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Equilibrium Equation of Thermal Radiation of Earth and Solution

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Abstract- The Earth is isolate on its orbit motion around the Sun. The thermal radiation on Earth determines climate warmer or colder. By Kirchhoff's law, the thermal radian on Earth must be in an equilibrium state. Which equivalents to an optimum problem. This paper establishes an equilibrium equation of thermal radiation of Earth, transmits it to an optimum problem, and proves that the equilibrium of thermal radiation of Earth is an indifferent equilibrium, neither stable, nor un-stable, based on the Stefan- Boltzmann law and the emissivity formula. The result means that the climate neither getting warmer and warmer, nor getting colder and colder.

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EQUILIBRIUMEQUATIONOFTHERMALRADIATIONOFEARTHANDSOLUTION

Strictly as per the compliance and regulations of:

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I. Introduction

Climate change is one of the focus topics in the world[1]. On the one hand, NASA scientists (NASA 2009)[2] found that fast-flowing Glaciers and thin Greenland and Antarctic ice sheets are accelerating. Which shows that the earth is being warming. On the other hand, cold wave, heavy snowfall, freeing temperature, with new-record sweeping Europe, North America, and East Asia have been reported in srtcles[3,4], news reports[5]. These reports query the earth warming.

Which one is correct? Or both are in-correct/correct?

What is the criterion for judging the climate of Earth to be warmer or colder?

II. The Criterion for Judging the Climate of Earth to be Warmer or Colder

Here, the "(Average) Earth's radian temperature T" is used as the criterion for judging the climate to be warmer or colder, based on reflecting the global factors of Earth's climate. It differs from that criteria based on local factors, such as local Glaciers, local temperature, local snowfall, etc. Where T is unknown, to be determined by the thermal radian equilibrium equation of Earth.

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III. Energy Exchanging of Earth

The Earth is isolate on its orbit motion around the Sun. The energy exchanging of Earth through Thermal radiation. The thermal radiation on Earth determines climate warmer or colder.

A body emits radiation at a given temperature and frequency exactly as well as absorbs the same radiation. This was proved by Kirchhoff.

By Kirchhoff's law[6], the absorption of thermal radiation on Earth is equal to its emission. That means that the thermal radiation on Earth must be in an equilibrium state.

IV. The Study on Thermal Equilibrium is Transferred to the Study of Optimum Problem

The study on equilibrium state in mechanics often take placed to the study of some Principles, e.g., the Generalized Principles of Variation was used to mechanics [7]; the Principle of Minimum Potential Energy [8] was used to study static mantle density distribution, etc. Here, the study on the thermal radiation equilibrium of Earth is transferred to the study of an optimum problem.

V. Construction the Thermal Radian Equilibrium Equation of Earth

$$\mathrm{T} = \mathrm{F}(\mathrm{T}) = (\min/\max)_{\mathrm{T}}\, \mathrm{p}(\mathrm{T}). \tag{1}$$

a) *By Plank's law[9], the emissivity* $\boldsymbol{\varepsilon}$ *is the function of* (λ, T),

$$\varepsilon = \varepsilon(\lambda, \mathrm{T}) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{(hc/\lambda kT)} - 1}, \tag{2}$$

Where λ =electromagnetic wavelenght,
h=Plank's constant,
c=speed of light,
k=Boltzmann' sconstant,
T=temperature of the radiator.
For total wavelengths, improper integrating of (2) from 0 to infinity of radiation, we have

$$\varepsilon(\Sigma\lambda, \mathrm{T}) = \int_0^\infty \varepsilon(\lambda, \mathrm{T})\, d\lambda = \varepsilon(\mathrm{T}), \tag{3}$$

Where the emissivity is the function only of T.

b) The Stefan-Boltzmann Law (S-B law)

There are many articles introducing S-B law[10], etc. The S-B law, formulated by J. Stefan (1879) based on experiment and derived by L. Boltzmann (1884) based on thermal dynamic. It states that the total radiant heat power emitted from a surface is proportional to the fourth power of its absolute temperature.

The S-B law gives:

$$p = \sigma\varepsilon T^4, \tag{4}$$

Where p=p(T)=the net radiant power per unit surface area of radiator.

σ=Stefan's constant, $\sigma = 5.6703 \times 10^{-8}$,watt/m^{2}K^4,

K=absolute temperature,

T= temperature of radiator,

$\varepsilon = \varepsilon(T)$=emissivity.

c) Construction the thermal radian equilibrium equation of Earth $T = F(T) = (min/max)_T p(T)$.

