would expect that the temperature of case 1 would be the coolest, while the temperature of case 3 would be the warmest; it is not clear which of the temperatures taken in case 2 or case 4 would be cooler.

I will now share the results of one of the first times that I did this experiment, on the evening of July 24, 2018. I took temperature measurements in my front yard at 10:00 p.m. EDT, about one hour after sunset. While it was still astronomical twilight, civil twilight had long ended, and possibly nautical twilight as well. At any rate, many stars were visible. The moon was waxing gibbous, 2.75 days from full. The sky was mostly clear, and the air temperature was in the mid-70s° Fahrenheit.

The results were as follows:

Case 1: T = 62.64° F, S.D. = 0.368° F
Case 2: T = 64.60° F, S.D. = 0.22° F
Case 3: T = 63.43° F, S.D. = 0.104° F
Case 4: T = 61.71° F, S.D. = 0.45° F

While I have reproduced full accuracy here, the average temperatures and standard deviations are probably meaningless past the first place to the right of the decimal point. Hence, in what follows I will round these the nearest 0.1° F.

Notice that the coolest average temperatures are cases 1 and 4, in line with the expectation of radiative cooling alone. However, the expectation of flat earthers that moonlight cools objects is not confirmed—case 3 is the second warmest average temperature, while case 2 is the warmest average temperature. I can express this a different way: take the average of the average temperature of case 1 and case 2, and take the average of the average temperature of case 3 and case 4. The former average temperature (in moonlight) is 63.6° F, while the latter average temperature (not in moonlight) is 62.6° F. That is, the combined average moonlight temperature is 1.0° F warmer than the combined average shade temperature. This contradicts the prediction of the flat earth. On the other hand, the average of the average temperatures of cases 2 and 3 (under the canopy) is 64.0°F, while the average of the average temperatures of cases 1 and 4 (no canopy) is 62.2°F. That is, the average temperature under the canopy is 1.8°F warmer than not under the canopy, which is consistent with the expectation of radiative cooling. Therefore, the results of this experiment disprove the flat earth prediction but are consistent with the expectation of radiative cooling.

In the four month period between late June and late October 2018, I did this experiment with the same methodology 32 times. For each run of the experiment, I formed two differences, the difference between the average temperature in moonlight with no canopy above and the average temperature with no moonlight with no canopy above (case 1 minus case 4), and the difference between the average temperature between moonlight under a canopy and the average temperature with no moonlight under a canopy (case 2 minus case 3). If moonlight is cooling, as many flat earthers maintain, then these two temperature differences ought to be negative. However, if moonlight is warming, these two temperature differences ought to be positive. If moonlight has no effect on temperature, then the two temperature differences ought to be zero. I found that the first temperature difference (case 1 minus case 4) was negative on six of the 32 nights and was positive on the remaining 26 nights. The first average temperature difference for the 32 nights was 1.2°F, with a standard deviation of 1.5°F. I found that the second temperature difference (case 2 minus case 3) was negative on 13 nights, with the difference being positive on the remaining 19 nights. The second average temperature difference was 0.3°F, with a standard deviation of 1.2°F.

These results clearly contradict the prediction of the notion that the moon's light is cooling. Taken at face value, the results could be interpreted as confirming the idea that the moon's light is warming. However, notice that the standard deviations of both average temperature differences are greater than the average temperature differences themselves. This means that statistically both average temperature differences are consistent with zero average temperature difference. Therefore, these results are consistent with moonlight having no effect on the temperature of objects. The very modest positive value of these two average temperature differences, and the fact that both average temperature differences were positive on more nights than they were negative, could be the result of differences in grass at different locations sampled each night. If so, further experiments could reduce the average temperature differences. At any rate, the results that I've presented do not confirm the prediction of the flat earth model.

Experiment 2

I devised a second experiment to test the flat earth claim that moonlight is cooling. While similar to the first experiment, this approach is less likely to be affected by differences in the surface sampled that could skew the results of the first experiment. On the evening of October 21, 2018, I placed a ¼ in piece of plywood 6 in wide and 45 in long on two bricks set on their ends so that the plywood was 7¾ in above concrete on the sidewalk and driveway in front of my house. One-half the board was exposed to moonlight, while the other half was shaded from the moonlight by a van parked a short distance away (see fig. 1). The moon was waxing gibbous, three days short of full. The air temperature was in the low 40s °F. I began taking temperature measurements with the IR thermometer shortly after 8:00 p.m. EDT, more than 20 min after I had set up the board as described. I took temperature measurements of either end of the board, in moonlight and not in moonlight, using the same technique of the first experiment, taking ten readings and averaging the results. The average temperature of the moonlit end of the board was 30.16°F, with a standard deviation of 0.24°F, while the average temperature of the end of the board not in moonlight was 28.28°F, with a standard deviation of 0.096°. This is a temperature difference of +1.88°F. As before, digits more than one place to the right of the decimal point probably are not significant. Since this temperature difference is positive, this would seem to disprove the flat earth claim that moonlight is cooling. However, I would not expect the moonlit end of the board to be warmer. Given the sizes of the standard deviations of the temperature averages, the positive temperature difference appears to be real.

