Conduction is the Primary Mechanism of Heat Transfer at the Surface-Atmosphere Boundary.

By Nasif S. Nahle

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Abstract

In several articles *(1)(2)(3)(4)(5)*, it has been demonstrated, from the strict standpoint of physics, thermodynamics and quantum mechanics, that the carbon dioxide is not physically capable of causing any global warming or climate change on Earth *(1)(2)(3)(4)(5)*. Some years ago, I had read from Pitts' and Sissom's book on Heat Transfer *(6)* the next paragraph: "*It is important to keep in mind that the fundamental energy exchange at a solid-fluid boundary is by conduction and that this energy is then convected away by the fluid flow*" (cursives by the author of this paper). The assertion did not cause a great impression in me because I knew that theory (theory is a statement that has been solidly established through experimentation and/or the observation of natural phenomena) since my High School years, and this was what I taught to my university students when I held the chair on biophysics. In this article, I demonstrate that the "greenhouse" effect, or warming of the atmosphere, is due to the energy exchange by conduction at the surface-atmosphere boundary and by convection from the boundary layer to other parcels of air. Therefore, the principle enunciated by Pitts and Sissom *(6)* is factual from any scientific standpoint. For completing this evaluation, I have appealed to well known formulas, procedures and principles on heat transfer which the reader can verify from those texts written by well recognized scientific authorities on heat transfer, thermodynamics and physics. *(6)(7)(8)(9)(10)(11)*

Introduction

As we explore the propagation of energy, we must take into account the science of thermodynamics, which allows us to predict the trajectories of the processes, and the science of heat transfer for knowing the modes by which energy is propagated from one system to other systems. *(10)* We know that heat is not temperature because heat is energy in transit. Heat can exist in rotational, vibrational and translational motions of the particles of a system, whereas temperature is the measurement of the average of the kinetic energy of the particles of a substance. The average of the molecular kinetic energy depends on the translational motion of the particles of a system. *(11)*

The energy absorbed or stored by a substance causes an increase in the kinetic energy of the particles that form that substance. This kinetic energy or motion causes the particles to emit heat, which is transferred to other regions of that substance or towards other systems with a lower energy density.

To understand heat transfer we have to keep in mind that heat is not a substance, but energy that flows from one system toward other systems with lower density of energy.

Radiation heat transfer at the surface-atmosphere boundary layer is a very weak process of energy exchange between both systems *(1)(2)*. Conversely, the fundamental process of heat transfer at the surface-atmosphere boundary is by conduction *(6)*. The energy absorbed by means of conduction from the surface to the atmosphere is transferred away by the air flow (convection). *(6)*

A strange term applied by the Anthropogenic Global Warming hypothesis is “radiative forcing”, which is absolutely incorrect from a scientific viewpoint because it suggests the appliance of artificial engines that “forces” the heat flows against the natural stream. This “forcing” doesn’t exist in nature, given that the process is natural, obviously.

There is not “radiative forcing”, either “convective forcing” or “conductive forcing”, in natural processes. The concept “forcing” is used exclusively for systems where a device can take the thermal energy and place it into another system for doing work, e.g. an engine, a refrigerator, air conditioning, a fan, a nuclear reactor, etc.

Conductive Heat Transfer

Conduction is the flow of heat through solids and liquids by vibration and collision of molecules and free electrons *(6)(7)(11)(12)*. The molecules in a segment of a system at high temperature vibrate faster than the molecules in other regions of the same or another’s systems which are at lower temperatures. The molecules with higher motions strike the less energized molecules and transfer some of their energy to the molecules at the colder regions of the system. For example, heat is transferred by conduction from the car’s bodywork to the materials inside the car which are in touch with the car’s bodywork.

