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A Simple Method for Assessing Global Warming of the Earth

Slavoljub Mijovic

Univerzitet Crne Gore, Cetinjski put 2, 20000 Podgorica, Crna Gora,

corresponding.author slavom@ucg.ac.me

Abstract. Observational science, such as climate science, is experiencing unprecedented development owing to the enormous volume of data generated every day and the increasing use of artificial intelligence, which significantly facilitates and accelerates data processing, analysis, and interpretation. Any significant change in the main measured or calculated variables used for environmental monitoring represents a challenge for the scientific community and requires a sound physical explanation.

One of the most important indicators used to monitor global warming is the global mean surface temperature, which is conventionally calculated as a linear combination of temperatures measured throughout the year at selected locations. As demonstrated by the author in previous studies, this widely accepted method is not fully adequate because it lacks a direct physical interpretation and an explicit relationship with the Earth's energy budget.

A simple new method for the relative assessment of global warming is proposed in this paper. The analysis is based on the ERA5 reanalysis dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), using 2-m air temperature data. Hourly data covering the period 1950–2025 were used on a global grid consisting of approximately 1.04 million cells representing the Earth's entire surface.

The proposed method confirms the long-term warming trend and provides a comparative analysis with the results obtained using the conventional method.

Keywords: global warming; ERA5; new method; global mean temperature; effective mean temperature.

INTRODUCTION

Climate change and the closely related phenomenon of global warming transcend political and geographical boundaries and represent one of the most important issues facing the world today [1]. Physics plays a vital role in understanding the environment in general and climate change in particular. As NASA physicist and climatologist Drew Shindell stated, "Climate change is all about energy, a quantity familiar to every physicist" [2].

In this study, a new method that relates global warming to energy [3,4] was tested in order to evaluate relative global warming during the period 1950–2025. As demonstrated in the aforementioned work, the currently accepted method for estimating Earth's global mean temperature is not adequate because, in the case of an extremely non-uniform surface temperature distribution such as that of the Moon, it yields completely incorrect results.

METHOD

The basic idea of the new method is to relate the energy flux by which a celestial body cools to a corresponding temperature, previously termed the *effective temperature of potential cooling*. Since all celestial bodies ultimately cool exclusively by radiation according to the Stefan–Boltzmann law, the cooling energy flux is proportional to the fourth power of this effective temperature.

If Earth's surface is divided into N grid cells, with area ΔS_i and temperature $T_{i,j}$ of the $i-th$ cell during a time interval Δt_j, and if the total surface area of Earth is $S_{Earth} = \sum_{i=1}^{N} \Delta S_i$, then the energy flux of Earth's potential cooling (in the absence of an atmosphere) is calculated as

$$\sum_{i=1}^{N} \Delta S_i \left(\sum_{j=1}^{M} \varepsilon_{i,j} \sigma T_{i,j}^4 \Delta t_j \right), \tag{1}$$

where $\varepsilon_{i,j}$ –is the emissivity of the $i-th$ cell during the time interal Δt_j, M is the total number of time intervals for the selected period $\tau = \sum_{j=1}^{M} \Delta t_j$ and σ is the Stefan–Boltzmann constant.

To test how this energy flux, which is proportional to global warming, changed with time, ERA5 data from the European Centre for Medium-Range Weather Forecasts (ECMWF) were used, specifically the dataset *ERA5 hourly data on single levels from 1940 to present*. The variable selected was the air temperature at 2 m above the surface (T_2m). Hourly data for the period 1950–2025 were downloaded for approximately 1.04 million grid cells covering the entire globe.

The T_2m variable was chosen because it allows a simple treatment of emissivity, which can be assumed identical for all grid cells. Furthermore, because only relative changes in global warming over time are considered, emissivity can be set equal to unity, leading to the simplified working equation

$$\sum_{i=1}^{N} \Delta S_i \left(\sum_{j=1}^{M} \sigma T_{i,j}^4 \Delta t_j \right). \tag{2}$$

With the assistance of artificial intelligence (ChatGPT, https://chatgpt.com/), a MATLAB script was developed to retrieve ERA5 data and compute the above sum, i.e., the total radiated energy $\boldsymbol{E_{tot}}$ for each year.

