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The New Method of Estimation Greenhouse Effect and Climate Change

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Abstract

Global climate change is one of the major concerns of modern society. To estimate this change, the global mean temperature is often used. Measuring and calculating the Earth's average temperature is a complex, multi-step process that combines data from various sources and employs statistical techniques. Today, datasets containing spatial-temporal data on Earth's temperature are readily available. Although scientists claim to achieve an accuracy of a few tenths of a degree, the fundamental question is not accuracy but whether the global mean temperature is a meaningful metric at all.

This paper demonstrates that the current methodology for determining the global mean temperature is inadequate for estimating the greenhouse effect and climate change, potentially leading to misleading scientific conclusions in the long term. A new methodology is introduced, focusing on the energy budget of the Earth's heating and cooling processes. The total influence of the atmosphere on the greenhouse effect and global warming can be estimated by comparing Earth's temperature with that of the Moon, treated as a bare body. The concept of 'potential temperature for cooling' is introduced as a more appropriate parameter for assessing the greenhouse effect, global warming trends, and climate change. Applying this new methodology to temperature averaging is expected to yield surprising results and offer a more accurate insight into climate change.

Keywords: Climate change; The average planet's temperature; Greenhouse effect; Modelling.

Introduction

The climate system primarily consists of the land, ocean, ice surfaces, atmosphere, and solar radiation that provides energy. These components interact to produce the conditions on and around the Earth's surface that we refer to as climate [1]. Climate is defined by averaging physical quantities that characterize these conditions over space and time, typically over a 30-year period [2]. The physical quantities considered include surface temperature, precipitation, cloud cover, wind patterns, and more.

As Klaus Hasselmann, Nobel Laureate in Physics (2021), noted, a major task in climate science is the detection problem—identifying the most sensitive climate indices that best distinguish climate change signals from natural climate variability. Examples of such indices include global or regional mean surface temperature, vertical temperature differences, sea ice extent, sea level change, and integrated deep ocean temperatures [3]. Nevertheless, measuring and reconstructing global mean temperatures remains a primary focus of leading organizations such as NASA's Goddard Institute for Space Science, the National Oceanic and Atmospheric Administration (NOAA), and the UK Met Office's Hadley Centre [4].

Measuring and calculating global mean temperature involves collecting temperature data from various locations worldwide and averaging these values. The globe is divided into numerous spatial cells, and for each grid cell, the temperature anomaly—the difference between the measured and usual temperature for a given day—is calculated.

The average of all anomalies is then determined and compared across years. This process is highly complex, requiring sophisticated methods to address data quality, spatial and temporal gaps, and biases. Moreover, different organizations may use slightly different methodologies and datasets, leading to variations in reported global mean temperature values.

Recent advances in atmospheric and oceanic science, coupled with new global measurement systems such as remote sensing and numerical computer models, have enabled quantitative studies and predictions of climate change and global warming [1-6].

For instance, the IPCC Sixth Report (Climate Change 2021) was based on over 14,000 scientific publications, while the IPCC Fifth Report stated with high confidence that human-induced warming had reached approximately 1°C (likely between 0.8°C and 1.2°C) above pre-industrial levels by 2017, increasing at a rate of 0.2°C per decade [1]. These results, derived from models and observations, are impressive yet remain subject to scientific debate.

This paper examines a fundamental question: Does the global mean temperature provide a meaningful measure of climate change? The findings suggest that local surface temperatures are misused in the current methodology, which is inadequate for assessing climate change. At a minimum, additional temperature metrics should be considered for comparison.

The current method

Summing and averaging temperatures from different regions of the Earth's surface yields a quantity with no direct physical meaning. In other words, global mean temperature is a purely statistical indicator that is insensitive to climate change and has been misinterpreted. The following thought experiments illustrate why the current averaging method is flawed.

Thought experiments

A simple proof of the current methodology's inadequacy: A Simple Proof of the Current Methodology's Inadequacy t_{earth}=15°C. Now, suppose that due to climate change, one hemisphere's mean temperature drops to t_1=0°C while the other rises to t_2=30°C. The calculated global mean temperature remains $t_{earth}=(t_1+t_2)/2$=15°C. This demonstrates that infinite temperature distributions each reflecting different climate conditions can produce the same mean temperature, proving that mean temperature is insensitive to climate change.