Metals are the best thermal conductors; while non-metals are poor thermal conductors *(11)*. For comparison, the thermal conductivity (*k*) of the copper is 401 W/m*K, while the thermal conductivity (*k*) of the air is 0.0263 W/m*K. The thermal conductivity of the carbon dioxide (CO_2) is 0.01672 W/m*K, which is comparable to the thermal conductivity of a good insulator. *(11)(12)*

The formula for obtaining the energy exchange by conduction in a given thermodynamic system is as follows:

$\Phi q = - k (A) (\Delta T/\Delta n)$ (*ref. 6*)

Where, $\Delta T/\Delta n$ is the temperature gradient in the direction of area *A*, and *k* is the thermal conductivity of a thermodynamic system obtained by experimentation in units of W/m*K.

Conduction is the main heat transfer mechanism from the surface to the atmosphere, not radiation as the AGW hypothesis proposes. However, convection is very important because it is the mechanism by which the thermal energy is taken away from the surface-atmosphere boundary layer and transferred to other volumes of air which are at lower temperatures.

Convection is the flow of thermal energy through currents within a fluid (liquid or gas). Convection is a movement of liquid or gaseous volumes.

When a mass of air flows over the warm surface is heated up, its molecules acquire motion energy and flow towards colder volumes of air causing that its density diminishes. Given that the volume of the hot fluid becomes less dense, it is displaced as much vertically as horizontally, while the colder denser volume of air descends (the low-kinetic-energy molecules displace to the molecules with high-kinetic-energy). Through this process, the molecules of the warmed fluid transfer thermal energy continuously towards the colder volumes of fluid, the air, in this case.

For example, when we heat up water on a stove, the volume of water of the bottom of the pot will be warmed up by conduction of thermal energy from the metallic bottom of the pot to the water, which becomes less dense. After that, because the water has become less dense, it flows upwards (up to the surface of the water) and displaces the upper colder and denser volumes of water, which flow to the bottom of the pot.

The formula for obtaining the load of energy transferred by convection from the surface to the atmosphere or from hotter thermodynamic systems to colder thermodynamic systems is as follows:

$q = h (A) (T_s - T_{air})$ (*ref. 6*)

Where *h* is the convective heat transfer coefficient, *A* is the area implied in the heat transfer process, *Ts* is the temperature of the surface and $T\infty$ is a reference temperature.

As radiation is not too important *(6) (3)* for assessing the mechanisms of thermal energy transfer between the surface and the atmosphere and vice versa, I shall only describe the process in the following paragraphs. If the reader wishes to learn more about radiative heat transfer, please read on the topic from one of the best websites on physics at:

http://hyperphysics.phy-astr.gsu.edu/HBASE/thermo/stefan.html#c2 (Visited: July 25, 2010)

Radiation is the heat transfer by means electromagnetic waves and/or photons. It does not need a propagating medium (1)(6)(7)(11). The energy transferred by radiation moves at the speed of light. The heat radiated by the Sun can be exchanged between the solar surface and the Earth's surface without heating the intermediate space between the systems.

For example, if we place an object (such as a coin, a car, or your own body) under direct sunbeams, we shall notice that in a little while the object is heated up. The exchange of heat between the Sun and the object would have taken place by radiation.

The formula for obtaining the amount of thermal energy transferred by radiation between two or more thermodynamic systems is:

$$\Phi q = e\, \sigma\, (A)\, [(\Delta T)]$$

Where Φq is the thermal energy transferred by radiation, E is the emissivity of the system, σ is Stefan-Boltzmann constant (5.6697 x 10^-8 W/m^2 K^4), A is the area involved in heat transfer by radiation, and (ΔT) is the difference between the fourth power of the temperature of the hotter system and the fourth power of temperature of the colder system (T_{hot}^4 – T_{cold}^4).

I have read from many deniers of science on AGW side who write down a wrong formula which supposedly is applied for obtaining the change of temperature caused by the carbon dioxide. The formula in question is written by them as follows:

ΔT = 5.35 (W/m^2) [LN (CO2 current / CO2 standard)]

The formula written by AGW proponents is wrong because it lacks of many terms. If we develop the formula introducing magnitudes, the result would be in W/m^2, which is units for denoting flux of power, not units for temperature.