RESULTS AND DISCUSSION

The results of the calculation are shown in **Figure 1**. The peaks in the graph reflect the fact that leap years contain more hourly data and therefore produce larger values of the calculated energy flux. To eliminate this effect and smooth the curve, the results were averaged over four-year periods.

The values on the ordinate represent calculated rather than actual radiated energies because emissivity was assumed to be unity. The four-year averaged energies are shown in **Figure 2**. A clear increasing trend is visible during the last decades, although the maximum relative change is only about 1.68%.

The corresponding effective temperatures were calculated as

$$T_{eff} = \left(\frac{E_{tot}}{\sigma S_{Earth}\tau}\right)^{1/4}. \tag{3}$$

Since the analysis is intended only for relative measurements, these effective temperatures indicate only the trend of change; their absolute values must be determined by other methods and using additional variables.

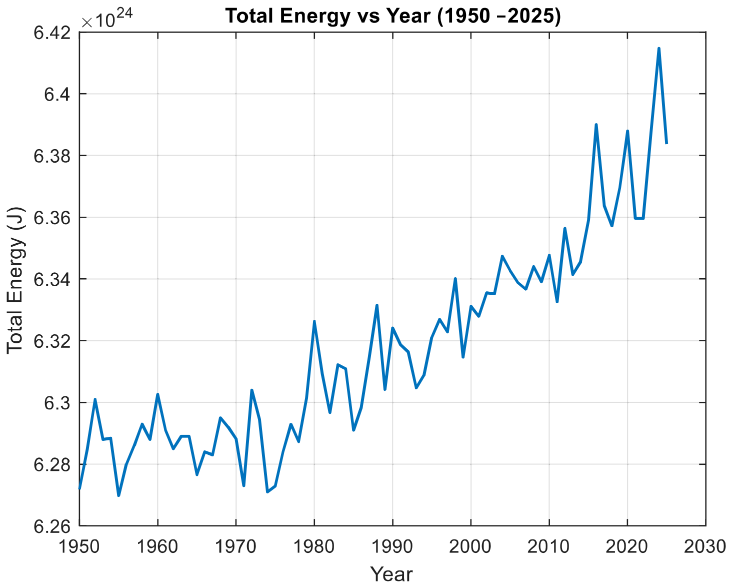

Figure 1.

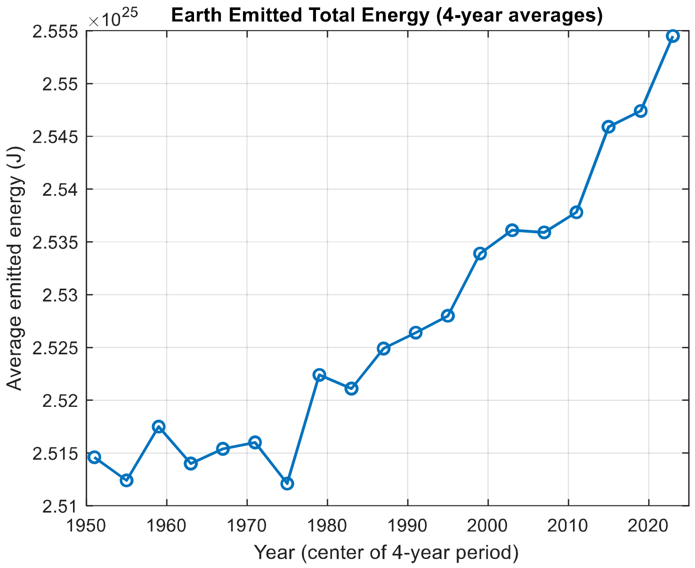

Figure 2.

