Controlling the Global Mean Temperature by Decarbonization

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Abstract: Establishing a reliable method to predict the global mean temperature (T_e) is of great importance because CO₂ reduction activities require political and global cooperation and significant financial resources. The current climate models all seem to predict that the earth's temperature will continue to increase, mainly based on the assumption that CO₂ emissions cannot be lowered significantly in the foreseeable future. Given the earth's multifactor climate system, attributing atmospheric CO₂ as the only cause for the observed temperature anomaly is most likely an oversimplification; the presence of water (H₂O) in the atmosphere should at least be considered. As such, T_e is determined by atmospheric water content controlled by solar activity, along with anthropogenic CO₂ activities. It is possible that the anthropogenic CO₂ activities can be reduced in the future. Based on temperature measurements and thermodynamic data, a new model for predicting T_e has been developed. Using this model, past, current, and future CO₂ and H₂O data can be analyzed and the associated T_e calculated. This new, esoteric approach is more accurate than various other models, but has not been reported in the open literature. According to this model, by 2050, T_e may increase to 15.5 °C under “business-as-usual” emissions. By applying a reasonable green technology activity scenario, T_e may be reduced to approximately 14.2 °C. To achieve CO₂ reductions, the scenario described herein predicts a CO₂ reduction potential of 513 gigatons in 30 years. This proposed scenario includes various CO₂ reduction activities, carbon capturing technology, mineralization, and bio-char production; the most important CO₂ reductions by 2050 are expected to be achieved mainly in the electricity, agriculture, and transportation sectors. Other more aggressive and plausible drawdown scenarios have been analyzed as well, yielding CO₂ reduction potentials of 1051 and 1747 gigatons, respectively, in 30 years, but they may reduce global food production. It is emphasized that the causes and predictions of the global warming trend should be regarded as open scientific questions because several details concerning the physical processes associated with global warming remain uncertain. For example, the role of solar activities coupled with Milankovitch cycles are not yet fully understood. In addition, other factors, such as ocean CO₂ uptake and volcanic activity, may not be negligible.

Key Words: Calculation method for global mean temperature; CO₂ in the atmosphere; Water in the atmosphere; Global warming; CO₂ reduction

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通过脱碳控制全球平均温度

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摘要: 建立能可靠预测全球平均温度(T_e)的方法, 对于寻求政治和全球合作以及大量财政资源来推动CO₂减排至关重要。基于可预见的若干年内CO₂排放量不能显著降低这一假设, 目前的气候模型似乎都预测 T_e 将会持续上升。然而, 将大气中的CO₂作为多因素地球气候系统的唯一变量, 来关联观察到的温度异常, 很可能过于简单化了, 因为大气中H₂O的存在是至少应该要考虑的。受控于太阳活动的大气H₂O含量是 T_e 的首要决定因素, 其次才是与人类活动相关的CO₂排放, 而CO₂排放将来可能降低。基于地球平均温度观测值和热力学数据, 建立了新的预测模型。应用该模型方程, 可以分析过去、当前和未来大气中CO₂和H₂O含量并可计算出相应的 T_e 。这是一个还未见公开报道的、更精确的模型。本模型预测, 依据将较基准情景(business-as-usual, BAU), 到2050年 T_e 可能上升至15.5 °C; 通过合理的绿色技术行动方案, T_e 可能降至约14.2 °C, 预测未来30年CO₂可减排513千兆吨。绿色技术应用场景包括诸如各种CO₂减排行动, 碳捕获, 矿化以及生物碳生产等, 其中至2050年CO₂减排的主要贡献将来自于电力、农业和运输行业。另外, 也对更激进的Plausible和Drawdown方案进行了分析, 预测未来30年CO₂可分别减排1051和1747千兆吨, 但这些方案可能会减少全球粮食生产。要强调的是, 全球变暖的成因和预测应该视为开放的科学问题, 因为涉及与全球变暖相关的物理过程的多个问题仍然无解。例如, 太阳活动耦合米兰科维奇(Milankovitch)循环扮演的角色就没有完全理解。还有, 海洋对CO₂的吸收和火山活动等其它因素的影响, 可能无法忽略。

