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THE GREENHOUSE AND ITS EFFECTS



By

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ABSTRACT

The climate of the earth is said to be controlled by a mechanism called "The Greenhouse Effect" named because of its resemblance to the action of a greenhouse, which is supposed to cause a warming effect on its contents. Yet what actually happens in a greenhouse is imperfectly understood, and its influence on our climate confused.

This article surveys the history of attempts to explain the action of a greenhouse and its relationship to our climate. It provides an improved explanation of the behaviour of a greenhouse which applies also to the behaviour of the climate.

The so-called pioneers, Fourier, Pouillet, and Tyndall, believed that the earth was warmed by absorption of the sun's ray by the atmosphere. Tyndall thought that this absorption was by water vapour. Arrhenius, who first claimed warming was caused by atmospheric absorption of radiation from the earth, claimed it was caused by carbon dioxide but he actually measured water vapour. Callendar, who revived the Arrhenius theory, firmly blamed carbon dioxide and ignored expert opinion that he had omitted the influence of air movement.

R W Wood showed that the air in a greenhouse is warmed by convection but failed to notice that this also implies cooling the earth, and that this only happens when the sun shines. When the sun does not shine, the previously warmed air helps to reduce cooling.

A greenhouse protects its contents from outside weather, and by convective and water vapour evaporation cooling when the sun shines, and mitigation of cooling when the sun does not shine. Similar mechanisms dominate the climate. Human influences such as weather protection and reduction of convection and water evaporation/deposition would cause warming.

Current computer models are shown to ignore the difference between day and night, and to place too much emphasis on radiation. Their calculations show that changes in convection and evaporation/deposition of water vapour, caused either by natural or human action are far more plausible reasons for changes in climate than increases in minor trace gases.

HISTORY OF THE GREENHOUSE EFFECT

FOURIER



The “greenhouse effect” is claimed^{1,2} to have been initiated in 1824 by Jean Baptiste Joseph Fourier (21 March 1768 – 16 May 1830)³.

He made several mathematical innovations which included the partial differential equations for conductive heat flow and the use of a series of sines of multiples of a variable to replace the variable, a technique now known as Fourier analysis.

On his return to France in 1801 he did experiments on the propagation of heat. He was in England from 1816-1822 and on his return became permanent secretary of the French Academy of Science.

In his 1822 book *Théorie Analytique de chaleur*^{4,5} he described the various forms of heat transfer and he postulated that heat transfer in solids varied according to a constant which became known as the thermal conductivity.

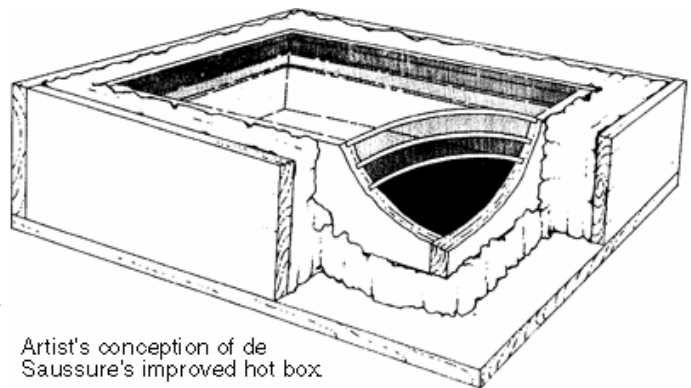
Fourier attempted to calculate the temperature of the earth in two publications^{6,7}. Casey⁸ has published the English translation of the 1824 paper by Burgess⁹ and an edited version of the paper based on it¹⁰. He has also provided an edited English translation of the 1827 paper¹¹ and useful discussion of the errors and misconceptions which have arisen¹², from which much of the following discussion has been derived.

Fourier was led to his theory from the experiments of his friend de Saussure with his solar heated "hot box", which was a miniature greenhouse¹³.

Horace-Bénédict de Saussure¹⁴ (February 17, 1740 – January 22, 1799) was a Swiss aristocrat, physicist and Alpine traveller, often considered the founder of alpinism, and considered to be the first person to build a successful solar oven. The increased use of glass during the eighteenth century made many people aware of its ability to trap solar heat.



.De Saussure gave a roundabout opinion of how the sun heats a hotbox as



Artist's conception of de Saussure's improved hot box

follows”¹³.

“Physicists are not unanimous as to the nature of sunlight. Some regard it as the same element as fire, but in the state of its greatest purity. Others envisage it as an entity with a nature completely different from fire, and which,

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incapable of itself heating, has only the power to give an igneous fluid the movement which produces heat."

This statement shows how far away from the concepts of modern science was the current understanding of the atmosphere and climate at the time.

Fourier in his 1824 paper¹⁰ (page 154) explained the "hot box as follows:

"The theory of the instrument is easily understood. It is sufficient to remark, 1st, that the acquired heat is concentrated, because it is not dissipated immediately by renewing the air; 2nd, that the heat of the sun, has properties different from those of heat without light. The rays of that body are transmitted in considerable quantity through the glass plates into all the intervals, even to the bottom of the vessel. They heat the air and the partitions which contain it. Their heat thus communicated ceases to be luminous, and preserves only the properties of non-luminous radiating heat. In this state it cannot pass through the plates of glass covering the vessel. It is accumulated more and more in the interval which is surrounded by substances of small conducting power, and the temperature rises till the heat flowing in, shall exactly equal that which is dissipated".

This statement amounts to the following propositions.

- Part of the heat is retained in the structure. (1st proposition)
- Most of the sun's rays (a considerable quantity) is transmitted through the glass
- They go to all parts of the vessel
- They heat the air and all the structure.
- The heat of the sun that is transferred to the air and to the structure ceases to be luminous and has the properties of non luminous heat.
- Non luminous heat cannot pass through plates of glass.
- It accumulates until the system is in equilibrium.

