RESEARCH

Reproducing the Mid-Piacenzian warm period climate in the 2020s

Richard M. Blaber

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ABSTRACT

The current expectation of climatologists is that levels of atmospheric carbon dioxide (CO_2) and other greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), will correspond, in the 2020s, to an increase in mean annual global near-surface atmospheric temperature of less than 1.5°C above the pre-industrial Holocene norm (1750 baseline; atmospheric CO_2=278 ppm). This paper will argue, contrarily, that it is not possible to reproduce the atmospheric chemistry of the Mid-Piacenzian Warm Period (3.3-3 Mya) of the Pliocene Epoch, 5.3-2.588 Mya, without also reproducing its climate, and that consequently we can expect to see global warming of 3°C this decade.

Key Words: *climate; anthropogenic climate change; carbon dioxide (CO_2); other greenhouse gases; global warming; Mid-Piacenzian Warm Period; Pliocene Epoch; transient versus equilibrium climates*

INTRODUCTION

It shall be argued in this paper that reproducing the atmospheric chemistry of the Mid-Piacenzian Warm Period (3.3-3 Mya; hereinafter MPWP) of the Pliocene Epoch is liable, *ceteris paribus*, to reproduce the climatic conditions of that period, and that the same applies to any other period or epoch of the geological past.

The qualification is important: it is not argued here that merely replicating previous high levels of carbon dioxide will result automatically in high surface temperatures if, for example, the Earth's orbital parameters (eccentricity, obliquity and precession) [1]. Were to be like those prevailing in the Pleistocene glacial periods. However, it is accepted that the KM5c marine isotope stage (see ref), 3.205 Mya, corresponds to a time when Earth had the same orbital configuration as it does today, and in contrast to the Pleistocene Epoch, the Ice Ages which resulted from the cycles in Earth's orbital parameters identified by ref [2-6].

Using the formula derived from (Ref 2008, p.3), which stipulates that solar luminosity increases by 1% every 110 million years, we can calculate that, 3.205 million years ago, the Sun was 0.029% less luminous than it is today [7].

All scholars agree that atmospheric carbon dioxide (CO_2) levels during the MPWP are comparable to today's, with de la Vega et al (op.cit.) claiming that they reached a maximum of 421 ppm during the KM5c interglacial, corresponding to a mean annual global near-surface atmospheric temperature ~3°C above the pre-industrial Holocene norm. The US National Oceanographic and Atmospheric Administration reports that, in August 2023, atmospheric CO_2 reached 419.68 ppm, having been as high as 424 ppm in May of this year [8]. The 'de-seasonalised' figures for May-August 2023 are 420.55 ppm, 421.19 ppm, 421.42 ppm and 421.62 ppm, respectively.

Equilibrium versus transient climates

It is argued that the MPWP was an equilibrium climate, and so is not strictly comparable to today's climate, which is transient [9]. The parallel is between Equilibrium Climate Sensitivity (ECS), which is the change in Surface Atmospheric Temperature (SAT) in response [10]. However, as note, this difference can, in fact, mean that transient climates are warmer than equilibrium ones, not cooler [11].

Total Solar Irradiance (TSI), otherwise known as the solar constant, or insolation is the average amount of solar electromagnetic radiation, measured over the entire spectrum, incident upon unit area of a surface of the Earth perpendicular to the Sun's rays, at a distance of one astronomical unit (~100 million kilometres), from the Sun during the course of one year, and is 1.361 kWm^{-2} [12]. The cross-sectional area of the planet's surface exposed to the Sun's rays annually is one quarter of TSI, which is 340.25 Wm^{-2}. Schmutz WK. (2021) discusses the relationship between reconstructed TSI and climate (specifically March temperature records from Kyoto, Japan) for the 660-year period from 1230 to 1890, and concludes that the TSI can decrease by up to 10 Wm^{-2} during Maunder Minimum 'cold climate excursions' (p.1) [13]. However, concluded that solar forcing probably had a minor effect on the Northern Hemisphere climate

Independent Researcher, retired. United Kingdom

Correspondence: Independent Researcher, retired. United Kingdom. E-mail: richardblaber1956@gmail.com

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over the past millennium [14]. We have already seen that solar luminosity was slightly lower than its present value during the MPWP, so solar forcing, as well as orbital forcing, cannot account for the higher mean annual global surface temperature at that time.

