

## The Earth's Internal Heat is Leaking into the Ocean in Amounts that Exceed the Global Warming Heat

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### ABSTRACT

Global warming began increasing exponentially in the 1940s. However, the annual increase of the ocean heat content now greatly exceeds the annual increase of global warming heat, which is all of the heat that the Earth receives from the Sun. Thermal expansion of the Earth's crust would cause the boundaries of its cracks to be enlarged. This enlargement is evidently causing some undersea cracks to admit more of the Earth's internal heat into the ocean. The 50th percentile of 1.5°C global warming is estimated to arrive in the 2030s.

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### Introduction

Global warming is “the global average temperature anomaly with sea ice temperature inferred from air temperatures” according to *Berkeley Earth* (1850–), and “the land-ocean temperature index” per *NASA* (1880–) [1,2]. Global warming heat is trapped by excess atmospheric greenhouse gases that have long half-lives, which is the greenhouse effect [3]. The main excess greenhouse gas is carbon dioxide that is mostly caused by fossil fuel combustion, and which has a minimum half-life of 100 year [4]. *Fourier* (1824) deduced the greenhouse effect without coining the term [5-8]. *Conrath et al.* (1970) used satellite measurements to prove the Earth's excess heat is trapped by excess greenhouse gases that block heat emission at specific wavelengths of the Earth's infrared emission band. Data used herein are: (a) global warming, (b) the *Annual Greenhouse Gas Index* (AGGI, 1979-) that lists the emission-blocking of each greenhouse gas relative to that of carbon dioxide; (c) the ocean heat content, and (d) sea level rise [1,2,9-13].

### The Exponential Rise in Global Warming is Explained by The Earth's Decreasing Emissivity

*Arrhenius* (1896) described how atmospheric carbonic acid (carbonated water, or  $H_2CO_3$ ) raises the temperature of the ground [14]. *Arrhenius' power balance model*, Equation (2), is also called the zero-dimensional climate model, but the present work does no climate modeling. The Earth is assumed to be a linear isotropic homogeneous (l.i.h.) sphere of radius  $r$  and albedo (reflectivity) at temperature  $T$  that is emitting  $\varepsilon\sigma T^4$  W/m<sup>2</sup> heat per unit area and rotating in a circular orbit around the Sun. The heat transfer in equilibrium is described by Equation (2) [15],

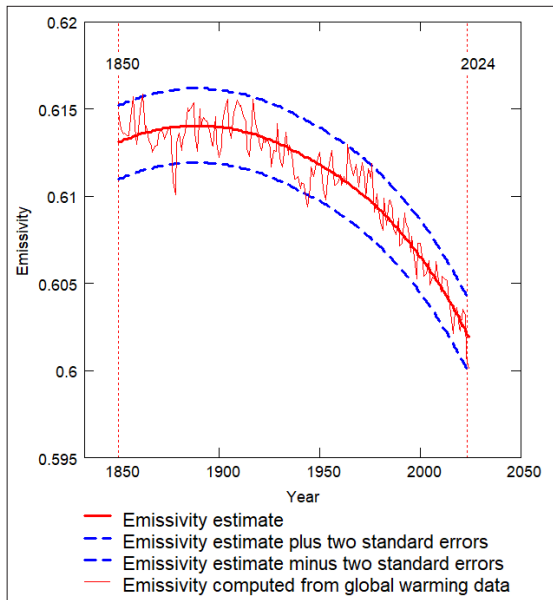
$$\pi r^2(1-a)S = 4\pi r^2\varepsilon\sigma T^4 = \text{const.} \quad (2)$$