The complete formula is as follows:

ΔT = [5.35 W/m^2 * (LN (CO_2 current / CO_2 standard))] / 4 (5.997 x 10^-8 W/m^2 K^4) (T^3)

Therefore, eliminating units, we obtain units of temperature in Kelvin:

ΔT = [5.35 ~~W/m^2~~ * (LN (CO_2 current / CO_2 standard))] / [4 (5.997 x 10^-8 ~~W/m^2~~ K^4) (T^3)]

If we don't include the second segment of the formula (4 (5.997 x 10^-8 W/m^2 K^4) (T^3), then the units would be in W/m^2, which is absolutely erroneous. Therefore, the correct formula is as follows:

ΔT = [5.35 W/m^2 * (LN (CO_2 current / CO_2 standard))] / 4 (σ) (T^3)

Heat Transfer by Conduction at the surface-atmosphere boundary layer:

Have you read or heard that the atmosphere heats up the surface? Perhaps you have read that conduction is not a significant process of thermal energy (heat) transfer between the surface and the air? Well, I must tell you that what you have heard until now from the AGW proponents are not true arguments, but imaginary concepts.

The boundary layer, as its name says it, is the layers where two thermodynamic systems are in touch one with another. For example, the stratum of air flowing over the surface of the land or the oceans is a boundary layer. The same accounts for the facing up layer of soil or water in touch with the air flowing above them.

There is not radiation of heat between the surface and the air at the boundary layer, but just conduction. After conduction, the thermal energy absorbed by the air is taken away to other layers of air, or to other volumes of air, by convection. The formula for obtaining the load of thermal energy transferred from the surface to the atmosphere is:

$\Phi q/s = h (A) (T_s - T_{air})$ (*ref. 6*)

Example 1: On July 23, 2010, at 17:15 hour (UT), the temperature of the surface was 67 °C (340.15 K, 152.6 F), and the air's temperature was 37 °C (310.15 K, 98.6 F). What is the load of thermal energy transferred from the surface to the air by conduction-convection and what the increase of the air's temperature would be?

1st step: Determine the temperature of the air at the boundary layer between the surface and the air through the following formula:

$T_f = (T_s + T_{air}) / 2 = (67\ °C + 37\ °C) / 2 = 104 / 2 = 52\ °C$, or 325.15 K.

2nd step: Determine the Grashof number knowing that at 325.15 K

v (viscosity of air) = 15.69 x 10^-6 m^2/s

k (conductivity of air) = 0.03003 W/m*K

Pr (Prandtl number) = 0.697 (at length 1 meter).

α (correction factor for surfaces facing up) = 0.14

β (coefficient of volume expansion of the air) = $1/T_f$ = 1/325.15 K = 3.0755 x 10^-3 K^-1

g = 9.8 m/s^2

c = 1/3

Formula for determining the Grashof number:

$Gr\ L = g\ \beta\ (T_s - T_a)\ D^3 / v^2$

Introducing magnitudes:

$Gr\ L$ = [(9.8 m/s^2) (3.0755 x 10^-3 K^-1) (340.15 K – 310.15 K) (1 m^3)] / (15.69 x 10^-6 m^2/s)^2

$Gr\ L$ = 0.9042 (m^4/s^2) / 2.461761 x 10^-10 (m^4/s^2) = 3.673 x 10^9

3rd Step: Determine the convective coefficient using the following formula and introducing the magnitudes from the 2nd step:

h = (k/1 m^3) (α) [(Gr) (Pr)]^c

h = (0.03003 W/m*K /1 m^3) (0.14) [(3.673 x 10^9) (0.697)]^1/3

h = (0.03003 W/m^2 K) (0.14) (1368) = 5.751 W/m^2 K.