关键词: 全球平均温度计算方法; 大气CO₂含量; 大气H₂O含量; 全球变暖; CO₂减排
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1 Introduction

Many climate models have been developed, based on mathematical computer simulations of many factors such as the temperature of the atmosphere, the oceans and the land surface and activities on the sun and other factors. These factors all interact and are important to determine the average mean world temperature (T_e) and other events related to the earth's climate. Many scientists legitimately have wondered how accurately these climate models can predict earth's future T_e . A recent study by environmental scientists from Berkeley¹ has shown that the climate models published during the past five decades have skillfully described T_e changes, with most examined models showing global temperature warming consistent with observations, particularly when mismatches between model-calculated and observationally estimated were taken into account. Regarding the future T_e , the current climate models all seem to predict that the earth's temperature will continue to increase mainly assuming that CO₂ emissions cannot be lowered significantly in the foreseeable years.

In this paper, we will analyze observational data regarding global warming. Using readily available data, a simple calculation method for the T_e is proposed since other models published in the literature are not accurately predicting the future. This new proposed model should take into consideration the water in the atmosphere and anthropogenic CO₂. The simple

new model must also be consistent with thermodynamic calculations of the atmospheric energy balance. We also like to show how the earth's temperature may be decreased by certain reasonable CO₂ reduction activities. Other climate change events not caused by the T_e have not be the objective of this paper.

2 Data and methods

2.1 Global warming

Fig. 1 shows the T_e (in blue) from 1850–2020. In brown, we indicate what the T_e would have been if the temperature increase were 0.0025 °C per year, which was the case from 1600 till 2000, according to Table 1. At this moment, the measured temperature is about 1 °C higher than the brown temperature. If this trend would continue (see Fig. 2), the T_e would be 16.4 °C by 2050,

Fig. 1 The T_e in °C in the past 140 years, based on data from Refs. 2–4.

Table 1 Global temperature increase per year, including data from the National Aeronautics and Space Administration (NASA) and the Goddard Institute for Space Studies (GISS).

	Years	ΔT	$\Delta T/\text{year}$	$\Delta T/100 \text{ year}$
Core Ice	10000	11	0.0011	0.11
1600–2000	400	1.0	0.0025	0.25
1910–2020	110	1.4	0.0127	1.27
1980–2019	39	0.9	0.0231	2.31

Ref. 3 (NASA, GISS), Ref. 4 (Buis), Ref. 5 (Moore), Ref. 6 (Spencer), and Ref. 7 (Petit).

Adaptation of IPCC prediction and including Authors' estimate – see Section 3.3

Fig. 2 Expected global temperature change according to the IPCC² and the author's scenario.

and by 2100, the T_e would be 19.0 °C². It becomes clear that the current global temperature increases of 0.0231 °C/year (from 1980 till 2019, see Table 1) is considerably higher than ever experienced on earth. However, we like to understand the causes of the observed increase of the T_e , on a solid scientific basis.

2.2 Global temperature as a function of water vapor and CO₂ in the atmosphere

The T_e is related to the amount of water in the atmosphere (largely controlled by solar irradiation^{8,9}) and added CO₂. The amount of CO₂ in the atmosphere is currently measured daily. That has not been the case for water vapor in the atmosphere. However, data from the National Aeronautics and Space Administration (NASA) covering global precipitation (in mm per day) from 1900 till 2000 allow us to estimate the water content of the atmosphere since the residence of rain is known to be approximately 9 days.

Using the observed CO₂ and water data of the earth's atmosphere in 1970 and 2019 and the measured T_e at those times (see Fig. 3), one can calculate two coefficients, one for water a and one for CO₂ b according to the following equation.

$$T_e (\text{in } ^\circ\text{C}) = a \times [10^{-6}(\text{v}) \text{ H}_2\text{O}] + b \times [10^{-6}(\text{v}) \text{ CO}_2] \quad (1)$$

The experimental value of $a = 2.696 \times 10^{-3}$ in °C/(10⁻⁶(v)), while the value for $b = 1.065 \times 10^{-2}$ in °C/(10⁻⁶(v)).