The air is heated by passage of the sun's rays, and this heat becomes "non luminous" (infrared) and then it emits radiation. The base and the sides are heated because it is still warm when the air is changed This heat also becomes "non luminous" and emits radiation. He does not say which is more important.

This "non-luminous" radiation cannot get out so it accumulates.

He would not have been aware of the discovery in 1850 by Melloni¹⁵ that glass absorbs most low temperature infrared radiation.

Casey¹² considered Fourier was talking about convection but there is nothing here to suggest heat transfer by conduction from the base and sides to the air. This is somewhat strange as he was well aware that such a process existed.

Fourier's study of the atmosphere began with his belief believed that space was filled with aether, which had a common temperature resulting from the radiation coming from all the stars, everywhere in the universe. He believed that heat from the sun warmed the earth to such a degree as to cause a variation with latitude and with the seasons. Yet he did not consider that the sun played an important part in heating the surface¹⁰ (page 165).

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"The solar heat has accumulated in the interior of the globe, the state of which has become unchangeable. That which penetrates in the equatorial regions is exactly balanced by that which escapes at the parts around the poles. Thus the earth gives out to celestial space all the heat which it receives from the sun, and adds a part of what is peculiar to itself."

He thought that the temperature of the earth was dominated by heat received from outer space, which led him to the view that the temperature of space was only just below that of the poles.

He considered that the extra heat needed was that which "has accumulated in the interior" and is "peculiar to itself".

However, when he added this in, it was not enough, so he had to find some extra heat

Fourier¹⁰ (page 154) reads

"In short, if all the strata of air of which the atmosphere is formed, preserved their density with their transparency, and lost only the mobility which is peculiar to them, this mass of air, thus become solid, on being exposed to the rays of the sun, would produce an effect the same in kind with that we have just described. The heat, coming in the state of light to the solid earth, would lose all at once, and almost entirely, its power of passing through transparent solids: it would accumulate in the lower strata of the atmosphere, which would thus acquire very high temperatures. We should observe at the same time a diminution of the degree of acquired heat,"

As with de Saussure's hotbox, "heat", which is part of the sun's rays and which "comes in the state of light to the solid earth" "loses its ability to pass through transparent solids" (eg glass) and "accumulates". This "heat" which is part of the sun's rays is thus absorbed by the atmosphere on the way down. He says:

"All the terrestrial effects of solar heat are modified by the interposition of the atmosphere and the presence of water. The great motions of these fluids render the distribution more uniform. The transparency of the waters appears to concur with that of the air in augmenting the degree of heat already acquired, because luminous heat flowing in, penetrates, with little difficulty, the interior of the mass, and non-luminous heat has more difficulty in finding a way out in a contrary direction."

He regards water vapour as "augmenting the degree of heat already acquired". There is no mention of any absorption from possible radiation from the earth itself.

Again, Casey¹² interprets his views as convection.

Fourier proposed that the earth's atmosphere is heated by absorption of the sun's rays, not by absorption of radiation from the earth. His views were very different from what is currently referred to as "the Greenhouse Effect".

The view of Fourier that the earth was warmed by absorption of the sun's rays by the atmosphere was supported by Claude Pouillet and John Tyndall, both of whom believed in a warm ether.

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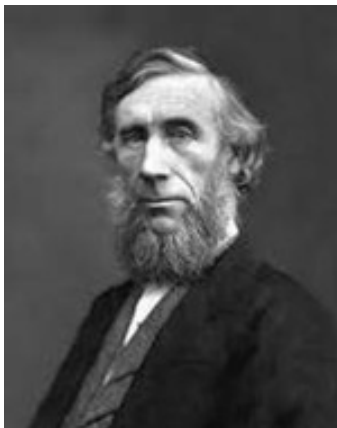
\CLAUDE POUILLET



Claude Servais Mathias Pouillet¹⁶ (February 16, 1791– June 14, 1868) was a French physicist who developed a pyr heliometer and made, between 1837 and 1838, the first quantitative measurements of the Solar constant. His publication in 1838¹⁷ has been translated into English by Taylor¹⁸

Pouillet accepted the view of Fourier that the earth was warmed above the temperature of the aether by the absorption of the sun's rays by the atmosphere. However, by this time, his friend Poisson (the famous statistical mathematician) had calculated that the upper regions of the atmosphere were much cooler than the aether. He carried out experiments at night with an actinometer, an instrument for measuring radiation and from the results calculated that the temperature of space was -142°C .

JOHN TYNDALL



John Tyndall (2 August 1820 – 4 December 1893)¹⁹ was an Irish-born physicist and mathematician who studied in Germany and from 1853 to 1887 was Director of the Royal Institution in London as the immediate successor of Michael Faraday. For 12 years from 1859 he carried out a series of studies on the passage of low temperature radiation through a number of gases and vapours.

Tyndall's Bakerian lecture of 1861^{20,21} gives details. It is also part of his book "Heat as Mode of Motion"²²

Tyndall was inspired by the recent experiments of Melloni¹⁵ who had studied the infrared behaviour of various gases using a thermomultiplier, a combination of a thermopile and a galvanometer.

Tyndall^{21,22} says (page 171)

"Melloni found that a glass plate one-tenth of an inch in thickness intercepted all the rays emanating from a source of the temperature of boiling water, and fully 94 per cent. of rays from a source of 400° Centigrade.



