The average temperature of Earth's surface and thermo-balance of heat fluxes suggest internal heat generation via Kuroda's Oklo-type natural nuclear reactor

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An independent heat source inside the Earth, in addition to Earth's heating by solar radiation, is required to account for differences between the measured and calculated values of Earth's average surface temperature.

A mathematical model of thermo-balance for Earth's heat fluxes is used for the calculations reported here. Using well-known data (albedo of the Earth's surface, constant of the heat radiation from the Sun per square meter of Earth's outer atmosphere surface, etc.), it is shown that the process of heating only by solar activity would yield an average value for Earth's surface temperature of about fifty degrees below zero (-50° Celcius scale). Since this calculated value of Earth's surface temperature is almost seventy degrees cooler than the value reported for the surface of the World Ocean there must exist other sources of heating for the Earth. That is *the inner* sources of heating of Earth itself.

The Earth's inner sources of heat could be associated with Kuroda's theory of natural nuclear reactors or with ohmic heating, caused by interactions of the solar wind with the geomagnetic field that induce electric currents in the Earth's outermost atmosphere. Kuroda also foresaw the heat source in Jupiter and the Sun.

1. Introduction.

Let us assume the Earth to be the absolutely (or ideally) *black body* [1] with the shape of sphere with radius R, which has the average temperature of the surface T.

To estimate thermo-balance of Earth's heat fluxes, we should account the amount of the heat flows as below:

- The Solar radiation energy flow [2-3]:

$$F_{ext} = f \cdot (\pi R^2) \cdot (1 - A), \tag{1.1}$$

- here f – is a measure of flux density of the mean solar electromagnetic radiation (the solar irradiance) per unit area that would be incident on a plane perpendicular to the rays, at a distance of one astronomical unit (AU) from the Sun, $f = 1.361$ kilowatts per square meter (kW/m²) at solar minimum [2]; R – is the radius of the Earth; A – is the Earth's albedo, $A \cong 0,36$ [3].

Let us also assume that the surface of Earth *re-radiates* all the fluxes of energy to the outer Space according to the Stefan-Boltzmann law [4]:

$$F_{out\,(1)} = 4\pi R^2 \cdot (\sigma \cdot T^4), \tag{1.2}$$

- here σ – is the constant of Stefan-Boltzmann law [4]; also, we should take into account the losses for the evaporation of water from the surface of Ocean [3]:

$$F_{out\,(2)} = 4\pi R^2 \cdot (h \cdot \rho_w \cdot Q), \tag{1.3}$$

- here $Q = Qo - \eta \cdot T = (25 - 0,024 \cdot T) * 10^5$ [J/kg] – is the amount of heat of water evaporation

from the unit of Ocean's square per unit of time ($25 \cdot 10^5$ J/kg – is the amount of heat of water evaporation at temperature $0°C$); h – is the average height of water in mm, which is assumed to be evaporating from the surface of Ocean per unit of time; $\rho_w \approx 1024\ kg/m^3$ - is the density of sea water.

Thus, we could estimate the thermo-balance of Earth's heat fluxes near the surface of Earth (without accounting of effects of diffusion as well as effect of heat transfer by turbulence):

$$\frac{d\,H}{d\,t} = F_{ext} + F_{int} - (F_{out\,(1)} + F_{out\,(2)}) \qquad (1.4)$$

- here H – is the effective enthalpy of Earth's surface; $F_{int.}$ – is the source of internal heat generation (of unknown nature). So, we should obtain from (1.1)-(1.4) as below:

$$\frac{d\,(C \cdot T)}{d\,t} = \frac{F_{ext} + F_{int}}{4\,\pi\,R^2} - \sigma \cdot T^4 - h \cdot \rho_w \cdot (Q_0 - \eta \cdot T)$$

- here t – is the time-parameter; C – is the isobaric heat capacity of the Earth's surface per the unit of square; $F_{ext} = f \cdot \pi\,R^2 \cdot (1 - A)$. If we designate:

$$\Delta f_{int} = \frac{F_{int}}{4\,\pi\,R^2}, \qquad (1.5)$$

- the last equation above could be transformed as

$$\frac{d\,(C \cdot T)}{d\,t} = \{f \cdot \frac{(1-A)}{4} + \Delta f_{int}\} - \sigma \cdot T^4 - h \cdot \rho_w \cdot (Q_0 - \eta \cdot T) \qquad (1.6)$$

We should especially note that in (1.5): $\Delta f_{int} = \Delta f_{int}\,(t)$, in general case.

So, we could conclude: - Eq. (1.6) is the generalization of the equations of *Riccati* and *Abel*

types [5]. Due to a very special character of *Riccati's type* ordinary differential equation, its general solution is proven to have a proper jumping of the components of a solution at some definite meanings of time-parameter *t*, or so-called *gradient catastrophe* [6].