The left side of the equation is the constant solar power intercepted by the Earth which appears as a disc of area  $\pi r^2$  when viewed from the Sun, and the right side of the equation is the omnidirectional heat power radiated by the l. i. h. spherical Earth of surface area  $4\pi r^2$ . The solar constant is  $S = 1366 \text{ W/m}^2 \pm 0.1\%$  and the Earth's radius  $r$  is 6357 km – 6378 km. The Bond albedo, or reflectivity is  $a \approx 0.3$ , where  $0 < a < 1$ , because the more reflective land covers about 30% of the Earth, in contrast with the darker waters. Power per unit area radiated by a blackbody, or perfect electromagnetic energy emitter and absorber, is  $\sigma T^4$  according to the Stefan-Boltzmann law, where the Stefan-Boltzmann constant is  $\sigma = 5.67 \cdot 10^{-8} \text{ W/(m}^2\text{K}^4)$ . A blackbody has perfect emissivity  $\varepsilon \equiv 1$ , but the Earth emits  $\varepsilon\sigma T^4$ , which is the grey body radiation in Equation (2), wherein  $0 < \varepsilon < 1$ .

The expression  $\varepsilon T^4$  in Equation (2) is constant because everything else is constant, so the emissivity  $\varepsilon$  and  $T^4$  are inversely related:

$$\varepsilon = \frac{(1-a)S}{4\sigma T^4} \approx 0.6. \quad (3)$$

Adding the Earth's preindustrial temperature of 13.7°C to the global warming record and converting to Kelvins yields the Earth's rising absolute temperature  $T$ , wherewith Equation (3) yields the falling emissivity curve shown in Figure 1 [16].



**Figure 1:** The Earth's Falling Emissivity  $\epsilon$  is Caused by the Rising Berkeley Earth Global Warming Temperature  $T$ .

This falling emissivity inhibits the Earth from radiating as much heat as it did from 125,000 years ago until the Industrial Revolution. The annual emissivity decrease  $\Delta\epsilon$  causes a corresponding temperature increase  $\Delta T$  in global warming. Substituting  $\Delta\epsilon$  for  $\epsilon$  in the right side of Equation (2) yields the annual incremental decrease in the radiated global warming heat,

$$\Delta GWH = -4\pi r^2 \Delta\epsilon \sigma T^4 \Delta t, \quad (4)$$

where  $\Delta\epsilon < 0$  and  $\Delta t = 1$  year.

This incremental decrease in radiated global warming heat equals the annual increase in retained global warming heat.

Numerically differentiating Equation (3) gives the annual decrease

in the Earth's emissivity estimate  $\Delta[\epsilon] = \Delta[(1-a)S / 4\sigma T^4]$  where

the  $\Delta$ -operator yields the difference between successive discrete annual values of its argument. Moreover, analytic differentiation

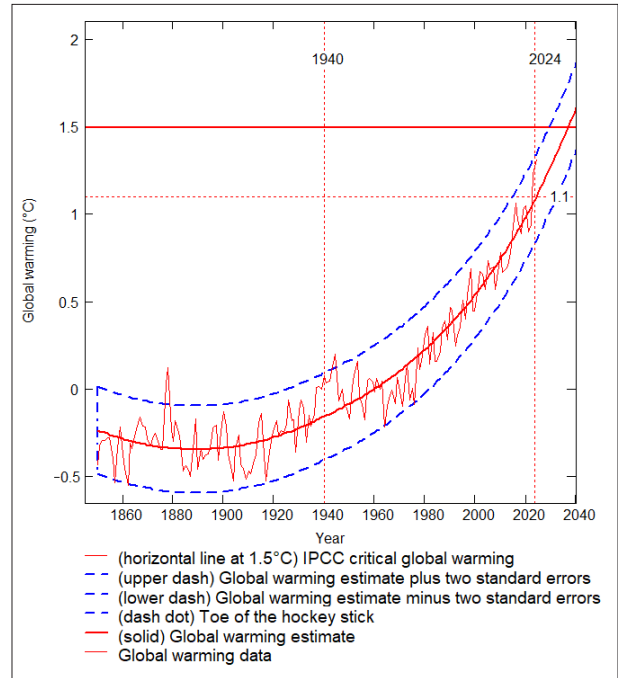
of Equation (3), whereby  $\frac{d\epsilon}{dT} = -\frac{(1-a)S}{\sigma T^5}$ , means  $\Delta\epsilon = -\frac{(1-a)S}{\sigma T^5} \Delta T$ .