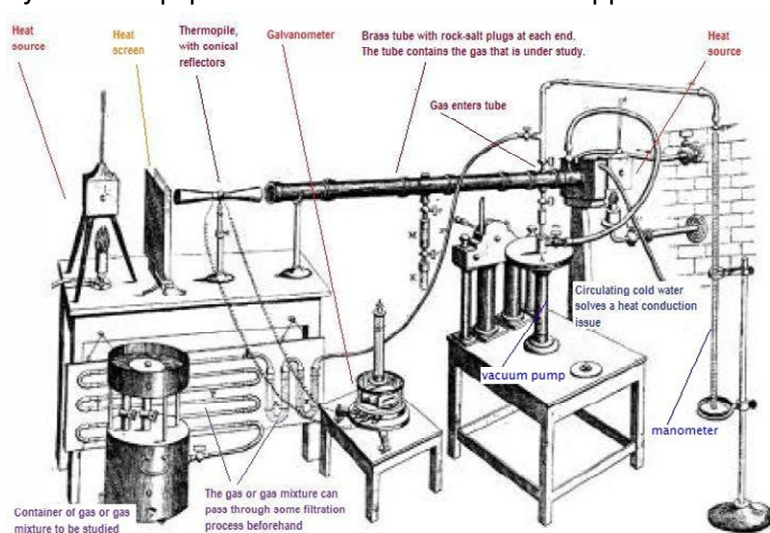
Macedonia Melloni

Hence a tube closed with glass plates would be scarcely more suitable for the purpose now under consideration, than if its ends were stopped by plates of metal"

De Saussure and Fourier could not have known that glass absorbed most low temperature radiation

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Tyndall's equipment is illustrated here. A copper cubic container at the right is full of



water kept boiling by a flame underneath. The front is coated with lampblack and the radiation passes through a rock salt window and through a brass tube cooled with water. The radiation passes out through another rock salt window and to a double conical device with a thermopile inside it connected to a galvanometer. The tube can be evacuated to

give a zero reading for the galvanometer and filled with a gas or vapour to different pressures. Water is circulated around the rock salt to keep it cool. A compensating radiation source is at the far end to enable setting the zero on the galvanometer. He measured the loss of radiation from putting the various gases in the tube.

It has been pointed out by Casey^{12 21} that this arrangement does not measure *absorption*, a term repeatedly used by Tyndall. It measures relative *opacity* which is the proportion of radiation passing through the gas. He did not understand that the gas would re-radiate part of the heat as radiation in all directions, some being absorbed by the sides of the tube and some radiating backwards. He seemed to have a rudimentary knowledge of spectroscopy, but his belief in the ether led him to believe in a linear relationship between absorption and concentration. The actual relationship is close to logarithmic.

Tyndall's biographical memoir²³ has the following passage:

"he was able to determine the position of aqueous vapour, which, on account of condensation, could not be experimented on directly. Experiments made with dry and humid air corroborated the inference that, as water transcends all other liquids, so aqueous vapour is powerful above all other vapours as a radiator and absorber"

Tyndall wrote (Ref 21 page 276 paragraph

"Air sent through the system of drying-tubes and through the caustic-potash tube produced an absorption of about 1.

Air direct from the laboratory, containing therefore its carbonic acid and aqueous vapour, produced an absorption of about 15.

Deducting the effect of the gaseous acids, it was found that the quantity of aqueous vapour diffused through the atmosphere on the day in question, produced an absorption at least equal to thirteen times that of the atmosphere itself.

It is exceedingly probable that the absorption of the solar rays by the atmosphere, as established by M. Pouillet, is mainly due to the watery vapour contained in the air. The vast difference between the temperature of the sun at midday and in the evening is also probably due in the main to that comparatively shallow stratum of aqueous

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vapour which lies close to the earth. At noon the depth of it pierced by the sunbeams is very small; in the evening very great in comparison.

The intense heat of the sun's direct rays on high mountains is not, I believe, due to his beams having to penetrate only a small depth of air, but to the comparative absence of aqueous vapour at those great elevations.

But this aqueous vapour, which exercises such a destructive action on the obscure rays, is comparatively transparent to the rays of light. Hence the differential action, as regards the heat coming from the sun to the earth and that radiated from the earth into space, is vastly augmented by the aqueous vapour of the atmosphere”.

He believed that “solar rays” are absorbed mainly by water vapour the atmosphere and it is “far more important than that radiated from earth into space” So he is also not responsible for the current concept of the “greenhouse effect” and he did not consider carbon dioxide as important at all,

He also wrote^{20,21} (page 277 paragraph 1):

“De Saussure, Fourier, M. Pouillet, and Mr. Hopkins regard this interception of terrestrial rays as exercising the most important influence on climate”.

Tyndall does appear to be the first person to point out that trace gases in the atmosphere are capable of influencing climate. He studied carbon dioxide and methane but he thought water vapour was far more important.



SVANTE ARRHENIUS

Svante August Arrhenius (19 February 1859 – 2 October 1927)²⁵ was a Swedish scientist, originally a physicist, and one of the founders of the science of physical chemistry. The Arrhenius equation, lunar crater Arrhenius, and the Arrhenius Labs at Stockholm University are named after him. He received the Nobel Prize in Chemistry in 1903 for his discovery of ions in aqueous salt solutions. He played a prominent part in the selection of subsequent winners of the award.

He published several articles on the effects of carbon dioxide on the atmosphere. That published in English in 1896 was the most influential²⁶.

He made very few measurements himself and the paper depended entirely on his calculations from the measurements by Langley and Very²⁷.

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SAMUEL PIERPONT LANGLEY (August 22, 1834, - February 27, 1906)²⁸

was an American astronomer, physicist, inventor of the bolometer and pioneer of aviation.

He is probably best known from the fiasco of his two attempts to launch a man-carrying flying machine across the Potomac river in October and December 1903, both of which failed when the machine plunged directly into the river. He refused to recognise the December 1903 success of the Wright brothers and as Director of the Smithsonian Institution he claimed priority in his museum. The original Wright brothers' flyer was therefore donated to the Science Museum in

London where I used to visit as a boy. The Smithsonian claimed priority for Langley when I visited the museum as recently as the 1960s, but then a deal was done and the Wright machine is now in the Smithsonian and the Science Museum has a replica.