The difference between the amount of energy Earth receives from the Sun and that which it reflects back out into space is the Earth's Energy Imbalance (EEI), and it is both positive and growing in size, with 89% of the heat stored in the oceans and seas, 6% on land, 1% in the atmosphere, and 4% available for melting the cryosphere (polar ice caps + glaciers and permafrost). The heating rate amounts to ~0.76 Wm^{-2} over the most recent period measured, 2006-2020, and the total heat energy accumulated from 1971-2020 amounted to ~381 ZJ (zettajoules; 1 ZJ=10^{21}, or 1 sextillion joules); see [15]. This will have contributed to the record high global Sea Surface Temperatures (SSTs) reported for August of this year by the European Union's Copernicus Climate Change Service (2023), reaching 21.02°C on the 23rd and 24th of August [16]. The North Atlantic Ocean reached a record high of 25.19°C on the 31st August.

At the same time, as the NASA Earth Observatory (2023) reported in August, Antarctic sea-ice extent, which should be increasing by over 15 million km^2 in the Austral Winter, averaged only an additional 13.5 million km^2 throughout July, 2 million km^2 less than the 1981-2010 average, and 1.5 million km^2 less than the previous record low of July 2022 [17,18].

The US National Snow and Ice Data Center (NSIDC, 2023) informs us that, in August of this year, Arctic sea-ice extent (Boreal Summer) averaged 5.57 million km^2, 1.63 million km^2 below the 1981-2010 reference period [19].

They discuss the relationship between EEI and what they term the 'effective climate sensitivity to CO_2', which they estimate to be 5.46 K (= °C), and which differs from ECS because it only includes CO_2, like ECS is run for 150 years under an abrupt quadrupling of the gas, but unlike ECS ignores the carbon cycle and ice-sheet responses and that of ocean and sea ice beyond 150 years [20]. It is obtained, they say, by 'regressing Top-Of-The-Atmosphere (TOA) radiative imbalance against SAT surface air temperature] and then linearly extrapolating to determine the temperature at which the radiative imbalance is zero.'

It should be noted that the variable λ they use is not the same as the one used below, but is a negative climate feedback parameter, measured in W $m^{-2}K^{-1}$.

The polar ice sheets in the MPWP were much smaller than those of present-day, and sea-levels were ~20 m higher [21]. They note the MPWP was not only warmer than present-day conditions, but wetter, and that temperate and boreal vegetation zones were shifted northwards from their present positions [22]. They concur, finding considerable warming in the higher latitudes, a wetter climate, but less warming in the tropics [9].

They ask if the MPWP can constrain ECS, and conclude that it yields a range of 1.9-3.7°C [23]. They argue that: 'when paleoclimate models are forced with early Eocene boundary conditions (dimmer sun, vegetation distribution, continental configuration, and a lack of ice sheets) but preindustrial greenhouse gas concentration, simulated global surface temperature response tends to be around 5°C warmer than simulations of the present-day Earth' [24].

They therefore argue for a broader measure than ECS, Earth System Sensitivity (ESS), which takes account of slow climate feedbacks, as well as faster ones. They claim there was a two-fold increase in the ESS at some time during the Pliocene and Pleistocene Epochs. They derive a value for ESS of 3-4.7°C for every doubling of CO_2.

They agree with Sun (op.cit (Ref).) regarding the modest warming of the Pliocene tropics (only about 1°C warmer than present value) and noted there was no permanent 'El Niño', as predicted by some climate models, say that higher CO_2, along with (consequent) changes in ice and vegetation, and some differences in topography, are enough to explain Pliocene climate [9,25].

They claim that ECS is ~1.2°C m^2 W^{-1} [10]. Full climate forcing (CO_2 +non-CO_2) of 4.1 Wm^{-2} would, they say, result in 'equilibrium global warming' of 10°C, but this is reduced to 8°C by contemporary aerosols. They argue the decline in aerosol emissions since 2010 should increase the post-2010 global warming rate to at least 0.27°C per decade, and that the 2015 Paris Agreement target of 1.5°C will be exceeded in the 2020s, with the 2°C target by 2050.

They note that the IPCC has a mean estimate for ECS of 3°C (see Ref, p.926); they argue it is 'virtually certain' to be >1.5°C, and the 'very likely' range is 2°C-5°C, while the 'likely' range is 2°C-4°C) [26]. Air quality improvement legislation is likely to reduce anthropogenic aerosol emissions, as Hienola et al. (2018) argue, and this, as they say, could make global warming 'noticeably faster and stronger' [27]. It (2019) defines the ECS as: 'the global- and time-mean, surface air warming once radiative equilibrium is reached in response to doubling the atmospheric CO_2 concentration above pre-industrial levels [28].