Fig. 1. The plywood board supported on bricks with half the board in moonlight and half the board in shade. The glow to the lower right is the light of a flashlight.

There is another possible explanation for why the temperature change is positive rather than zero. Differences in grain, color, texture, and finish between the two ends of the board could account for the positive temperature difference. To mitigate this possibility, I turned the board around, swapping which end of the board was in moonlight and which end was not. After about 20 min, I repeated the experiment. This time, the average temperature of the moonlit end of the board was 25.56°F, with a standard deviation of 0.112°F, while the end of the board in shadow was 26.44°F, with a standard deviation of 0.22°F. This is a difference of –.088°F. This result could be interpreted as confirmation that there is a difference in the two ends of the board, with one end consistently reading a lower temperature. The average of the two temperature differences was +0.5°F. Given the uncertainties indicated by the sizes of the standard deviations, this result could be consistent with no temperature difference due to moonlight.

Notice that the temperature of either end of the board fell between the two runs of the experiment discussed above. This temperature drop undoubtedly was due to radiative cooling, since this experiment was conducted with no canopy overhead. On the next evening, October 22, 2018, I repeated and expanded the experiment under conditions that largely removed radiative cooling as a factor. I conducted the experiment on the deck next to Johnson Observatory at the Creation Museum. The observatory has a roof that rolls off the observatory and over the deck. I removed the roof from the observatory, using it to cover the deck, more than 1½ hr after sunset. This time after sunset was adequate for the deck and its furnishings to have cooled below air temperature, which was in the low to mid 50s°F. However, since the roof was now over the deck, further radiative cooling was inhibited. Instead of using bricks to support the board, I placed the same board on two traffic cones so that the board was 27¼ in above the floor of the deck. I set up the board so that one end was in moonlight while the other end was in the shadow of the roof. As before, about half the board was in moonlight and half of the board was in shadow. As before, I let the board sit this way for 20 min before making measurements, after which I turned the board around, waited 20 min, and repeated the experiment. But then I rolled the board over, waited 20 min, took the measurements again, and then turned the board around, waited 20 min, and then took measurements again. That is, I used both ends of both sides of the board to get four sets of measurements. This was to account for any differences between either end and either side of the board.

Numbering each arrangement sequentially, here are my results:

1. moonlight temperature = 48.66°F, SD = 0.14°F
   no moonlight temperature = 48.15°F, SD = 0.09°F
2. moonlight temperature = 48.52°F, SD = 0.27°F
   no moonlight temperature = 48.12°F, SD = 0.14°F
3. moonlight temperature = 49.08°F, SD = 0.16°F
   no moonlight temperature = 48.56°F, SD = 0.22°F
4. moonlight temperature = 46.74°F, SD = 0.35°F
   no moonlight temperature = 46.09°F, SD = 0.15°F

Notice that, due to the roof over the deck, there was not much temperature drop during the nearly 1½ hrs of the experiment. The average temperature difference of all four runs was +0.5°F. Interestingly, like the previous run of this experiment and most of the runs of the first experiment, there appears to be an inclination for moonlight temperatures to be very slightly warmer than shadow temperatures. I have no explanation for this. The difference may not be statistically significant, but I would have expected at least one of the moonlit temperatures of this particular run of this experiment to be cooler. At any rate, these results do not agree with the claims of many flat earthers with regards to supposed cooling properties of the moon's light.

Experiment 3

While the first two experiments disprove the flat earth claim that moonlight is cooling, there is the pesky problem of evidence from either experiment that could be interpreted as moonlight having a heating effect. But, as argued above, this result may not be statistically significant enough to warrant that conclusion. I conducted a third experiment that was a more direct way to test this flat-earth claim that is similar to two experiments Rowbotham (1881) mentioned.

