A Novel Perspective on the Greenhouse Effect

What a Heat Loss Vacuum Gauge Can Teach Us about Energy Balance in the Lower Atmosphere

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The figure below, published by NASA, is one example of many that attempt to visualize the various factors in the "Energy Budget" of the Earth. The yellow arrows on the left depict the incoming solar radiation. It is in part absorbed by the atmosphere, partially reflected into space by clouds and the atmosphere, partially reflected by the surface of the Earth, and a bit less than 50% is absorbed by the surface of the Earth and converted into heat. On the right, the red arrows depict the paths that transport the energy from the Earth's surface to space, as postulated by the greenhouse effect. This model of the "Energy Budget" is the basis of climate models attempting to predict the effects of hypothesized Anthropogenic Global Warming (AGW) from greenhouse gases.

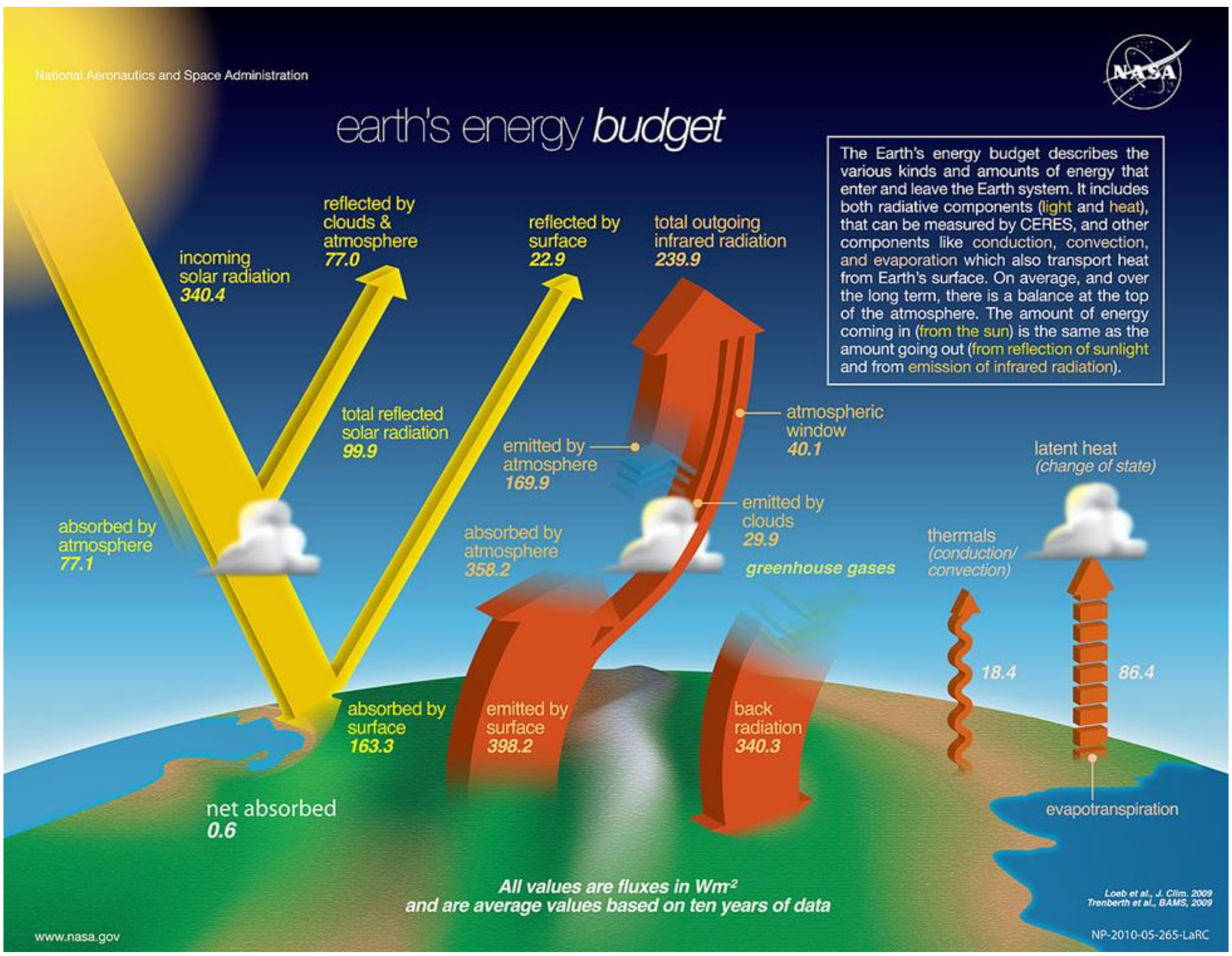


Diagram Courtesy of NASA

As the inset paragraph in the NASA diagram states, "*On average, and over the long term, there is a balance at the top of the atmosphere*."