They give an estimate for ECS of between 2.42-5.83 K (°C, p.4). The graph below (from the Scripps Institution of Oceanography, 2023) shows how atmospheric CO2 has increased from 278 ppm in 1750 to ~420 ppm in 2023, an increase of 51.079% in 273 years–almost all of it since 1960, i.e., in the last 63 of those years (Figure 1)[29].

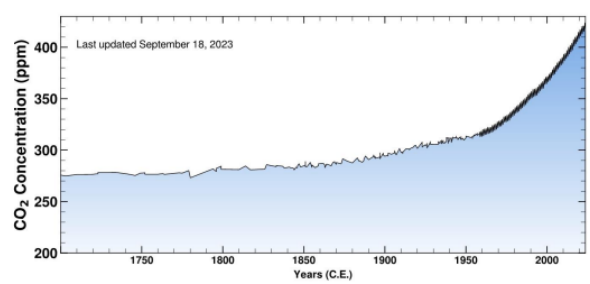

Figure 1) *CO_2 concentration*

DISCUSSION

There may well be some confusion regarding what units ECS is measured in, whether it is °C, K, or °C m^2W^{-1}. In reality, for this purpose, °C and K are equivalent, although the former is to be preferred, as the Paris agreement targets are measured in celsius, and that temperature scale is the one used by the IPCC and UNFCCC.

With regard to the latter, it is multiplied by a climate forcing, measured in Wm^{-2}, to obtain an ECS measured in °C. Using the formula discovered by Ref (1895, 1896), we determine that the increase in mean annual near-surface atmospheric temperature since 1750 (CO_2 =278 ppm) [30].

ΔT is given by:

$$\Delta T = \Delta F \times \lambda \times \log_n \left(C / 278 \right)$$

Here, ΔF is the climate forcing and λ is the ECS, measured in °C $m^2 W^{-1}$. C is then the current atmospheric level of CO_2 (we are here ignoring other greenhouse gases). It is obviously easier to deal with an ECS than it is the product of λ. ΔF, so that shall be our usage from now onwards, symbolized by Λ.

If the MPWP achieved global warming – that is to say, a mean annual global near-surface atmospheric temperature ~3°C above the 1750 level (13.42°C, only 0.3°C below the 1900 level, illustrative of the small degree of change over that 150-year period) –that would have corresponded to a similar CO_2 baseline of 278 ppm. The maximum during the KM5c marine isotope stage of the MPWP, 3.205 Mya, as we have seen (p.2), was 421 ppm. However, this leads us to only one –and one quite horrifying –conclusion –as we shall see [30-32].

CONCLUSION

The conclusion we are forced to draw from the above is straightforward, but one many will find distressing and profoundly discomforting, and it is this: if we re-arrange the above equation to obtain a value for Λ in the KM5c stage of the MPWP, we get

$$\Lambda = 3°C / log_n \left(421 / 278 \right) = 7.2287°C$$

This is well above the ECS given by Hargreaves and Annan, Rugenstein et al (op.cit.) and Forster et al (op.cit.), but is less than the 8.55 K (=°C) ECS outlier identified, and rejected by, Rugenstein and her colleagues (p.4, ibid.). It is also above that given by Hansen et al, the figure for ESS supplied by Ring, Mutz and Ehlers (op.cit.), and that for 'effective CO_2 climate senility' given by Chenal, Meyssignac, Ribes and Guillaume-Castel (op.cit.).

The result will be stark: if this ECS is replicated in the 21st Century – and there is no reason to doubt that it will be then global warming will reach 3°C, not at the end of the century, but this decade – in fact, within the next year or so, see NOAA Global Monitoring Laboratory (op.cit.). If Hansen et al are right in their estimat

on of the value of GHG forcing, namely 4.1 Wm^{-2}, that only requires a figure for λ of 1.7631 °C m^2W^{-1}, rather than 1.2 °C m^2W^{-1}, to produce the value for Λ given above.

There is, therefore, absolutely no room for the sort of complacency about the climate emergency displayed by the British Prime Minister, Rishi Sunak, or the British Opposition Leader, Sir Keir Starmer, recently.

On the contrary, we need an immediate, global, end to the burning of fossil fuels, to deforestation, and to the destruction of wetlands. There can be little doubt that none of these things will occur, and therefore no grounds at all for optimism regarding the future of our species. However, nature is nothing if not resilient, and the possible extinction – or severe culling – of our species may lead to the survival, and flourishing, of many others that have hitherto faced oblivion. That, at any rate, is cause for optimism for all but the most purblind of anthropocentrists.

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