The Souther telescope at the Johnson Observatory at the Creation Museum is a 16 in Newtonian. This large aperture collects much light, and its relatively short focus produces a small image, thus concentrating the light of any object at which the telescope is pointed. A piece of paper placed at the focal plane while the telescope is pointed toward the sun will ignite in about one second. Therefore, one would expect that any appreciable cooling (or heating) of the moon's light will be detectable when the telescope is pointed at the moon. I conducted the following test with this telescope on the evening of September 18, 2018 when the air temperature was 21°C.

I drilled a hole through the center of a number 7 stopper. The diameter of the narrower end of a number 7 stopper is slightly less than 1¼ in. Since the standard eyepiece barrel has 1¼ in diameter, a number 7 stopper easily and snugly fits into the eyepiece holder of the Souther telescope. I placed a standard lab alcohol-filled bulb thermometer through the hole in the stopper so that the bulb was at the focal point of the telescope. The thermometer reads between –10°C and 110°C and is graduated with 1°C increments, but with a magnifier, one can interpolate the temperature to 0.1°C. With the thermometer so placed, I recorded the temperature on the thermometer and then pointed the telescope at the moon. The sidereal drive of the telescope kept the moon centered on the thermometer bulb. After five minutes of exposure to the moon's light, I recorded the temperature on the thermometer, and then moved the telescope so that the moon's light did not fall on the thermometer's bulb. After five minutes with no moonlight exposure, I recorded the reading on the thermometer. I repeated this procedure ten times. If the moon's light has a cooling effect, then the temperatures ought to fluctuate between warmer temperatures when the telescope was not pointed at the moon and cooler temperatures when the telescope was pointed at the moon.

The recorded temperatures are listed in Table 1, along with times of each measurement. Fig. 2 is a plot of the temperatures as a function of time. The initial temperature recorded on the thermometer equaled the air temperature, but the temperatures recorded thereafter show a consistent trend of decreasing temperature over time. This steady temperature decrease is the result of radiative cooling of the telescope as it was exposed to the clear sky. This does not match the prediction of the hypothesis that moonlight is cooling. Hence, the conclusion is that the hypothesis is false.

Why is there a nearly constant decrease in temperature? As I mentioned before, objects exposed to a clear sky at night with little wind radiate heat, usually assuming a temperature several degrees below air temperature. The observatory has a roll-off roof, which I removed shortly before beginning the experiment. Being under a roof all day and into the evening, the temperature of the telescope initially was warmer than air temperature. Hence, the trend in decreasing temperature is expected. While the plot of temperatures at first appears linear, the trend is more accurately described as an exponential decay toward an equilibrium temperature. The exact value of the equilibrium temperature depends upon several factors, such as air temperature, humidity, transparency of the sky, wind, and the emissivity of the object that is radiating (the telescope in this case). The plot shows a slight flattening in the temperature decrease after about 80 min. This conforms to the expected exponential decay in temperature.

Is it possible that moonlight has a very modest cooling effect that is masked by the overall trend of radiative cooling? If so, then there ought to be small increases in temperatures in going from moonlight to no moonlight. Table 2 shows the temperature changes in successive measurements when going from moonlight to no moonlight, as well as when going from no moonlight to moonlight. None of the

Table 1. Bulb theremometer temperatues taken on September 18, 2018.

Time (EDT)	Temp. (C)
22:20	21.0
22:25	20.6
22:30	20.2
22:35	20.0
22:40	19.8
22:45	19.7
22:50	19.5
22:55	19.1
23:00	19.0
23:05	18.8
23:10	18.4
23:15	18.2
23:20	18.0
23:25	17.8
23:30	17.5
23:35	17.2
23:40	17.0
23:45	17.0
23:50	17.0
23:55	16.9
0:00	16.8
0:05	16.7
0:10	16.5

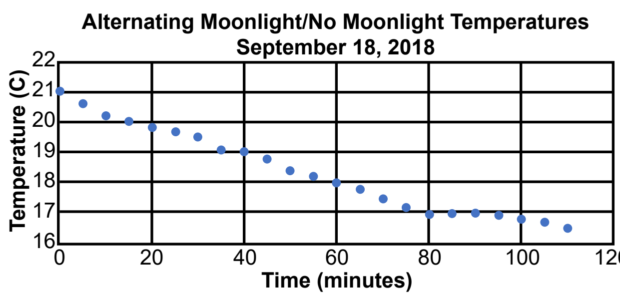

Fig. 2. Thermometer bulb temperatures taken under alternating conditions of focused moonlight and no moonlight on September 18, 2018. The temperatures do not fluctuate between alternating higher and lower temperatures, as would be expected if moonlight has a cooling effect.

temperature changes were positive. If moonlight has any cooling effect, then at the very least the average of the temperature decreases in going from no moonlight to moonlight ought to be greater than the average of the temperature decreases in going from moonlight to no moonlight. However, the average temperature change in going from no moonlight to moonlight was –0.2°C, with a standard deviation of 0.1°C, while the average temperature change in going from moonlight to no moonlight was –0.2 C with a standard deviation of 0.1°C. These temperature changes statistically

Table 2. Comparison of moonlight/no moonlight temperatures of September 18, 2018.