The values associated with each of the arrows in the diagram are the corresponding energy fluxes in Watts/m^2. These values are derived in different ways, some of which are relevant to this exposition and will be described below. These values are used in climate models and may vary as the models evolve, though typically not by much. Some typical values from a NASA document can be found on page 16 HERE.[1] Certain assumptions led to the development of the Greenhouse Gas Theory. One of the conclusions explained at Earth Temperature without GHGs - Energy Education[2] is that without greenhouse gases, the earth would be approximately 33 C cooler, essentially an average temperature near freezing. This is the result of treating both the Earth and its atmosphere as blackbodies following the Stefan-Boltzmann Law, as is discussed in this VIDEO[3] from an online course about climate modeling.

From the energy budget diagram, there are four red arrows corresponding to (average) longwave (Infrared) radiation flux. They are as follows:

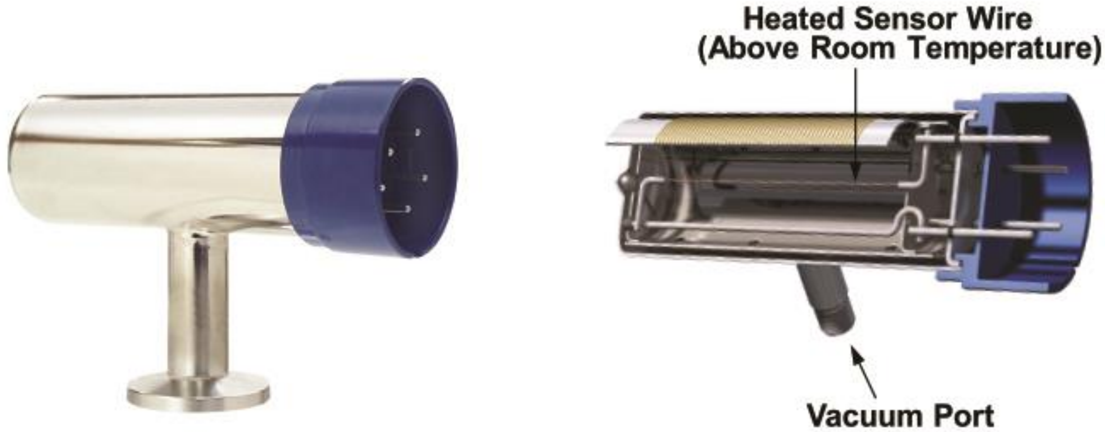
- 398.2 Watts/m^2 longwave radiation upwelling from the surface
- 18.4 Watts/m^2 upward from conduction/convection
- 86.4 Watts/m^2 upward from evapotranspiration
- 340.3 Watts/m^2 longwave radiation downwelling from the atmosphere as Back Radiation

According to the greenhouse effect, it is the downwelling Back Radiation that "traps" the heat in the atmosphere to keep the Earth warm.

For purposes of this exposition, we will consider only first two components above, as we will be investigating the relationship between upwelling longwave radiation and conduction/convection at the Earth's surface. According to the model explained above, 398.2 W/m2 represents approximately 95.5% of shared heat transport and conduction/convection approximately 4.5% of shared heat transport.

How might we measure this? We know that there are three mechanisms for transport of heat energy: conduction, convection, and radiation. One needs to design an experiment that can discern the proportion of heat loss due to radiation versus the heat loss due to conduction and convection. It so happens that there is a common instrument that has been in use for over 100 years that does precisely this.