Langley's bolometer was an absorptive element, such as a thin layer of metal, connected to a heat sink (a body of constant temperature) through a thermal link. The result is that any radiation impinging on the absorptive element raises its temperature above that of the heat sink. It was attached to the thermopile and was able to measure intensity of narrow emission bands in a spectrum that had been obtained with a rock salt prism.

Langley made a series of measurements of the full moon's radiation with this instrument at the Alleghany observatory in 1907. He made measurements at different angles with the moon.

Arrhenius had the idea that by finding out the difference he got from different angles he could calculate the absorption of the moon's radiation by the earth's atmosphere. By assuming that the radiation from the moon was approximately the same as that of the earth he could calculate the absorption of the earth's atmosphere by the trace absorbent gases water vapour and carbon dioxide.

Erren²⁹ has shown that Langley's measurements used by Arrhenius were preliminary and had serious errors. They became less accurate as they approached the region used by Arrhenius, the measurements were exaggerated, and did not reach far enough to include the major absorption frequency of carbon dioxide. He concludes from his study that Langley's observations were of little use in studying the influence of carbon dioxide on the climate.

Arrhenius published many subsequent publications³⁰⁻³⁴, parts of which are available from Erren^{29,35-40}, who provides modern information on the moon spectrum^{35,36}, which show that Arrhenius' values were exaggerated^{37,38} and that he did not subsequently amend them. Erren³⁹ disagrees with Weart² who claimed that the 1901 and 1908 Arrhenius papers lowered his original numbers

He also gives an account of the paper by K Angstrom⁴⁰ which wrongly criticized Arrhenius

On his first page²⁶ Arrhenius states:

"Fourier maintained that the atmosphere acts like the glass of a hothouse because it

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lets through the light rays from the sun but retains the dark rays from the ground"

This is not true, as explained above. Fourier, Pouillet and Tyndall thought that the sun's rays were absorbed by the atmosphere, not the "dark rays" from the ground. Ref 26 also says

"and Langley was by some of his researches led to the view that 'the temperature of the earth under direct sunshine would probably fall to -200°C, if that atmosphere did not possess the quality of selective absorption"

This opinion is based on the view that the earth is heated entirely by heat absorbed by the atmosphere on its way down, and that the sun by itself does not heat the earth at all.

Then Arrhenius²⁶ says *"This view... must be abandoned, as Langley himself in a later memoir, showed that the full moon, which certainly does not possess any sensible heat-absorbing atmosphere, has a 'mean effective temperature' of 45°C"*

So Fourier's theory, accepted by Pouillet and Tyndall, was wrong.

Arrhenius then proposed to replace it with the theory that the earth is heated by absorption of infrared radiation emitted by the earth, and from Tyndall's measurements, this means water vapour and carbon dioxide. However he seems to have completely failed to appreciate that Tyndall had found that water vapour was far more important than carbon dioxide.

Langley's figure for the temperature of the moon was 45°C. Today's figure is an average of 107°C for the day temperature, the one Langley measured. This huge discrepancy means that Langley's figures must be treated as completely unreliable, and so are the results calculate from them by Arrhenius.

Arrhenius assumed that the ratio of carbon dioxide (K) to water vapor (W) in the earth's atmosphere was K/W where K is 1.5 and W is 0.88, a ratio of 1.7.

The concentration of carbon dioxide in the earth's atmosphere is now thought to be 0.039%. The average concentration of water vapour is not known. Since it varies from place to place from 0 to 4% take 2% as typical. This means that the ratio of water vapour and carbon dioxide is about 50 to 1.

So, about 98% of Arrhenius' figures and calculations, even if soundly based, apply to water vapour and not to carbon dioxide.

Arrhenius no longer believed in the ether when he says "Empty space may be regarded as having a temperature of absolute zero".

He included this basic model of the climate

"All authors agree in the view that there prevails an equilibrium in the temperature of the earth and of its atmosphere. The atmosphere must, therefore, radiate as much heat to space as it gains, partly from absorption of the sun's rays, partly through the radiation from the hotter surface of the earth and by means of the ascending currents of air heated by contact with the ground. On the other hand the earth loses just as much heat by radiation into space and to the atmosphere as it gains by absorption of the sun's rays. If we consider a given place in the atmosphere or on the ground, we must also take into consideration the quantities of heat that are carried to this place by means of oceanic or atmospheric currents"

It may be noticed that Arrhenius regards as important "ascending currents of air

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heated by contact with the ground” and “the quantities of heat that are carried to this place by means of oceanic or atmospheric currents”. .

Arrhenius considered the warming effects of increased carbon dioxide as entirely beneficial.

Current models do not seem to have liberated themselves from Arrhenius’ grossly oversimplified model and they have almost ignored convection and ocean oscillations which Arrhenius included.



Robert Williams Wood (1868 – 1955) was an American physicist and inventor. He wrote a standard textbook on “Physical Optics”⁴¹.

He appears here because he presented a theory of the operation of a greenhouse.