4th Step: Determine the load of energy transferred from the surface to the air by conduction-convection:

$\Phi q/s = h\ (A)\ (T_s - T_{air})$ (*ref. 6 and 7*)

Where $\Phi q/s$ is the heat absorbed by the colder system each second, h is the convective heat transfer coefficient (obtained through the previous formula = 5.751 W/m^2 K), A is the area (1 square meter), and $T_s - T_a$ is the difference of instantaneous temperatures between the source of heat (surface) and the colder system (air).

Introducing magnitudes:

$\Phi q/s$ = (5.751 W/m^2 K) (1 m^2) (340.15 K – 310.15 K)

$\Phi q/s$ = (5.751 W/m^2 K) (1 m^2) (30 K) = 172.53 W

Solving for Φq:

Φq = 172.53 W*s

And Φq = 172.53 W*s = 172.53 Joule (J)

Therefore, 172.53 J represent the energy exchanged between the surface and the atmosphere at the boundary layer, which means that 172.53 J are taken by convection from the surface to the air.

This amount of energy transferred by conduction-convection from the surface to the atmosphere causes a mean temperature at the boundary layer of 325.15 K (from 1st Step).

5th Step: Determine the load of thermal energy transferred by radiation from the surface below the boundary layer to the layer of air in touch with the surface.

For determining the amount of energy transferred by radiation from the surface to the layer of air, we apply the following formula:

$\Phi q/s = e\,(A)\,(\sigma)\,(Ts^4 - Tair^4)$ (*ref. 6 and 7*)

The term *s* means that the event occurs each second; therefore, solving for Φq:

$\Phi q = [e\,(A)\,(\sigma)\,(Ts^4 - Tair^4)] * s$

Where Φq is the thermal energy absorbed by the colder system, *e* is the total emissivity of the emitter (0.85 for the surface), *A* is the area (= 1 square meter), *Ts* is the temperature of the surface and *Tair* is the temperature of the air.

The emissivity of the surface is 0.85. Therefore, *a grosso modo*, the energy emitted by the surface to the atmosphere by radiation is as follows:

Φq = [0.85 (1 m^2) (5.6697 x 10^-8 W/m^2 K^4) (4.133860432905 x 10^9 K)] * 1 s

Φq = 1.9922 x 10^2 W*s = 1.9922 x 10^2 J

Thus the energy emitted by radiation from the surface to the air is about 200 J

6th Step: Determine the energy emitted by the surface which is absorbed by the air by radiation during the process of heat transfer:

Now we must use the formula for energy absorbed by the colder system by radiative heat transfer:

Φq = [α (A) (σ) (Ts^4 – $Tair$^4)] * s

Where Φq is the thermal energy absorbed by the colder system, α is the absorptivity of the colder system (0.053 for the whole mixture of gases in the air) *(ref. 8)*, A is the area (= 1 square meter), Ts is the temperature of the surface and $Tair$ is the temperature of the air.

Again, the correct calculation gives the following result:

Φq = [0.053 (1 m^2) (5.6697 x 10^-8 W/m^2 K^4) (4.133860432905 x 10^9 K)] * 1 s

Φq= 12.422 W*s = 12.422 J

The difference between the energy radiated from the surface which is absorbed by the air in contrast with the energy transferred by conduction to the atmosphere is:

$\Delta q = \Phi q_{conduction} - \Phi q_{radiation}$

$\Phi q_{conduction}$ = 172.53 J

$\Phi q_{radiation}$ = 12.422 J

Δq = 172.53 J – 12.422 J = 160.1 J

And the efficiency of the thermal energy transfer by conduction-convection is 93% higher than the thermal energy transfer by radiation.

Example 2: Determine the energy transferred by convection between two adjacent layers of air if the layer of air at the boundary layer surface-atmosphere is 325.15 K, and the temperature of the layer above it is at 308.65 K, h is 5.751 W/m^2 K (from 3rd Step):

The formula for calculating the amount of energy transferred by convection is as follows:

$q = h\ (A)\ (T_{hot} - T_{cold})$ (*ref. 6*)

Where h is the convective heat transfer coefficient, A is the area implied in the heat transfer process, Ts is the temperature of the surface and $T\infty$ is a reference temperature.