This means the possibility of sudden global changing of temperature on the Earth's surface and the change of the global climate on Earth and environment (let us remember about so called Little Ice Age at the Maunder's minimum of Solar activity [7]).

2. Estimation of the source of Internal heat generation.

According to the data of modern climatology, the average temperature near the surface of the World Ocean [8] is circa ~ *17 °C ≈ 290,2 K*.

If we assume Δf_{int} = const, Eq. (1.6) for modeling of average temperature near the surface of the World Ocean could be presented as below (for the solid surface of Earth, heat capacity is lower than at the Ocean more than 2 times, density is higher more than 2 times):

$$\frac{dT}{\{0,25f \cdot (1-A) + \Delta f_{int} - h \cdot \rho_w \cdot Q\}/\sigma - T^4} = \frac{\sigma}{C} dt \qquad (2.1)$$

- here $Q = Qo - \eta \cdot T = (25 - 0,024 \cdot T)*10^5$ [J/kg], $Q = 18 \cdot 10^5$ [J/kg] for *T = 290,2 K*

  ~ near the surface of the Ocean; *h ~ 1325 mm/year = 4,2·10⁻⁸ m/s;*

- $C = C_{Ocean} + C_{Air}$, $C_{Ocean} = c_w \cdot \rho_w \cdot H_w$ (*c_w ≈ 4186,8* [J/(kg·K)], ρ_w ≈ *1024 kg/m³*, H_w ≈ *150 m*);

  also, the average Heat capacity of the Air near the surface of the World Ocean:

- $C_{Air} = c_{Air} \cdot \rho_{Air} \cdot H_{Air}$ (*c_{Air} ≈ 1005* [J/(kg·K)], ρ_{Air} ≈ *1,2 kg/m³*, H_{Air} = *50 m*).

Let us denote:

$$a = \left(\{0{,}25 f \cdot (1-A) + \Delta f_{\text{int}} - h \cdot \rho_w \cdot Q_0 \}/\sigma \right)^{\frac{1}{4}} \qquad (2.2)$$

If we exclude the influence of any source of Internal heat generation Δf_{int}, the maximal temperature of the Ocean surface could be calculated from expression (2.2) above as below:

$$a_0 = \left(\{0{,}25 f \cdot (1-A) - h \cdot \rho_w \cdot Q_0 \}/\sigma \right)^{\frac{1}{4}} = 223{,}16\ K \cong -50\ ^\circ C.$$

But in reality such temperature is about $\sim 17\ ^\circ C \approx 290{,}2\ K$, see [8].

It means that $\Delta f_{\text{int}} \neq 0$; moreover, we could estimate it as below:

$$\Delta f_{\text{int}} \approx 1{,}2 \cdot \{0{,}25 f \cdot (1 - A)\}$$

- so, the influence of the source of Internal heat generation Δf_{int} is even more than the influence of solar irradiance per unit area of Earth's surface.

Besides, by analyzing Eq. (2.1) we could obtain:

$$\begin{cases} dT/dt \geq 0 & \Leftrightarrow & T \leq a \\[2ex] dT/dt < 0 & \Leftrightarrow & T > a \end{cases}$$

It should mean that the main feature of the dynamics of temperature from (2.1) is formulated as follows: - temperature should be increasing up to the proper critical level a, then temperature should be decreasing.

Let us obtain the solution of (2.1) under condition $\Delta f_{int} = $ const:

$$\int\limits_{T}^{T+\Delta T} \frac{dT}{a^4 - T^4} = \frac{\sigma}{C}\Delta t \; ,$$

or

$$\frac{1}{4a^3}\cdot\ln\left(\frac{a+T}{a-T}\right) + \frac{1}{2a^3}\cdot\arctan\left(\frac{T}{a}\right)\bigg|_{T}^{T+\Delta T} = \frac{\sigma}{C}\Delta t \; ,$$

- which could be reduced at $\Delta T \rightarrow 0$ as below:

$$\frac{\Delta T}{a^4}\cdot\left(1 + \frac{T^2}{2\cdot(a^2 - T^2)}\right) \cong \frac{\sigma}{C}\cdot\Delta t \; .$$

So, we could conclude: - the critical level of temperature (a) could be calculated currently (up to the present moment), if we know the time-period Δt (during which the additional changing of temperature ΔT takes place), initial level of temperature T and the amount of the additional changing of the temperature ΔT

$$u = a^2 \; \Rightarrow \; u^3 - T^2u^2 - \left(\frac{\Delta T}{\Delta t}\cdot\frac{C}{\sigma}\right)u + \frac{\Delta T}{\Delta t}\cdot\frac{C}{\sigma}\frac{T^2}{2} = 0 \; .$$