The following article⁴² was published in the Philosophical Magazine in 1909 (Vol. 17, pp. 319-320):

“XXIV. Note on the Theory of the Greenhouse

By Professor R. W. Wood (Communicated by the Author)

There appears to be a widespread belief that the comparatively high temperature produced within a closed space covered with glass, and exposed to solar radiation, results from a transformation of wave-length,

that is, that the heat waves from the sun, which are able to penetrate the glass, fall upon the walls of the enclosure and raise its temperature: the heat energy is re-emitted by the walls in the form of much longer waves, which are unable to penetrate the glass, the greenhouse acting as a radiation trap. I have always felt some doubt as to whether this action played any very large part in the elevation of temperature. It appeared much more probable that the part played by the glass was the prevention of the escape of the warm air heated by the ground within the enclosure. If we open the doors of a greenhouse on a cold and windy day, the trapping of radiation appears to lose much of its efficacy. As a matter of fact I am of the opinion that a greenhouse made of a glass transparent to waves of every possible length would show a temperature nearly, if not quite, as high as that observed in a glass house. The transparent screen allows the solar radiation to warm the ground, and the ground in turn warms the air, but only the limited amount within the enclosure. In the “open,” the ground is continually brought into contact with cold air by convection currents.

To test the matter I constructed two enclosures of dead black cardboard, one covered with a glass plate, the other with a plate of rock-salt of equal thickness. The bulb of a thermometer was inserted in each enclosure and the whole packed in cotton, with the exception of the transparent plates which were exposed. When exposed to sunlight the temperature rose gradually to 65°C., the enclosure covered with the salt plate keeping a little ahead of the other, owing to the fact that it transmitted the longer waves from the sun, which were stopped by the glass. In order to eliminate this action the sunlight was first passed through a glass plate.

There was now scarcely a difference of one degree between the temperatures of the

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two enclosures. The maximum temperature reached was about 55°C. From what we know about the distribution of energy in the spectrum of the radiation emitted by a body at 55°, it is clear that the rock-salt plate is capable of transmitting practically all of it, while the glass plate stops it entirely. This shows us that the loss of temperature of the ground by radiation is very small in comparison to the loss by convection, in other words that we gain very little from the circumstance that the radiation is trapped. Is it therefore necessary to pay attention to trapped radiation in deducing the temperature of a planet as affected by its atmosphere?

The solar rays penetrate the atmosphere, warm the ground which in turn warms the atmosphere by contact and by convection currents. The heat received is thus stored up in the atmosphere, remaining there on account of the very low radiating power of a gas. It seems to me very doubtful if the atmosphere is warmed to any great extent by absorbing the radiation from the ground, even under the most favourable conditions.

I do not pretend to have gone very deeply into the matter, and publish this note merely to draw attention to the fact that trapped radiation appears to play but a very small part in the actual cases with which we are familiar”

THEORY OF THE GREENHOUSE

A greenhouse has, as a main function, the protection of the interior from loss of heat absorbed from the sun by the outside weather, from wind, and rain

When the sun is shining, its radiation passes through any panes of glass with minimal absorption and is absorbed, mainly by the base, where plants are present, but also by any part of the structure it encounters, raising their temperature.

The air within the greenhouse which is in contact with any heated surface receives heat by conduction. As heated air becomes lighter, it rises, and is replaced by cooler air. The warmer air rises to the surface but cannot leave, until the entire greenhouse has become warmer than the air outside the greenhouse. This process is called convection and it cools the surfaces that have been heated by the sun to a temperature which is almost uniform, but is higher than the outside climate.

This fact; that when the sun shines the air in the greenhouse cools the heated greenhouse base and walls, was not appreciated by any of the pioneers mentioned above and it is not mentioned by Wood. Everybody, including Wood, seems to forget that if the air in a greenhouse is heated by convection from the heated base and sides, it is therefore carrying out a cooling function. Also, none of them mention that for any water or moist surface the sun's rays will evaporate water, and this will also cool the heated surface and establish a moist atmosphere.

All the surfaces, both external and internal, as well as the air inside, will radiate in the infrared according to their temperature but as Wood believed, this is probably small. All the internal radiation will be absorbed by the sides and roof. The entire structure will largely be cooled from outside by external convection and radiation\

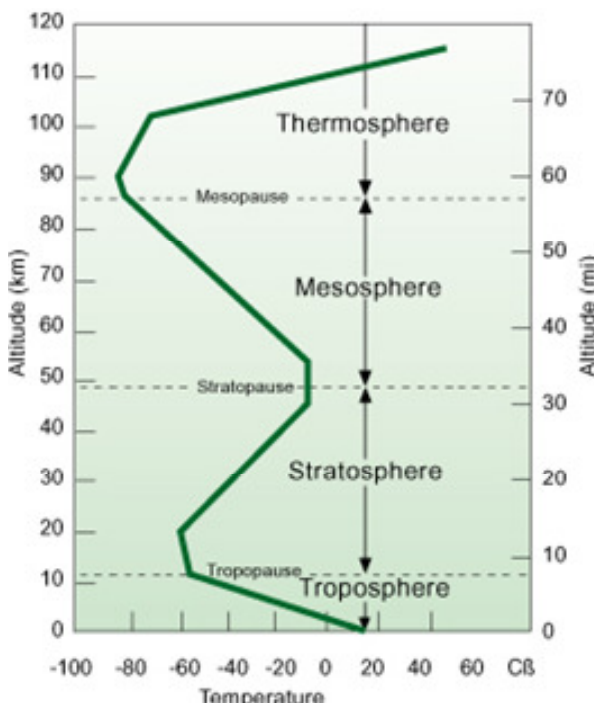
Nobody seems to have noticed it is all different at night, or even when the sun is not shining. Then, the loss of heat by radiation and convection by the whole structure and its contents is reduced by the heat which is stored by the interior air. In addition the extra moisture in the air is deposited, releasing latent heat.

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THE REAL GREENHOUSE EFFECT

The real Greenhouse effect is the behaviour of the earth's atmosphere in a similar way as in a greenhouse. The atmosphere is held in place by gravity, so the top of the troposphere performs a similar function as the glass ceiling of a greenhouse, as it prevents loss of air heated by convection. The sun's rays are absorbed by the earth and if there were no atmosphere the temperature would rise to a higher level by day and fall to a lower level at night.