Known values:

T_{hot} = 325.15 K

T_{cold} = 308.65 K

v (viscosity of air) = 15.69 x 10^-6 m^2/s

k (conductivity of air) = 0.03003 W/m*K

Pr (Prandtl number) = 0.697 (at length 1 meter).

α (correction factor for surfaces facing up) = 0.14

β (coefficient of volume expansion of the air) = $1/T_f$ = 1/281.4 K = 3.554 x 10^-3 K^-1

g = 9.8 m/s^2

c = 1/3

First, we obtain the mean temperature at the boundary layer:

$T_f = (T_s + T_{air}) / 2$ = (52 °C + 35.5 °C) / 2 = 16.5 / 2 = 8.25 °C, or 281.4 K.

Second, we determine the Grashof number:

$Gr\ L = g\ \beta\ (T_s – T_a)\ D$^3 / υ^2

Introducing known values:

$Gr\ L$ = [(9.8 m/s^2) (3.554 x 10^-3 K^-1) (325.15 K – 310.65 K) 1 m^3] / (15.69 x 10^-6 m^2/s) ^2

$Gr\ L$ = 2.0515 x 10^9

Now, we proceed to determine the convective coefficient using the following formula and introducing the magnitudes:

h = (k/1 m^3) (α) [(Gr) (Pr)]^c

h = (0.03003 W/m*K /1 m^3) (0.14) [(2.0515 x 10^9) (0.697)]^1/3 = 4.74 W/m^2 K

Let us proceed to calculate the energy transferred by convection between the two layers of air:

$\Phi q/s = h\ (A)\ (T_s - T_{air})$ (*ref. 6 and 7*)

$\Phi q/s$ = 4.74 W/m^2 K (1 m^2) (325.15 K – 310.65 K) = 68.7 W

Solving for Φq:

Φq = 68.7 W (1 s) = 68.7 W*s = 68.7 J

By comparing the amount of energy transferred between two adjacent layers of air by convection with the energy absorbed by radiation we can see that convective heat transfer surpasses radiative heat transfer by almost 82%.

Example 3: What is the amount of thermal energy lost from 1 m^2 of saturated soil with organic matter surface each second, if the average change of temperature (ΔT) from the surface to a depth of 5 cm is 1 °C?

1st Step: The soil average thermal conductivity ($-k$) of the saturated soil with organic matter is 3.375 W/m*K. *(14)*

2nd Step: Determine the gradient $\Delta T/\Delta n$:

$\Delta T/\Delta n$ = 1 °C /100 cm = 0.05 °C/cm

3rd Step: Determine the heat loss:

Formula to be applied:

$\Phi q = - k\ (A)\ (\Delta T/\Delta n)$ (*ref. 6*)

Where, $\Delta T/\Delta n$ is the temperature gradient in the direction of area A, and k is the thermal conductivity of a thermodynamic system obtained by experimentation in units of W/m*K.

Known magnitudes:

$\Delta T/\Delta n$ = 0.05 °C/cm = 5 °C/m

$k_{\text{Saturated Soil w. org. matter}}$ = 3.375 W/m*K

A = 1 m^2

Introducing quantities:

Φq = - 3.375 W/m*K (1 m^2) (5 °C/m) = -16.875 W.

As we know the event takes place each second; therefore, the loss of thermal energy is -16.875 W*s (-16.875 J).

Consequently, 16.875 J (rounding up the cipher, 17 J) of thermal energy is transferred by conduction from the layer of soil at the surface to the layer of soil at 5 cm depth.

The net loss of energy by the surface is 160.1 J + 17 J = 177 J, which is a 2.61% lower than the average amount of solar thermal energy absorbed by the surface (181.64 J - 177 J = 4.665 J), assigning a value for the Total Conductivity Power of the surface of ~0.97.