Using thermodynamic data^{10,11}, one can estimate the value of a and b . For water, one uses the heat of formation of gaseous water, minus the heat of vaporization divided by the heat capacity C_p of liquid water to calculate the coefficient a in °C/(10⁻⁶(v)). Since CO₂ is a gas at 13.95 and 15.10 °C, one

T_e in °C	$a \times [10^{-6}(\text{v}) \text{ H}_2\text{O}]$	$b \times [10^{-6}(\text{v}) \text{ CO}_2]$	
13.95 =	$a \times 3891$	$+ b \times 325$	[ca. 1970]
15.10 =	$a \times 3973$	$+ b \times 412$	[2019]
$a =$	2.696×10^{-3}	°C/10 ⁻⁶ (v)	[Water]
$b =$	1.065×10^{-2}	°C/10 ⁻⁶ (v)	[CO ₂]
$T_e (\text{in } ^\circ\text{C}) = a \times [10^{-6}(\text{v}) \text{ H}_2\text{O}] + b \times [10^{-6}(\text{v}) \text{ CO}_2]$			
10 ⁻⁶ (v) H ₂ O is based on data.giss.nasa.gov/precip_cru/graphs/fig. A			

Fig. 3 Calculating a and b coefficients from experimental data.

only needs the heat of formation divided by heat capacity C_p for calculating b . The thermodynamic calculations for H₂O and CO₂ are shown in Table 2 and Table 3. The a and b values using thermodynamics are close to the experimental data, with a delta of less than 2%.

The value of b can be used to establish the CO₂ sensitivity as a function of CO₂ increases in the atmosphere. Starting with a CO₂ level is 280 ($\times 10^{-6}(\text{v})$) in 1870 and 410 ($\times 10^{-6}(\text{v})$) in 2019, the CO₂ sensitivity becomes $(1.065 \times 10^{-2}) \times (410 - 280) = 1.38$ °C. If the CO₂ doubled to 560 ($\times 10^{-6}(\text{v})$), the CO₂ sensitivity would become 2.98 °C, in line with recently reported data in the literature with values from 2.2–3.4 °C¹². On this basis, we estimated that the CO₂ in the atmosphere should not pass beyond 440 ($\times 10^{-6}(\text{v})$) by 2050 if one aims at a maximum temperature increase of 1.5 °C in the future. It will be shown in Section 3.2 how this stringent objective is achievable.

Table 2 Thermodynamic calculations^{*} of a coefficient.

$T/^\circ\text{C}$	T/K	$\Delta H_f/(\text{kJ}\cdot\text{mol}^{-1})$	$\Delta H_{\text{vap}}/(\text{kJ}\cdot\text{mol}^{-1})$	$C_p/(\text{kJ}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})$	$a/^\circ\text{C}/(10^{-6}(\text{v}))$
25.00	298.15	-241.89	44.54	0.07537	2.6182×10^{-3}
13.50	286.65	-242.27	43.98	0.07560	2.6227×10^{-3}
13.95	287.10	-242.25	44.01	0.07559	2.6226×10^{-3}
14.50	287.65	-242.23	44.03	0.07558	2.6225×10^{-3}
15.10	288.25	-242.21	44.06	0.07556	2.6224×10^{-3}
15.50	288.65	-242.20	44.08	0.07555	2.6223×10^{-3}
16.00	289.15	-242.18	44.10	0.07554	2.6221×10^{-3}
16.50	289.65	-242.17	44.13	0.07553	2.6220×10^{-3}
17.00	290.15	-242.15	44.15	0.07552	2.6219×10^{-3}

^{*} Thermodynamic data in Refs. 10, 11.

Table 3 Thermodynamic calculations^{*} of b coefficient.