Let p=p(T) be an object functional of an optimum (min or max), then, the variation problem becomes:

$$F = F(T) = (\min/\max)_T\, p(T), \tag{5}$$

Where $F = F[SB(T), \varepsilon(T)] = F(T)$ is a functional. SB is the S-B law. Satisfying (4)

d) The necessary condition of the thermal radiation of Earth laying on an equilibrium state

The thermal radiation laying on equilibrium, by (6), it must be:

$$\frac{dF}{dT} = \sigma\left[\frac{d\varepsilon}{dT}T^4 + \varepsilon\frac{dT^4}{dT}\right] = 0, \tag{6}$$

(6) is the necessary condition of an equilibrium state. The point at equilibrium is called a stationary point.

(6) is expressed:

$$\frac{d\varepsilon}{\varepsilon} = -\frac{dT^4}{T^4}, \tag{7}$$

Integrating both sides of (7), we have

$$\int\frac{d\varepsilon}{\varepsilon} = \ln\varepsilon = -\int\frac{dT^4}{T^4} - \ln C = -\ln C\,(T)^4 = \ln C(T)^{-4}, \tag{8}$$

$$\varepsilon = \varepsilon(T) = C(T)^{-4}, \tag{9}$$

Where the integral constant C can be determined by the known condition between ε and T, that is: ε=1 (black body), T=0°K (black body), then, C=1 Then, we have

$$0 \le \varepsilon = (T)^{-4} \le 1, \tag{10}$$

(10) is called "emissivity formula".

Substituting (10) and (4) into (5), we have:

$$F(T) = \sigma = \text{constant}, \tag{11}$$

That means operator F maps T into a constant. Or, F independents to temperature T. That is already shown in (6), the necessary condition of the thermal radiation of Earth laying on an equilibrium state.

e) The sufficient condition of the thermal radiation equilibrium of Earth to be an extreme point

According to optimization theory[11], the sufficient condition of an equilibrium state reaching to its extreme point depends on the sign of its higher order derivatives. By(4) and (10), we have

$$\frac{d\varepsilon}{dT} = -4T^{-5}, \tag{12}$$

$$\frac{d^2\varepsilon}{dT^2} = 20T^{-6}, \tag{13}$$

By (4), we have

$$\frac{d^2F}{dT^2} = \sigma\left[\frac{d\varepsilon^2}{dT}T^4 + 2\frac{d\varepsilon}{dT}(4T^3) + 12\varepsilon T^2\right], \tag{14}$$

Substituting (10), (12), (13) into (14), we have

$$\frac{d^2F}{dT^2} = \sigma T^{-2}[20 - 32 + 12] = 0, \tag{15}$$

Similarly, we have

$$\frac{d^nF}{dT^n} = 0, \ \ (n = 1,2, \dots \infty) \tag{16}$$

According to the third rule (p. 232 of [11]), (16) shows that no extreme point exists. The equilibrium is an indifferent equilibrium, neither stable, nor um-stable. The indifferent equilibrium holds for arbitrary temperature T.

VI. Discussion

Q=question, A=answer,

Q1: There are many factors, influent climate of Earth, such as: Forest fire, heat energy emitted from inside of the Earth via earthquake [12- 16], and volcano, and human activity caused density of CO_2 increasing, etc. Do these factors causing the Earth's radian temperature T going up?

A1: Do not worry about hat. If the emissivity ε changingand causing T increasing, then, by the S-B law, more heat energy. With four power shall emitted to the space and keeps T unchanged.

Q2: You works on relating problem ?

A2: 1, On Atmosphere, Book [17]. and papers [18 – 22,25].

2, On Earthquake [12].

Features: Earthquake and Earth self-rotation are two problems, it is linked by conservation law of energy.

Highlights:

- Energy release of Earthquake proportions to square of velocity of Earth rotation;
- Earthquake happens in pulse-mode, the releasing energy storages in fasten rotation of Earth. Once the velocity of rotation of Earth returned to normal, the storage energy transfers to kinetic energy and disaster happening. People should get out from dangerous zone before the rotating velocity returned to normal.

3, On Earth Science[8 23 24],

Highlight of series studies on "static mantle density distribution 1, equation, 2, solution, 3, application":

- Why the Tibet-Qinghai high-land rising up? Why earthquakes happen frequently at the belt (about 35°of south & north latitudes)? The study of three papers found that the static mantle density distributes in "X-types", where the un-continuity of masses locates at the turning point of "X" (about 35°of south & north latitudes). Earthquakes happen frequently at this belt and the Tibet-Qinghai high-land raising up can be viewed as supporting to the study.

VII. Conclusion

The thermal radian equilibrium equation of Earth is an indifferent equilibrium, neither stable, nor un-stable. Any temperature T satisfies the necessary condition, while does not satisfy the sufficient condition of an extreme point. Therefore, It has no unit solution T.

Data Availability Statement: all data are cited from open publications.

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