A more striking example involves a spherical celestial body heated uniformly to 1K. The total power radiated, according to the Stefan-Boltzmann law, is:

P=AσT4…… (1)

where A is surface area, σ is the Stefan-Boltzmann constant, and T is temperature. If half of the body's surface is cooled to 0K while the other half is heated to 2K, the global mean temperature remains 1K, but the power needed to maintain this distribution increases eightfold. This illustrates how global mean temperature fails to reflect energy balance.

Spatial and temporal temperature distribution matters

The Earth's temperature is governed by energy balance solar shortwave radiation heats the planet, while long-wave infrared radiation cools it. The Earth's effective radiometric temperature, calculated as:

$$T_{Earth} = \sqrt[4]{\frac{(1-\alpha)S}{4\sigma}} \approx 255K = -18^{\circ}C \quad \text{...... (2)}$$

where S is the solar constant, σ is the Stefan-Boltzmann constant, and α is albedo (~ 0.3), differs significantly from the actual mean surface temperature (~13.9°C), highlighting the atmosphere's role [6]. Two problems arise immediately, making these comparisons meaningless. First, the albedo differs between a bare planet and a planet with an atmosphere. Second, the temperature calculated using equation (3) assumes a uniformly heated planet, which never actually occurs in reality.

To emphasize the importance of spatial temperature distribution, let us consider an extreme case. Imagine, for simplicity, that one side of the planet is uniformly heated while the other side remains cold at T2≈0K.The temperature of the heated side can be calculated using equation (2), with the denominator adjusted from four to two, yielding T1≈303KT. Consequently, the global mean temperature, given the same energy input, is now $T_{Earth} = (T_1 + T_2)/2 \approx 152K$.

Now, imagine a planet that is heated uniformly for half of the time by two Suns (i.e., 2S) and remains unheated for the other half. On average, over time, the planet receives the equivalent of one Sun's energy input. If we further assume that the planet has a low heat capacity and cools immediately when not exposed to a heat source, we obtain the same result as in the previous example.

Thus, one can conclude that any spatial or temporal temperature variation leads to a decrease in the global mean temperature. However, this does not necessarily mean the planet is cooling it simply affects the way energy is distributed over time and space.

The proposed method

The core idea is to establish a relationship between energy balance and global temperature. Due to the complexity of atmospheric influences, let us first analyse a bare planet, such as the Moon. Since it is at the same distance from the Sun as Earth, the solar constant remains unchanged. The Moon's albedo is approximately 0.12, allowing us to estimate its average temperature using the zeroth-order model [6]: Tmoon = 270K.

However, since the Moon's temperature distribution is highly inhomogeneous, and the cooling at each point on the surface is proportional to the fourth power of its temperature, it is essential to account for temperature variations over time and space to accurately determine the outgoing energy flux. In theory, the total outgoing energy flux can be calculated by integrating the emitted radiation over a given period and across all points on the surface. At equilibrium, the total incoming energy flux over a certain period must equal the total outgoing energy flux, ensuring an energy balance.

The simplest model of the moon's temperature distribution

To demonstrate the application of this methodology, let us assume steady-state radiative equilibrium at each point on the Moon's sunlit surface, following the cosine law for solar irradiation. Furthermore, we assume that the absorbed energy at any given point is entirely radiated into space as thermal energy:

$$S(1-A)\cos(\theta) = \varepsilon\sigma T^4_{Moon}(\theta) \quad \text{...... (3)}$$

where A-the Moon's albedo (~0.11), q-angle of incidence, e-the emissivity (~0.95) and T_Moon (q)-represents the surface temperature at a given point. Although this model serves as a first-order approximation of the Moons temperature distribution, it ignores rotation, thermal inertia, and heat conduction. Therefore, it should only be used for quick estimations. The resulting frozen-in-time temperature distribution is illustrated in Figure 1.

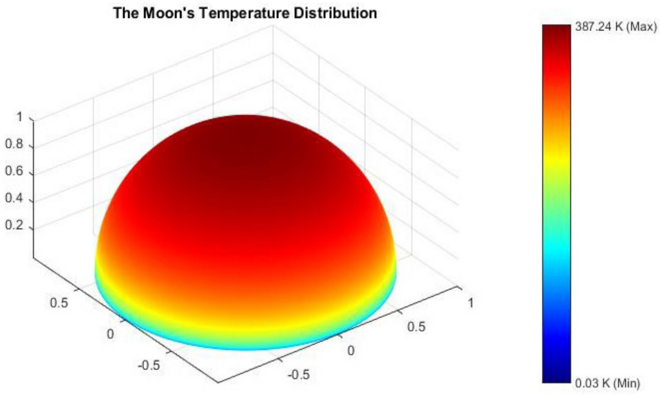

Figure 1: The simplest model of the Moon's surface temperature distribution (Sun-facing hemisphere).