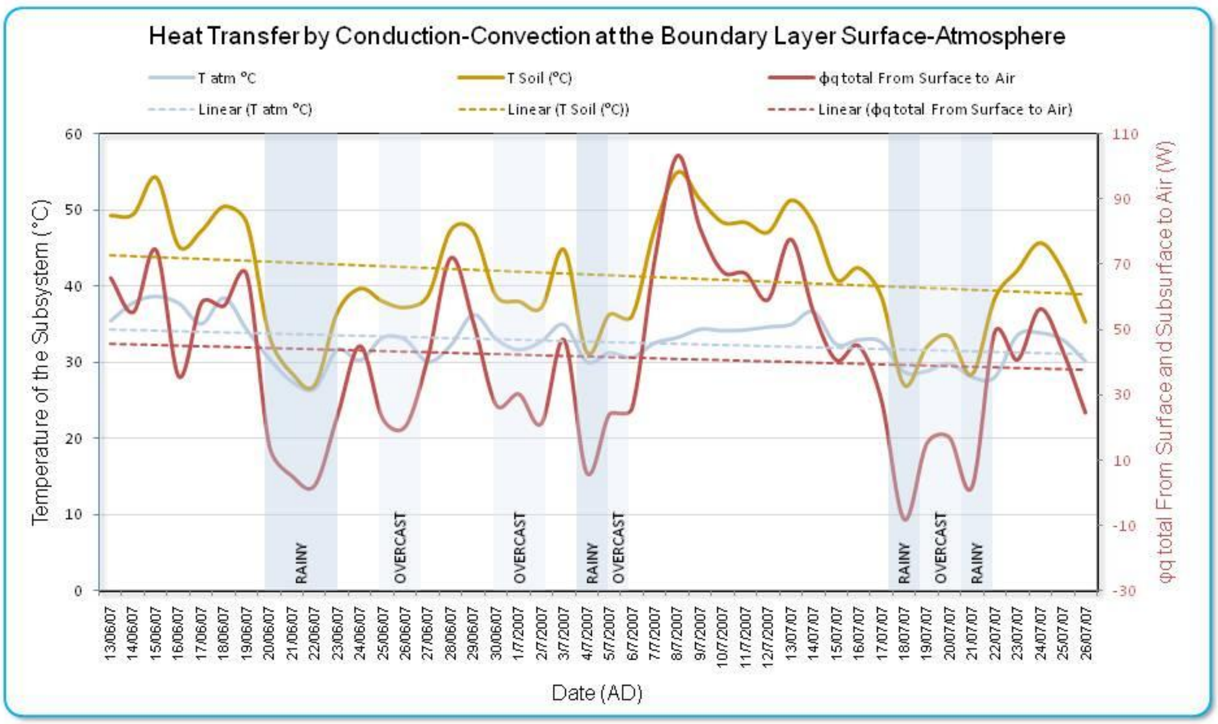
Conclusion

The calculations of the energy exchange between the surface and the atmosphere at the boundary layer demonstrate that the heat transfer by conduction-convection from the surface to the atmosphere is more efficient than the heat transfer by radiation.

The process of thermal energy transfer by conduction-convection explains satisfactorily the warming of the Earth's atmosphere.

The total energy implied in both radiation and conduction-convection heat transfer processes is 184.952 J. Therefore, the results of the calculations in this paper are consistent with other calculations about the energy budget made by the author of this paper *(13)*.

The effect of insolation on different subsystems of the Earth's climate is shown in the next graph:



This graph shows the temperatures of the surface and the air, and *φq* (heat transfer) at the boundary layer, through 13 June 2007-26 July 2007.
Hour: 18:05 – 18:24 UT
Location: San Nicolas de los Garza, N. L. Mexico. Coordinates *in situ*: 25° 48' North-lat- and 100° 19' West-long. Altitude 513 m ASL
Tools:
Thermometers: Brannan, Skyscan, Hanna HI98501, IR w Laser pointer Ex Tech 12530, Guide-Tech
Hygrometers: Shack, Skyscan, Guide-Tech.
Thermo-photometer: Sekonic.

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