Temp. Difference (C) Moon—no moon	Temp. Difference (C) No moon—moon
–0.4	–0.4
–0.2	–0.2
–0.1	–0.2
–0.4	–0.1
–0.2	–0.4
–0.2	–0.2
–0.2	–0.3
–0.3	–0.2
0.0	0.0
–0.1	–0.1
–0.1	–0.2

are the same. Therefore, there was no difference in temperature change when alternately exposing the thermometer bulb to moonlight and no moonlight. Again, the hypothesis that moonlight is cooling is disproved with high statistical significance.

Lest anyone suggest that the cooling of the entire telescope was because of the moon's light, I repeated the experiment as a control on the morning of October 17, 2018, when the moon was not in the sky. The telescope was parked (the sidereal drive was not engaged) in the approximation position of the experiment of September 18, 2018. As before, I took temperature readings at five minute intervals. However, since the moon was not visible, I did not move the telescope between temperature measurements. I began taking measurements at 4:15 a.m. EDT, more than three hours after the first quarter moon had set, and concluded at 6:00 a.m., shortly before the onset of astronomical twilight. The air temperature was 4°C. Table 3 lists the time and temperature measurements, and fig. 3 shows the plot of the data. The initial temperature measurement was slightly less than air temperature, and the temperature fell more rapidly than during the September 18, 2018 experiment. The expected exponential decay was much more obvious than with the earlier experiment, but, as before, the flattening in the temperature decay set in after about 80 min. The temperature drop was greater than during the earlier experiment. Indeed, the telescope had already cooled approximately 1°C below air temperature before I started taking measurements. This cooling had occurred even though I began collecting data almost immediately after removing the observatory roof, whereas, during the earlier experiment I did not start taking readings immediately. All of this is explained by the fact that the air was much drier in the second experiment, leading to much more efficient radiative cooling than in the previous experiment.

Table 3. Bulb termometer temperatures taken on October 17, 2018.

Time (EDT)	Temp. (C)
4:15	3.2
4:20	2.3
4:25	1.5
4:30	0.5
4:35	0
4:40	–0.2
4:45	–0.8
4:50	–1
4:55	–1.2
5:00	–1.3
5:05	–1.4
5:10	–1.6
5:15	–1.7
5:20	–1.8
5:25	–1.9
5:30	–1.9
5:35	–2
5:40	–2
5:45	–2
5:50	–2
5:55	–2
6:00	–2.1

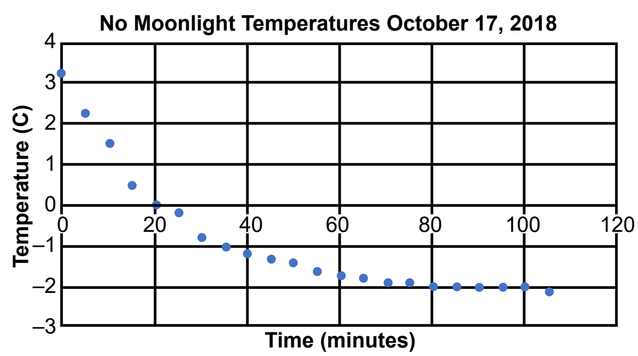

Fig. 3. Thermometer bulb temperatures taken with no moon on October 17, 2018.

Finally, I conducted the experiment with moonlight through the telescope a second time, on the evening of October 22, 2018. (I did this experiment while also doing the second run of the second experiment discussed above.) The air temperature at the start of the experiment was 17°C. I followed the same procedure as before. The temperature measurements are in Table 4, and the data are plotted in fig. 4. Notice that, as before, the temperature follows an exponential decline that appears to bottom out after about 80 min. The data don't appear to show a trend of larger temperature decreases when the thermometer was exposed to moonlight. Table 5 shows the temperature differences in going from moonlight

Table 4. Bulb thermometer temperatures taken on October 18. 2018.