Knowing the surface temperatures in any point, one can now discretize the Moon's surface into N cells with the same temperature and calculate the sum of outgoing flux:

$$\varepsilon\sum_{i=1}^{N} S_i\sigma T_i^4 \quad \text{...... (4)}$$

This flux must be equal to the total absorbed solar energy:

$$(1-A)S\pi R^2_{moon} \quad \text{...... (5)}$$

To characterize the energy balance with a single parameter (which we call Global Energetic Temperature TGET, we use the following relation:

$$\varepsilon\sum_{i=1}^{N} \Delta S_i\sigma T_i^4 = \varepsilon 4\pi R^2_{moon}\sigma T^4_{GET} \quad \text{...... (6)}$$

This derived temperature has a physical meaning: it represents the temperature the Moon would have if its entire surface were uniformly heated. In our simplified model, this temperature is approximately 274K. In contrast, the traditional approach of computing the global mean temperature using:

$$T_{ave} = (\sum_{i=1}^{N} \Delta S_i \mathrm{T}_i) / \sum_{i=1}^{N} \Delta S_i \quad \text{..... (7)}$$

(while assuming that the Moon's dark side is at 0K) yields Tave ≈ 154K. However, this value has no physical significance; it only serves as an indicator of temperature inhomogeneity rather than a meaningful global metric.

The earth case

The same methodology applies to Earth, though its temperature distribution is significantly more complex due to atmospheric effects. Unlike the Moon, the Earth's cooling mechanism involves both radiation and convection, making it difficult to model temperature evolution purely from radiative balance equations. However, using measured temperature datasets, one can estimate what Earth's cooling would look like in the absence of an atmosphere, keeping the same temperature distribution. The total potential outgoing radiative flux can then be expressed as:

$$\varepsilon \sum_{i=1}^{N} \Delta S_i (\sum_{j=1}^{M} \sigma T_j^4 \Delta \mathrm{t}_j) \quad \text{...... (8)}$$

where are Δ Si- the area of ith cell, N-total number of the grid cells, Δtj-j time step, M-total number of time steps in the chosen time period, $\tau = \sum_{j=1}^{M} \Delta t_j$, $S_{Earth} = \sum_{i=1} \Delta S_i$- the total surface area of Earth.

The total influence of the atmosphere, including the greenhouse effect, can be easily determined as the difference between the potential cooling energy (given by Equation 8) and the total incoming energy that the Earth would receive during the same period if it had no atmosphere. In this case, the albedo value is adjusted to match that of the Earth's surface, α (Earh surface)≈0.2 [7-10], and the total incoming flux is given by:

$$(1 - \alpha_{Earthsurface}) \mathrm{S} \pi \mathrm{R}_{Earth}^2 \tau \quad \text{...... (9)}$$

Thus, the correct method for calculating the Earth's temperature over a specific time period—allowing for estimates of climate change (warming or cooling) is:

$$\sum_{i=1}^{N} \Delta S_i (\sum_{j=1}^{M} \sigma T_j^4 \Delta t_j) = \mathrm{S}_{Earth} \sigma T_{P.C}^4 \tau \quad \text{...... (10)}$$

This temperature TP.C, can be referred as the "effective temperature for potential cooling". Previous parameter-the global mean temperature could serve as an indicator for spatial and temporal temperature redistribution.

Conclusion

This leads to the conclusion that the current methodology for estimating global warming and climate change based on calculating the global mean temperature is insensitive and inadequate. The primary issue is that the global mean temperature lacks direct physical meaning and has no explicit connection to the energy balance.

Mathematically, this inconsistency arises because the global mean temperature is a linear combination of individual temperatures, whereas the energy budget is highly nonlinear, depending on the fourth power of temperature (as dictated by the Stefan-Boltzmann law).

To address this limitation, we propose a more physically accurate method, which, when tested, could provide new insights into climate change using existing datasets. The concept of the "effective temperature for potential cooling" offers a more sensitive indicator of global warming and the impact of increasing greenhouse gas concentrations in the atmosphere.

An important advantage of this approach is that it can be easily implemented, as it utilizes existing climate datasets. The reference point could be set in the pre-industrial era (1850), allowing for a precise reconstruction of the natural greenhouse effect and a continuous assessment of climate change and global warming based on changes in the effective temperature for potential cooling.

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