Let us solve the polynomial algebraic equation of 3-rd extent in regard to the function u, using the conditions below:

$$T = 290{,}2 \; K, \; \Delta T = 0{,}5 \; K, \; \Delta t = 10 \; years \approx 315'576'000 \; sec,$$

- then we obtain the meaning of the critical level of temperature a:

$$u^3 - T^2 u^2 - \left(\frac{\Delta T}{\Delta t} \cdot \frac{C}{\sigma} \right) u + \frac{\Delta T}{\Delta t} \cdot \frac{C}{\sigma} \frac{T^2}{2} = 0 \ ,$$

$$\frac{C}{\sigma} = \frac{4186{,}8 \cdot 1024 \cdot 150 + 1005 \cdot 1{,}2 \cdot 50}{5{,}6697 \cdot 10^{-8}} \ [s \cdot K^4] = 11'343'682'734'536'200 \, [s \cdot K^4] \ ,$$

$$T^2 = 84216{,}01 \ [K^2], \quad \frac{\Delta T}{\Delta t} \cdot \frac{C}{\sigma} = 17'972'980{,}73 \ [K^4] \ ,$$

$$\frac{\Delta T}{\Delta t} \cdot \frac{C}{\sigma} \frac{T^2}{2} = 756'806'632'094{,}180 \ [K^6], \quad \Rightarrow$$

$$\Rightarrow \quad u^3 - 84216{,}01 u^2 - 17'972'980{,}73 u + 756'806'632'094{,}180 = 0 \ ,$$

$$u_2 = 84322{,}707 \quad \Rightarrow \quad a = 290{,}38 \ [K] \ .$$

As we can see, the critical level of temperature a is more than the value of the current temperature by ~ *0,2 K* (*the date of calculation above was ~ the summer of year 2010*); so, it means that during next 5 years the temperature of World Ocean should be decreasing (immediately after the reaching of the critical level ~ *290,4 K*).

Discussions.

The above calculations demonstrate that the process of heating only by solar activity is not sufficient to obtain the observed value for the temperature of Earth's surface. This means there must exist other sources of heating for planet Earth, i.e., *inner* sources of heating for Earth itself.

The inner sources could be those associated with Kuroda's theory [9-14] of natural nuclear reactors. Similar heat sources have been identified in Jupiter [15] and in the Sun [16].

Also, the inner sources could be associated with Kozyrev's [17] theory for generating heat in celestial bodies. For example, N.A. Kozyrev year 1959 by direct observations that confirmed the Moon is volcanically active.

An additional mechanism of internal heat generation within the system "Earth + atmosphere" may be produced as follows: high-intensity changing outbursts of solar wind (which brings the magnetic field of the Sun, frozen into the plasma of solar wind), through the intermediary of the geomagnetic field, will induce electric currents [18] in the outer atmosphere and Earth, causing ohmic heating, which should form an additional significant source of Earth's heating.

We should especially note that the existence of stable Earth's magnetic field should decrease the ohmic heating above; in the case of absence of a magnetic field of the planet (see the case of Venus [18]), such a process should have a chaotic character, so the temperature of the outer atmosphere would be circa ~ 400-500 degrees C.

Conclusion.

Estimation of average temperature of Earth's surface in dependence on heating by the Solar radiation energy flow is investigated here.

Mathematical model of thermo-balance of Earth's heat fluxes is suggested for such an estimation. Using well-known data (albedo of the Earth's surface, constant of the heat radiation from the Sun per square meter of Earth's outer atmosphere surface, etc.), we could conclude that the process of heating only by the Solar activity is not sufficient to obtain the real meaning of the temperature of Earth's surface. Estimation yields the average temperature about -50 degrees below zero (Celcius scale) in this case. It means that there exist other sources of heating of Earth; we suppose such sources should be *the inner* sources of heating of Earth itself.

As shown above, the influence of the sources of Internal heat generation (1.5) is even more than the influence of solar irradiance per unit area of Earth's surface. As for estimating of Solar radiation energy fluxes, it is an easy matter (see the formula (1.1), radius of the Earth, R = 6'371'000 m): having calculated, we obtain the meaning $F_{ext.}$ = 111'072 Terawatts (TW).

The inner source, associated with Kuroda's theory (natural nuclear reactor), gives the meaning of 'Global heat loss to space' in amount of 44,2 Terawatts (TW) [19], including 15 Terawatts (TW) of natural radioactivity without nuclear fission.

So, circa 111'028 Terawatts of internal heat generation is assumed to be associated with the ohmic heating, caused by the interaction of solar wind with the geomagnetic field, which induces the electric currents in the outer atmosphere of Earth (also, at some locations on the surface of Earth).

But we should note that a key point in the process above is the natural nuclear reactor, which is supposed to be located at the core of Earth [19]. Such a terracentric nuclear fission georeactor forms the stable magnetic field of Earth, which should decrease the ohmic heating as shown above.

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