Substituting this expression in Equation (4) yields the annual increase of global warming heat as a function of temperature,

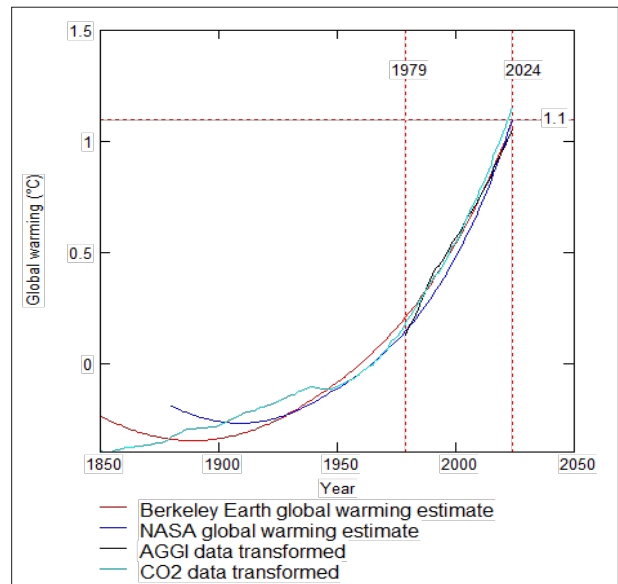
$$\Delta GWH = 4\pi r^2 (1-a)S \frac{\Delta T}{T} \Delta t. \quad (5)$$

### Global Warming Estimates

Figure 2 shows an upright hockey stick graph of the Berkeley Earth global warming data and a least squares approximation of it.



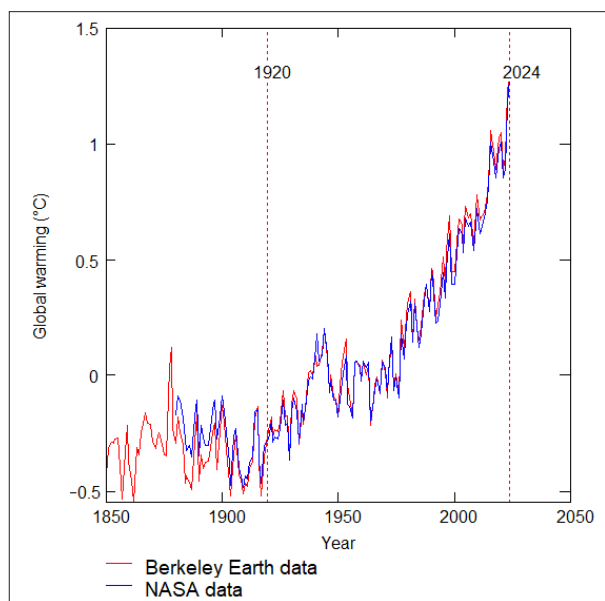
**Figure 2:** Global Warming vs. Year Per Berkeley Earth