The Pirani Gauge



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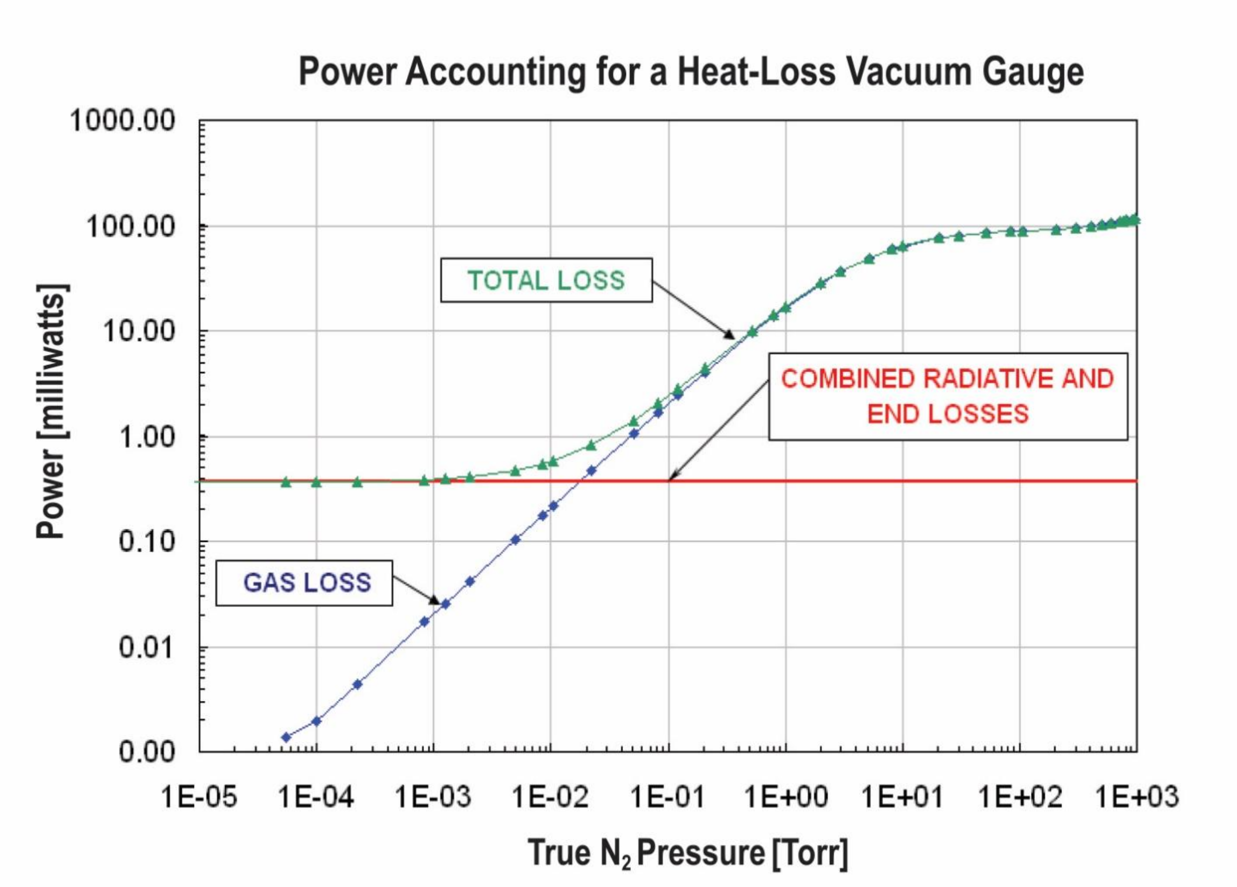
The modern Pirani Gauge is used to measure vacuum in the range from 760 Torr to 10^{-4} Torr, though some are designed to measure higher pressures up to 1000 Torr. It was invented in 1906 by Marcello Pirani, a German physicist working for Siemens & Halske, and has been used in a myriad of applications for over 100 years. The operating principle of the gauge is simple. Inside the gauge body there is a filament that is heated and maintained at a constant temperature. The energy going into the filament is controlled via the current flowing through it. Energy can be dissipated from the filament in four ways:

- Gas Conduction
- Gas Convection
- Radiation
- End Losses (i.e., conduction of heat from the filament to its support structure.)