It is also interesting to compare the global mean temperatures (**Figure 3**), calculated as

$$T_{ave} = (\sum_{i=1}^{N} \Delta S_i T_i) / \sum_{i=1}^{N} \Delta S_i \tag{4}$$

with the effective temperatures (**Figure 4**).

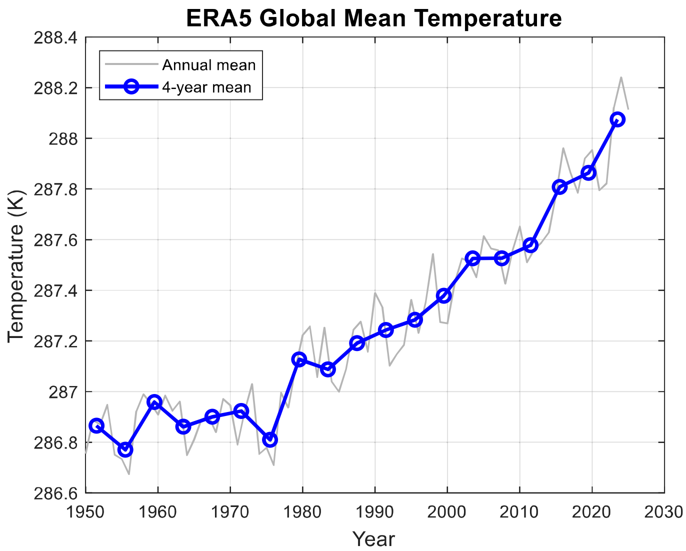

Figure 3.

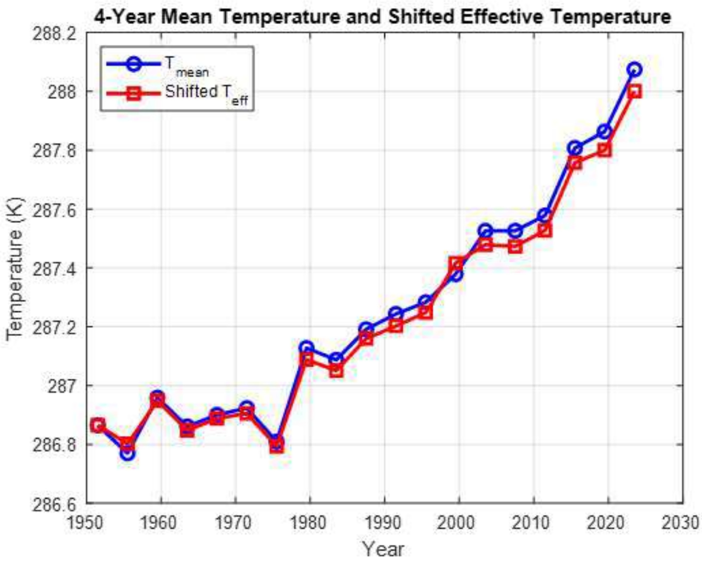

Figure 4.

To reduce random temperature fluctuations, four-year averaged values were compared. In addition, the effective temperature series was shifted so that its value in 1950 matched the corresponding global mean temperature value. The warming trends obtained by the two methods are practically identical.

This result is not surprising because, although the conventional approach is theoretically inadequate, both methods must yield the same trend if the spatial temperature distribution remains approximately constant over time.

CONCLUSION

The enormous amount of climate data currently available, combined with modern artificial intelligence tools, enables a re-examination of many aspects of the climate system and the possible redefinition of fundamental concepts such as global mean temperature. Data processing has become so efficient that climate-system models can now be tested on an ordinary personal computer within a few days, whereas such analyses previously required months.

In this work, a new method for estimating global warming was tested while avoiding the use of complex atmospheric radiative-transfer models. To obtain a complete picture and to evaluate absolute changes, additional variables should be included, such as land and sea surface temperatures and spatially varying emissivity, which may itself change due to anthropogenic influences. These variables are already available and can be readily incorporated into future models.

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