The average daytime temperature of the moon is 107°C and at night -153°C , but the time of rotation of the moon is 27 days, so the earth without an atmosphere would not reach such extreme values. However, the temperature would be much higher during the day and lower at night if it were not for the atmosphere



The atmosphere in contact with the surface removes heat by convection so that, to start with, its temperature is similar. Its temperature steadily falls with height as it is radiating all the time, some returning to the earth. It has the function of radiating outwards part of the heat absorbed from the sun.

This process can be seen in the temperature change with height. At the Tropopause most of the heat has gone but then there is a temperature increase from the reaction of ultraviolet with ozone in the stratosphere.

The earth is also cooled by evaporation of water, extracting latent heat. The moister atmosphere deposits the water higher up as clouds, releasing the heat. Precipitation sets up a cycle of this process.

In a greenhouse, the heated and moister air cannot mix with the entire atmosphere outside, and is therefore warmer than outside.

In the earth's atmosphere both the heat and the moisture in the air are distributed around the world by wind, enhanced by turbulence, which is highest over the land. Heat absorbed by the ocean is distributed by ocean currents.

The graph of atmospheric temperature with height is confusing as it is for an average climate, so it tries to combine what are quite different conditions, the climate with the sun and the climate without the sun. With the sun, the heated earth's surface cools by convection and evaporation of water as well as by radiation. Without the sun, it cools by radiation but is warmed by the previously heated air and by deposition of moisture as dew or frost. The turbulence from winds is greater on land than on the ocean and it enhances air and moisture movement. On a calm day the earth is warmer. On a calm night it is cooler but deposition of dew and frost reduce the surface cooling.

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THE CARBON DIOXIDE GREENHOUSE EFFECT

The claims of Arrhenius to have found a warming influence from an increase in atmospheric carbon dioxide were largely ignored for some 30 years, because the claims were doubtful, and the world was preoccupied with a world war and an economic crisis.

CALENDAR

Guy Stewart Callendar⁴² (1898 -1964) was an English steam engineer and inventor who published many studies and articles which revived the claim by Arrhenius that increased atmospheric carbon dioxide heated the earth. He measured the absorption



spectrum of water vapour and carbon dioxide and that of the sky. He ignored water vapour and even believed that radiation was the only form of energy transfer. In his 1938 paper⁴³ he stated *“If the whole surface of the earth is considered as a unit upon which a certain amount of heat falls every day, it is obvious that the mean temperature will depend upon the rate at which heat can escape by radiation, because no other type of heat exchange is possible”*.

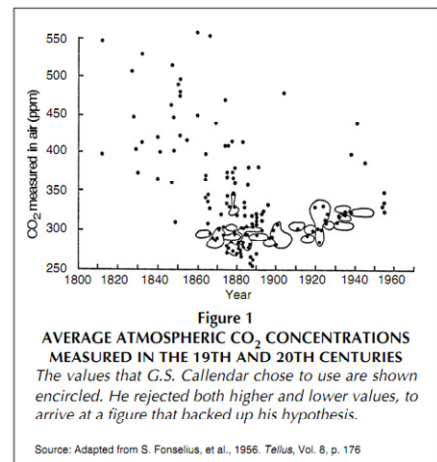
He seemed to be unaware of the existence of conduction convection and evaporation as possible mechanisms of heat transfer.

Jarowowski⁴⁴ has claimed that he chose only those figures for carbon dioxide that suited his theory.

Sir George Simpson, the eminent meteorologist, who was, at that time, Director of the UK Meteorological Office, in commenting on this paper³⁸ said

“It is not sufficiently realised by non-meteorologists who come for the first time to help the Society in its study that it was impossible to solve the temperature distribution in the atmosphere by working out the radiation. The atmosphere was not in a state of radiative equilibrium, and it also received heat by transfer from one part to another. In the second place, one had to remember that the temperature distribution in the atmosphere was determined almost entirely by the movement of air up and down. This forced the atmosphere into a temperature distribution which was quite out of balance with the radiation. One could not, therefore, calculate the effect of changing any one factor in the atmosphere, and he felt that the actual numerical results which Mr Callendar had obtained could not be used to give a definite indication of the order of magnitude of the effect.”

These remarks have been comprehensively ignored ever since



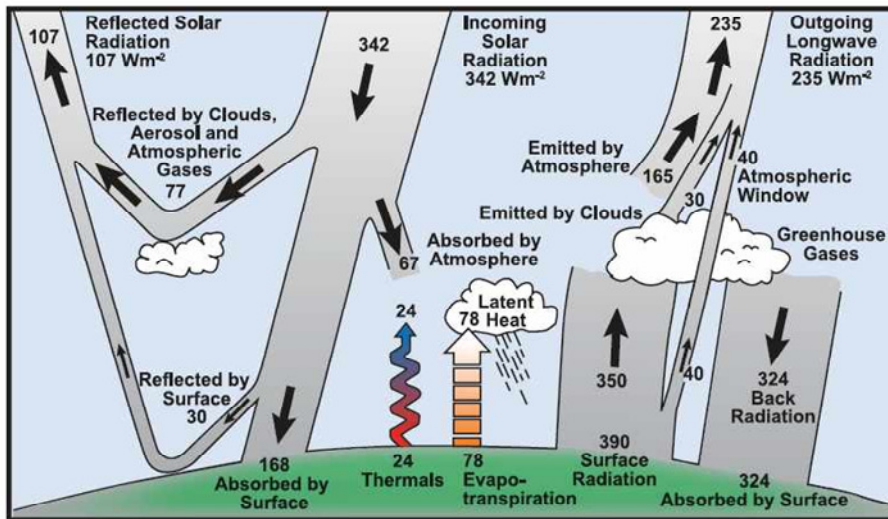
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MODERN DEVELOPMENTS

Since the 1980s, considerable effort has been spent on developing the theory that Callendar presented, that the energy of the climate is primarily controlled by absorption of the earth's radiation by carbon dioxide and other minor trace gases. It has been reviewed thoroughly by Weart².