**Figure 3:** Global Warming Estimates of Berkeley Earth and NASA, and the Transformed AGGI and CO2 Data, vs. Year

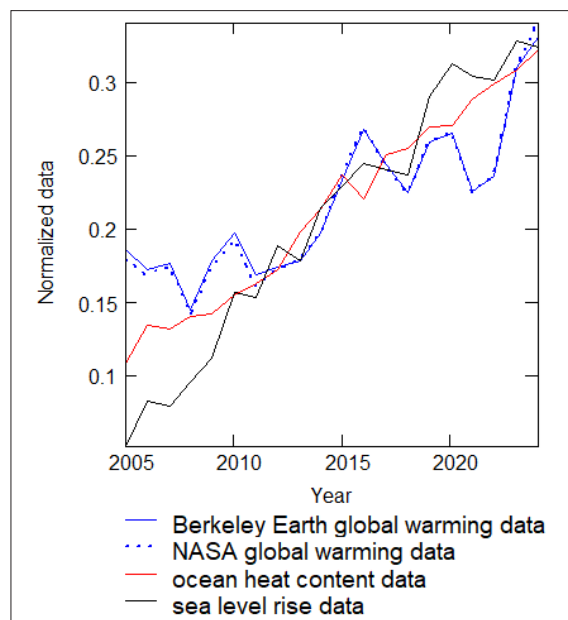
The voluminous Berkeley Earth global warming record includes the NASA global warming record [1,2,17]. Figure 3 shows the NASA global warming estimate separately. It is a parabolic least squares approximation before 1947.0 and an exponential approximation since 1947.0, which is midnight, December 31, 1947 when the 1947 measurements were complete. The Berkeley Earth estimate is exponential since 1940.0. On the aforementioned 1940s dates the annual exponential estimates most closely match the earlier annual parabolic least squares approximations, but they later surpass them, in 2006 for the Berkeley Earth data, and in 2010 for the NASA data. The current estimate of global warming is 1.1°C.

The atmospheric greenhouse gas curves are increasing in concert with global warming, and are shown in Figure 3. Figure 3 has no scale of greenhouse gas concentration, but the similarity among global warming, the CO<sub>2</sub> curve, and the AGGI are depicted by transforming the gas curves [18,19]. The transformation consists of aligning the gas curves with global warming at 1987.3 when the atmospheric CO<sub>2</sub> concentration was the ideal 350 ppm, normalizing the them by their 2-norms (Euclidean norms), and multiplying them by the Berkeley Earth global warming estimate [20]. The latest AGGI value is not yet available. Not all greenhouse gases are included in the AGGI. Carbon dioxide comprises 66% of the AGGI. The other AGGI gases include methane (16%), fluorinated gases (12%, now controlled), and nitrous oxide (6%).



**Figure 4:** Common Mode Noise in the Global Warming Data

Fourier (1822) proved that heat transfer is periodic [21,22]. Figure 4 reveals the common periodicity of the global warming data that is ostensibly caused by heat transfer in and out of the ocean, as suggested by climate change animations. The correlation of the Berkeley Earth data with the NASA data in Figure 4 is 0.99, so the Figure 4 periodicity is not random, but random noise is present in both Figures 3 and 4 because neither the global warming data nor their estimates are identical. Another high correlation is 0.98, between ocean heat content and sea level rise, as shown by the normalized data in Figure 5; i.e., the Earth's increasing ocean heat content and the increasing thermal expansion of its seawater are highly correlated. Figure 5 shows sea level rise catching up with ocean heat content, and foreshadows both of those parameters catching up with their impetus, global warming. The time period shown in Figure 5 is from 2005 until the present, the same as that of the ocean heat content data [12].



**Figure 5:** Normalized Noisy Data vs. Year Since 2005

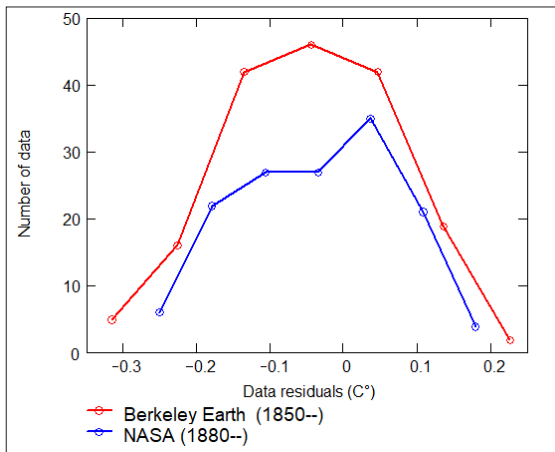
**Timetable for Global Warming T to Reach 1.5°C**

**Table 1: The Global Warming Rise to 1.5°C**

This per cent of global warming data will reach 1.5°C in the indicated years per estimates of →	Berkeley Earth data →	and NASA data.
2.5%	2029.4	2028.9
50%	2037.0	2034.6
97.5%	2043.6	2039.7

The 50th percentile dates show that 1.5°C global warming per the NASA data is estimated to arrive in the US 2.4 years before it appears everywhere else per the Berkeley Earth data.