The Radiation and End Losses are constant and can be measured by creating an adequate vacuum inside the gauge so that losses from conduction and convection are negligible. When gas is introduced to the enclosure, heat is removed from the filament via conduction and convection. The input power required to maintain the temperature of the filament will depend on how much energy is being removed via conduction and convection by the gas. In summary, the Pirani gauge tells us the relative contributions to heat transport by radiation versus conduction/convection as a function of gas pressure for an object (the filament in this case) held at a constant temperature. Referring to the paragraph preceding the above image, this is exactly the measurement we are looking for.

The response curve for a typical gauge is shown in next illustration. Both illustrations can be found in the Technical Note "Introduction to Vacuum Pressure Measurement" published by MKS Instruments, and the specific gauge illustrated in the figure is an MKS Instruments convection enhanced Pirani gauge.



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The red line in the chart represents the (constant) total radiative and end losses of approximately 0.4 mW. The blue line represents the power loss due to gas only, and the green curve that flattens out on the two ends represents the total loss, i.e., the total energy input required to maintain the temperature of the filament as a function of pressure. At atmospheric pressure, 760 Torr, the power required to maintain the temperature of the filament is 100 mW. Since the radiative and end losses are 0.4 mW, this means that the heat transport by gas is 99.6%, with only 0.4% due to radiative and end losses. This should not be surprising, because all gas molecules can transport heat via conduction and convection, not just the tiny fraction that constitute the so-called "greenhouse gases."

We can also consider the case of a vacuum pressure of 10 Torr, the equivalent of about 110,000 feet above sea level. In this case, about 60 mW of power is required to maintain the filament temperature, so the gas is still accounting for about 99.3% of heat transport with radiative and end losses only 0.7%. As one goes higher in altitude a larger proportion of the heat transport is attributable to radiation, and that is how all the heat eventually returns to space in the extreme upper atmosphere. The crossover point, where gas losses are equal to radiative and end losses, is at about 20 millitorr (.02 Torr), equivalent to an altitude beyond 250,000 feet. The response of the Pirani gauge is independent of the enclosure it is in or the lack thereof. If we took a "naked" Pirani gauge to an altitude where the atmospheric pressure is 10 Torr, the response would be the same as if it was attached to a vacuum system at a pressure of 10 Torr. There have been Pirani gauges made in many different sizes and configurations, some with radiative losses on the order of 0.1% at standard atmospheric pressure.[4]

The filament in the Pirani gauge is analogous to the surface of the Earth. The gas molecules collide with the surface and absorb energy raising their effective temperature (conduction). A "bubble" of this warmer gas then rises relative to the cooler gas around it as the cooler gas drops to the surface and repeats the cycle continuously (convection). This cools the surface and is perfectly illustrated by the response of the Pirani gauge. This is well understood by those who have worked with high temperature processes in vacuum systems, and no doubt by many others. The author can only speculate regarding why this has not been given consideration earlier.

Conclusions

The Pirani gauge provides a method to measure the relative contributions of radiation vs. conduction/convection to heat transport in a gaseous environment as a function of pressure. At pressures relevant to the lower atmosphere (troposphere + stratosphere) radiation accounts for less than 1% of the upward heat transport. This does not refute the existence of said radiation in the lower atmosphere, it only demonstrates experimentally that its role in upward heat transport is insignificant.

It has been demonstrated via the Pirani gauge operating principle that upward heat transport via radiation plays an insignificant role in the transport of heat at atmospheric pressures from the surface to the upper stratosphere. The greenhouse effect, if it exists, is based on upward heat transport via radiation in the lower atmosphere. Therefore the greenhouse effect, if it exists, plays an insignificant role in heat transfer and, by extension, the energy balance of the atmosphere.

Contemporary climate models are based on energy balance models of the type depicted in the NASA diagram at the beginning of this paper. It is clear from the NASA diagram as well as similar diagrams from other sources that the fundamental assumption of these models is that radiation is the primary driver of upward heat transport in the lower atmosphere. Because radiation is an insignificant driver of upward heat transport in the lower atmosphere, these models are based on a false assumption and are therefore invalid. Finally, because the models are generally intended to support the theory of Anthropogenic Global Warming because of the greenhouse effect, there is no scientific evidence for the greenhouse effect or Anthropogenic Global Warming.