The Intergovernmental Panel on Climate Change⁴⁵⁻⁴⁸ was set up in order to prove this theory, and despite their four major reports and several minor ones they have failed to do so. They have persisted in claiming that all energy changes in our atmosphere are dominated by radiation.

The basic climate models upon which these claims are based have evolved from the time of Arrhenius and Callendar. The 1997 version of Kiehl and Trenberth⁴⁹ (KT97) was the most important first basic concept at that time.



FAQ 1.1, Figure 1. Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).

This has recently been revised by Trenberth, Fasulla and Kiehl⁵⁰ (TFK09)

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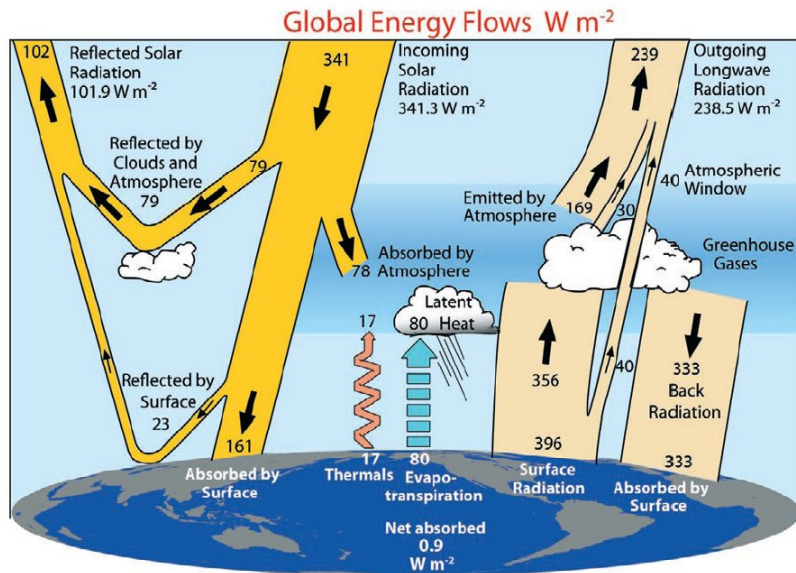


FIG. 1. The global annual mean Earth's energy budget for the Mar 2000 to May 2004 period ($W m^{-2}$). The broad arrows indicate the schematic flow of energy in proportion to their importance.

All the figures (except for the imbalance of $0.9W/msq$ in the second graph) are given as if they were known to an exact amount, when they actually represent averages of quantities that are very inaccurately known, or even just guessed. No estimates of accuracy are give for any of them. For the supposed surface radiation from the earth it would be necessary not just to have a figure for the average temperature but for the average of the fourth power of the absolute temperature. Neither of these quantities are known.

A major error is the claim that it is possible to average day and night. The climate by day is a quite different problem from the climate at night. By day the earth has a constant supply of energy, so it resembles a perpetual motion machine. By night, without the sun, it would tend to themodynamic equilibrium. Many of the figures would have very different values in the daytime than at night, yet they are quoted as averages, as if the sun shines all the time.

The claim of the first system (KT97) was that the earth's energy is "balanced" with the total energy received equal to the energy emitted. This could hardly be regarded a being in equilibrium from a thermodynamic point of view, for two reasons.

It is not an isolated system as the sun above and the earth below are not considered. The sun is regarded solely as an energy source and the surface cannot be considered to be insulated from the earth below. There is no mention of energy transferred and received from the earth.

As a system which has a permanent supply of external energy from the Sun, it could never be considered to be in equilibrium. It is perfectly capable of using its energy to violate the laws of thermodynamics, similarly to a refrigerator which uses external energy to transfer heat from a cold place (the refrigerator) to a warm place (the heat exchanger).

Several people⁵¹⁻⁵⁴ who have failed to understand this, have claimed that the system presented is wrong as it involves heat being transferred from a cool atmosphere back to the earth ("back radiation") which violates the Second Law of Thermodynamics.

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Gerlich and Tschuschner^{53,54} try to argue that the climate cannot be regarded as equivalent to a heat pump because the external energy to a heat pump is work instead of solar radiation. They give as references for the view that external energy has to be work two publications by Clausius^{55,56} The English translation⁵⁶ at least, does not support the view that since the climate is not fuelled by "external work" therefore it cannot violate the Second Law of Thermodynamics. This view is, however, supported by some textbooks (e.g. Smith and Cooper 1964⁵⁷). It cannot be right because it would involve violation of the Stefan Boltzmann and Planck's laws of radiation.

The ultimate source of all the energy on the earth (except geothermal and cosmic rays) is from solar energy, and this includes work and electric power. Any system fuelled by any form of external energy does not need to comply with the second law of thermodynamics.

TK97 covers the ERBE (Earth Radiation Budget Experiment) period from February 1985 to April 1989, which measured the external radiation from the earth but provided only an average and not the difference between day and night.

TFK09 covers the CERES (Clouds and the Earth's Radiant Energy System) period from March 2000 to May 2004.

The details of both results are given in TFK09.

There are two items in both graphs representing heat loss from the earth labelled "Thermals" (presumably convection) and "Latent Heat".

Latent Heat is the easiest to calculate, from the total annual precipitation. TK97 chose 78 W/msq which is less than any of the other calculations they list (80.2, 82.3 and 85.1 W/msq).

TFK09 chose 80.0 W/msq, which is again less than the other values listed (83.1 and 90.2 W/msq)

The other item, called "Sensible Heat" in their tables and "Thermals" in the graphs, is the heat loss from convection.