Before 1920, when the world economies had not yet begun to roar in synchronism, the Figure 4 data do not match closely. The two-sigma uncertainties of the estimated dates in Table 1 are computed by first computing the differences between the global warming data sets in Figure 4 beginning in 1920 and dividing the differences by  $\sqrt{2}$ . Then twice the standard deviation of those differences is computed, is added to and subtracted from 1.5°C, and the dates corresponding to the global warming spread are located on the time axis by inverting the equations of the estimates, so as to solve for time as a function of global warming. The two-sigma uncertainties in the dates in Table 1 since 1920 are then  $\pm 1.3$  years for the Berkeley Earth data and  $\pm 1.1$  years for the NASA data.

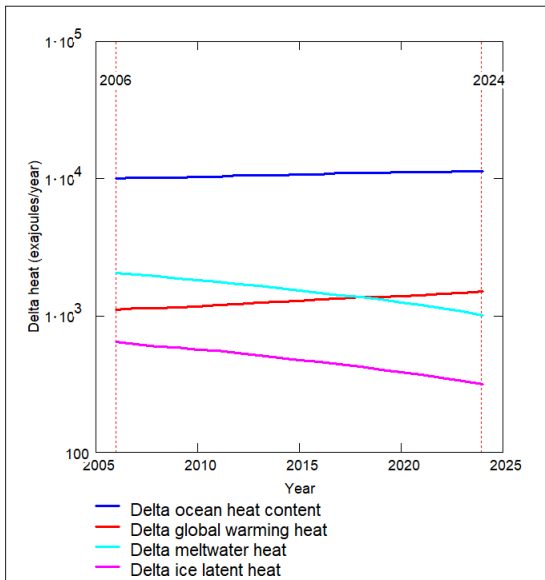


**Figure 6:** Global Warming Data Residuals for Berkeley Earth and NASA

The Figure 6 histograms show the distributions of the global warming residuals that are the data minus the estimates shown in Figures 2 and 3. These residuals are treated as random, although the much smaller errors between the data in Figure 4 shows that the large residuals in Figure 6 are mostly systematic errors.

**Relationships Among Annual Rates of Change of Heat in Reservoirs**

The ocean, down to 2000 m, contains the most heat because of its high specific heat capacity, low albedo, large mass, large area, and circulation [11]. All data used in this section are decoupled from data earlier than 2005 by considering only the *rates of change* of the data since 2006.



**Figure 7:** Estimates of Rates of Change of Annual Heat Increments

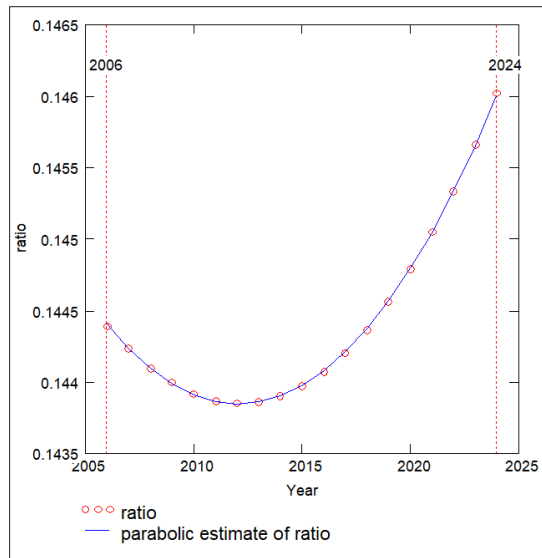
Figure 7 shows estimates of the annual rates of change of the heat in four heat reservoirs: (a) the ocean heat content ; (b) the global warming heat  $\Delta GWH$  calculated per Equation (5) from only the Berkeley Earth global warming estimate; and (c) the meltwater heat  $\Delta MWH$  and ice latent heat  $\Delta ILH$  estimated from sea level rise [11-13].