The radiation energy that the Earth absorbs from the Sun arrives at the speed of light. The Earth loses heat at a speed driven by convection in a process we call "weather." Weather is the chaotic process by which the Earth's atmosphere continuously tries to reach thermal equilibrium but never succeeds. The convection takes place continuously, but the speed at which heat is transported by convection is MUCH slower than the speed of light. This means that heat energy leaves the Earth more slowly than it arrives, and that is why the Earth is warmer than predicted by the Stefan-Boltzmann Law.

Appendix

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How did "Climate Science" get this so wrong?

The two fundamental assumptions leading to the Greenhouse Effect are that 1) The primary mechanism by which the surface of the Earth loses heat is radiation and, 2) Based on the Stefan-Boltzmann Law the temperature of the Earth's surface should be 33K cooler than what we observe.

The Stefan-Boltzmann Law (SBL) defines a blackbody (which is an idealized object that does not exist in nature) as having the following characteristics:

1. It exists in an environment at 0K, i.e., a perfect vacuum.
2. It is in equilibrium with its environment.
3. It is a perfect absorber of radiation.

With certain adjustments such as emissivity, the SBL provides a convenient means of measuring the temperature of an object based on its emitted radiation even in non-ideal environments. The estimation of the temperature of stars for example, and the use of infrared cameras to detect "hot spots." One must be careful, however, to keep in mind that it is only the "idealized" black body that behaves strictly according to the SBL.

The Earth and its atmosphere do not satisfy any of the conditions of SBL. Additionally, it has become common to ignore condition number 1 above. If one looks up the definition of a blackbody, a reference to the 0K (perfect vacuum) condition is often not mentioned. This typically has little effect when it comes to temperature measurements using optical techniques, but it is extremely important in understanding the dynamics of heat transfer in, for example, terrestrial conditions.

This is neglected in climate models. It assumes that with the surface temperature of 288K the power radiated upward from the surface is 398 Watts/m^2 and that it is all longwave IR radiation. It then becomes necessary to "balance" that upwelling radiation with "back radiation" to obtain "radiative balance" in the atmosphere.

What is happening is quite different. At 288K temperature the photon flux (generously assuming it is all at 15 micron wavelength to maximize the number of IR active photons) is approximately **$3X10^{22}$ photons/sec-m^2**. That is a lot of photons, and if the surface was in a perfect vacuum that radiative flux would be the only way for the surface to release energy.

But we have an atmosphere. At standard temperature and pressure, air has some very interesting properties. It is much denser than we typically imagine.

Average molecular velocity approximately **470 m/sec (1050 mph, supersonic at the macro level)**
Molecular collision frequency (each with another) approximately **7,000,000,000 collisions/sec (7 GHz)**
Mean free path approximately **70 nm (about 1/10 wavelength of visible light)**
Frequency of collisions with an ideal planar surface approximately **$3X10^{27}$ collisions/sec-m^2**

To put this in perspective, the last number is quite useful. The average surface area of an adult human is around a square meter. That means that each second about 100 lbs. of air molecules collide with each of us with an average speed of about 1050 mph. More importantly, given the photon flux at 288K this means that **approximately 100,000 air molecules collide with the surface for each *potential* infrared photon emitted.** Because the energy transfer from collisions will change the equilibrium at the surface by removing energy through conduction, it is likely that the actual emitted photon flux will be even less. To believe that radiative transfer is the primary mechanism for upward heat transfer at the Earth's surface would mean that one IR photon would transfer more energy than 100,000 molecular collisions. These numbers are for a perfectly smooth planar surface. The actual surface area at an atomic level can be much greater.

Clearly, the interface between the surface of the Earth and the atmosphere is an extremely chaotic place at the atomic level. This gives perspective to explain what we see in the operation of the Pirani gauge as explained in the body of this paper.

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[1] Kelly, Schmidt, et al, GISS-E2.1: Configurations and Climatology
[2] Earth Temperature without GHGs - Energy Education
[3] (224) Climate Dynamics Lecture 02 Energy and the Earth System - YouTube
[4] Fabrication of thermal-based vacuum gauge - Jung - 2014 - Micro & Nano Letters - Wiley Online Library