TK97 chose 24 W/msq for this quantity although the other authorities quoted have much smaller values (15.3, 15.3 and 18.8 W/msq). There is a suspicion that they needed the extra in order to "balance" the budget.

TFK09 chose 17 W/msq for "Sensible Heat, where other authorities had found 15.6, 19.4 and 17 W/msq. They had evidently abandoned all hope of "balancing" their budget, and they came out with a surplus of 0.9 W/msq.

Both papers give separate estimates of "Sensible Heat" for "Land" and "Ocean"

TK97 has figures from other authorities of 27.1, 25.8 and 27.5 W/msq for "Land": and 11.0, 11.5, 15.8, 9.5 and 14.0 W/msq for "Ocean" but no figures were chosen by the authors.

TFK09 chose a "Sensible Heat" figure of 27 W/msq for "Land" with other authorities giving 36.3 and 27.4 W/msq. They chose 12 W/msq for "Ocean" where the other authorities gave 11.7, 16.6, 14.6 and 10.8 W/msq.

There is much greater heat loss to the atmosphere over land than ocean. This is because of the greater turbulence caused by the irregular surface profile.

The difference is slightly greater because of the lower albedo over land which gives a

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lower solar absorption.

TK97 quoted Global albedo values between 28.1-33.8%, "Land" between 30.8 and 35.8%, and Ocean is 27.1-33.3% but did not make a choice itself.

TFK90 quoted figures for Global albedo of 27.9-34.2% and chose 29.8%, "Land" 30.6-35.2%, and chose 34.4%, "Ocean", 27.0-33.9% and chose 28.3%.

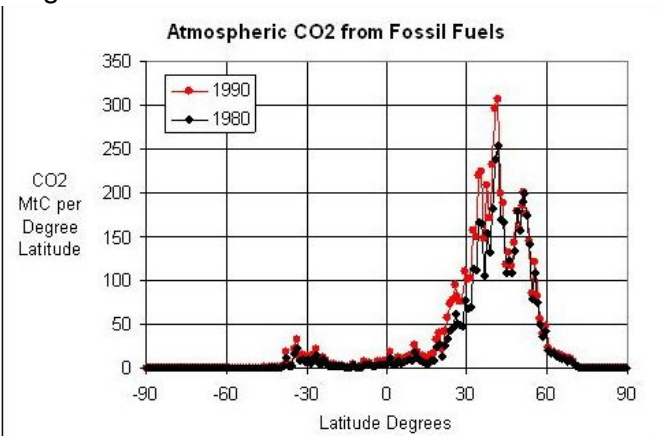
They therefore now consider that there is a difference of 6.1% between the albedo of "Land" and "Ocean"

It should be noted that the claimed global warming from the absorption of infra red radiation by trace gases calculated from the TFK model is a mere 1.6 W/msq since 1700. From their own figures changes in convection and evaporation could easily amount to more than this. They could arrive merely by a different choice of the figures reported by the authorities quoted or by any variability over time The models do not therefore provide a convincing case for the existence of the carbon dioxide greenhouse effect.

Changes in convection and evaporation could be caused naturally, by changes in the earth's orbit, in the radiation from the sun, cosmic rays, ocean circulation and volcanic eruptions.

The amount of heat lost by convection and evaporation would also be influenced by anthropogenic efforts to reduce convection or evaporation, so these could be considered as contributions to "global warming" if any such warming is detected.

Even a greenhouse, by preventing natural convection, reduces the extent of outside cooling by day and warms at night. All buildings act in the same fashion as a greenhouse. Shelter belts and wind barriers reduce heat loss by day. Changes in



albedo which reduce the surface from darker to lighter also are warming devices by day and cooling devices at night. Forests have a higher albedo than farmland, concrete roads and airport runways.

Devices that capture part of the natural heat loss such as windmills or solar panels actually cause global warming, for they remove part of the heat that would otherwise be removed by convection, and so

inhibit cooling. Inhibition of daytime cooling is caused by urbanisation and land use change giving an upwards bias to temperature readings by weather stations.

I have pointed out in my "Greenhouse Delusion"⁴⁵ that the average 0.02 W/msq of heat which is generated by humans is very unevenly distributed and there are some industrial areas where the amount generated exceeds that attributed to the supposed greenhouse effect of 1.6W/Msq since 1700 by almost 100 times. The attached graph (from Tom Quirk⁵⁸) shows how this heat is predominantly emitted between 30-60 degrees N. It is obvious that temperature measurements which are predominantly collected from these regions will give an upwardly biased view of global temperature

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as they concentrate on those areas most likely to warm from urban change. Measurements of carbon dioxide concentration which do not include these areas are likely to be downwardly biased.

CONCLUSIONS

Fourier, Pouillet and Tyndall believed the earth was warmed by absorption of the sun's rays by the atmosphere. Tyndall considered that it was due to water vapour. Arrhenius first claimed absorption of radiation from the earth by trace gases but he inadvertently measured the effects of water vapour instead of carbon dioxide. Callendar launched the carbon dioxide greenhouse effect despite the objections of Sir George Simpson who considered he had ignored air movement.

R W Wood was the first to show that the air in a greenhouse is heated by convection, but he did not notice that this meant the air cooled the surfaces by day, or that the warming function of a greenhouse is when the sun does not shine.

A theory similar to that of a greenhouse applied to the earth's climate. Convection and evaporation cool the earth by day and reverse convection and deposition of water or frost help to reduce night time cooling.

Even the official IPCC climate models admit that changes in these climate influences could be greater than claimed effects of trace gas emissions. Human attempts to interfere with convection and evaporation are a far more likely cause of possible global warming than changes in trace gases in the climate.

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