Twelve values of  $\Delta OHC$  for 2021-2024, computed from the  $OHC$  in Pan et al. (2025) and Cheng et al. (2025), average 1.5 times those of the  $\Delta OHC$  calculated from NOAA.gov (2014) used here [24,25,12]. The reason for this difference is not known. Consider the ratio

$$ratio = \frac{\Delta GWH + \Delta ILH}{\Delta OHC + \Delta MWH}, \tag{6}$$

which is just  $\frac{\Delta GWH}{\Delta OHC}$  corrected for ice melting. The  $\Delta ILH > 0$

are the annual differences in the ice latent heat that is absorbed by the ice during melting. This heat is supplied by the global warming heat. The  $\Delta MWH > 0$  are the annual differences in the freezing cold meltwater warmed by the 16°C ocean [26]. This heat is supplied by the ocean heat content.



**Figure 8:** The Equation (6) Ratio for Berkeley Earth Global Warming

The Equation (6) ratio is the parabola shown in Figure 6, and is now 15% for the Berkeley Earth  $\Delta GWH$  estimate, which reached a minimum in 2011.7. The figure for the NASA data is 17%. By a process of elimination, the ocean heat content is being outlandishly increased by more of the Earth's internal heat leaking through enlarged cracks in the Earth's brittle crust, because there is no other place wherefrom that much excess heat can come. The enlargement of the cracks evidently started around 1969.0 [11].

Rock, like concrete, is relatively strong in compression, but relatively weak in tension, such as that caused by thermal expansion of the Earth's rocky crust. The crust, which is mainly basalts under the ocean and granites under the land, lacks the reinforcing rods (rebar) used in steel-reinforced concrete construction [27]. If a continuous narrow belt of molten rock had been poured in a great circle around the Earth before the beginning of the Industrial Revolution, by now the present 1.1°C of global warming would have caused it to expand by hundreds of meters because of the positive volumetric coefficients of thermal expansion of rocks [28]. This expansion would cause existing cracks in the crust to become larger.

## Assumptions and Approximations

Smooth estimates allow noise-free numerical differentiation of noisy data. Annual data of global warming  $T$ , global warming heat  $GWH$ , ocean heat content  $OHC$ , and sea level rise are noisy, so they are estimated by smooth least squares approximations by using the Levenberg-Marquardt method [29-31]. All noise is assumed to be random. Global warming time series are assumed to proceed per extrapolation of their estimates until the 97.5<sup>th</sup> percentile of 1.5°C global warming is reached in a few years. Arrhenius' power balance model assumes the Earth is an i.i.h. sphere rotating in a circular orbit around the Sun.

## Summary and Conclusions

The rate of increase of ocean heat content is now about six times that of global warming heat. However, global warming heat comprises all of the excess heat that the Earth retains from the Sun. By a process of elimination, thermal expansion of the Earth, and subsequent enlargement of cracks in its brittle rock crust, must be increasing the leakage of its internal heat into the ocean. Global warming is estimated to approach 1.5°C at the 2.5<sup>th</sup> percentile around 2029–2030. The expected arrival times of the 50<sup>th</sup> percentiles of 1.5°C global warming are  $2034.6 \pm 1.1$  years for the NASA global warming data and  $2037.0 \pm 1.3$  years for the Berkeley Earth data.

## Appendix. Disclaimer

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