Time (EDT)	Temp. (C)
8:55	17.0
9:00	15.9
9:05	14.9
9:10	14.0
9:15	13.5
9:20	13.2
9:25	12.9
9:30	12.7
9:35	12.3
9:40	12.0
9:45	12.0
9:50	12.0
9:55	12.0
10:00	11.9
10:05	11.8
10:10	11.6
10:15	11.3
10:20	11.1
10:25	11.1
10:30	11.1
10:35	11.0
10:40	11.0
10:45	11.0

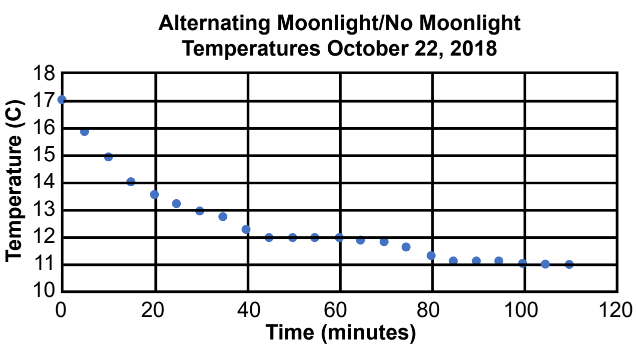

Fig. 4. Thermometer bulb temperatures taken under alternating conditions of focused moonlight and no moonlight on October 18, 2018. Again, the temperatures do not fluctuate between alternating higher and lower temperatures, as would be expected if moonlight has a cooling effect.

to no moonlight and the temperature differences in going back from no moonlight to moonlight. In no cases were the temperature changes positive. The average temperature change in going from moonlight to no moonlight was –0.30°C, with a standard deviation of 0.25°C; while the average temperature change in going from no moonlight to moonlight was –0.23°C, with a standard deviation of 0.23°C. Since the average temperature changes are similar to one another and comparable to their standard deviations, these average temperature changes don't indicate any trend. Therefore, the results of both runs of this experiment lead to the conclusion that there is no temperature change brought about by concentrating the moon's light.

Table 5. Comparison of moonlight/no moonlight temperatures of October 18, 2018.

Temp. Difference (C) Moon—no moon	Temp. Difference (C) No moon—moon
–1.1	–1.0
–0.9	–0.5
–0.3	–0.3
–0.2	–0.4
–0.3	0.0
0.0	0.0
–0.1	–0.1
–0.2	–0.2
–0.2	0.0
0.0	0.0
0.0	0.0

Conclusion

I have conducted three independent experiments to test the claim that moonlight is cooling. The first experiment involved measuring the temperature of grass under four different conditions. I did this experiment 32 times. The second experiment involved measuring a length of plywood with one end in moonlight and the other not in moonlight. I did this experiment twice, albeit the second time under more controlled conditions and with more extensive measurements. The third experiment involved measuring the effect of concentrated moonlight on the bulb of thermometer. I did this experiment twice, but I also did a control experiment with no moon in the sky to demonstrate that the overall cooling of the telescope was not due to exposure to moonlight.

The results of all three experiments disprove the claim of many flat earthers that moonlight is cooling. The first two experiments provided evidence that the moon's light might have a slight heating effect. However, that trend in the data is contradicted on some runs of the experiment, and the statistics suggest slight heating of moonlight may not be significant. The third experiment was the most robust, and its results provide no evidence for any heating or cooling of moonlight. The results of this study very clearly show that the claim that moonlight is cooling is false.

This claim about moonlight really does not depend upon the flat earth model. Rather, it seems to be an add-on that does nothing to advance the flat earth model. Rowbotham's one mention of this possibility appears to be outweighed by his other statements to the contrary. Carpenter didn't mention it. This embellishment of the flat earth model appears largely to have originated with Scott's book written after the books of Rowbotham and Carpenter. Consequently, if flat earthers were to repudiate this false claim about moonlight, it would not directly affect their model.

So why do flat earthers refuse to acknowledge that this claim about moonlight is false? (I'm not aware of a single flat earther who repudiates this claim.) The major reason probably is linked to the flat earth belief that the moon emits its own light rather than reflecting the light of the sun. In the estimation of flat earthers, if they can demonstrate that the moon's light is fundamentally different from sunlight, then that proves their contention that the moon is its own source of light. But it may be that flat earthers view any retreat as admission of weakness of their model. They may fear that if they concede that any claim made by fellow flat earthers (particularly those claims made more than a century ago) will raise the question of what other things about which fellow flat earthers are wrong.

Flat earthers frequently implore others, "Research it!" However, when I have presented original research such as this that disproves their model, flat earthers generally ignore it. They generally don't attempt a refutation. Instead, they refuse to interact with it all. Will flat earthers do the same with the research presented here?

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