$T/^\circ\text{C}$	T/K	$\Delta H_f/(\text{kJ}\cdot\text{mol}^{-1})$	$C_p/(\text{kJ}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})$	$b/^\circ\text{C}/(10^{-6}(\text{v}))$
13.50	286.65	-393.95	37.40	1.0532×10^{-2}
13.95	287.10	-393.93	37.42	1.0526×10^{-2}
14.50	287.65	-393.91	37.45	1.0519×10^{-2}
15.10	288.25	-393.89	37.47	1.0511×10^{-2}
15.50	288.65	-393.88	37.49	1.0506×10^{-2}
16.00	289.15	-393.86	37.51	1.0499×10^{-2}
16.50	289.65	-393.84	37.53	1.0493×10^{-2}
17.00	290.15	-393.82	37.56	1.0486×10^{-2}

^{*} Thermodynamic data in Refs. 10, 11.

3 Results

3.1 Past and future global temperatures using Eq. (1)

In many cases, one measured the T_e and the CO_2 in $10^{-6}(\text{v})$. Fig. 4 shows data for CO_2 , H_2O , and associated T_e from 1880 till 2019, using Eq. (1). The observed CO_2 and H_2O data of 1970 and 2019 were used to establish the a and b coefficients, as discussed in Section 2.2. The CO_2 did increase from 280 ($\times 10^{-6}(\text{v})$) in 1880 to 410 ($\times 10^{-6}(\text{v})$) in 2019 (see Fig. 4). The concentration of H_2O in the atmosphere varied slightly during this period, which is possibly a natural trend¹³, depending on the absorbed solar radiation. This indicates that, on average, 71% of the observed T_e is caused by H_2O in the atmosphere, while CO_2 contributes 29%.

From 1980 to 2019, the delta T_e increased from 0.50 °C to 1.44 °C, relative to maintaining CO_2 at 280 ($\times 10^{-6}(\text{v})$), as in 1870. The delta T_e increase due to higher CO_2 was, therefore, 0.024 °C per year from 1980 to 2019 (see Table 1), which is an alarming increase, according to the authors of the Intergovernmental Panel on Climate Change (IPCC) reports².

As shown in references^{14–17}, the earth's temperatures in the past have been significantly higher than the current T_e , while the levels of CO_2 have been higher as well as lower than the current CO_2 level at 410 ($\times 10^{-6}(\text{v})$) (see Fig. 5). We, therefore, conclude that there is no clear correlation between the T_e of the earth and the CO_2 in the atmosphere, as noted by other scientists as well^{6,18}.

In 1998, 24.4 gigatons of CO_2 was added to the atmosphere, increasing to 36.6 gigatons in 2018¹⁹. As a result, the atmosphere contained 3120 gigatons CO_2 in 1998 and 3450 gigatons in 2018. That corresponds to a CO_2 residence time of about 30 years, in line with various papers in the literature, e.g., Ref. 20. Consequently, only a fraction of the emitted CO_2 remains in the atmosphere (equal to 0.918), while the remaining CO_2 will be absorbed by oceans, seas, and land, including photosynthesis activities.

3.2 Approaches to decrease CO_2 in the atmosphere

Using a similar approach for calculating the CO_2 in the atmosphere from 1998 till 2018 (see Section 3.1) and applying a “business-as-usable” scenario, we estimate that the T_e could be

Fig. 4 CO_2 and H_2O in the atmosphere and associated T_e from 1880 till 2019.

Global temperatures (T_e) plus H_2O and CO_2 atmospheric concentrations

Past	H_2O	CO_2	Total	Current	H_2O	CO_2	Total
T_e in °C	17.5	3.1	20.6	T_e in °C	10.6	4.5	15.1
$10^{-6}(\text{v})$	6535	280	History many years ago*	$10^{-6}(\text{v})$	3981	410	2019
$10^{-6}(\text{wt})$	4083	428		$10^{-6}(\text{wt})$	2449	626	
Gigaton	22496	2356		Gigaton	13494	3450	

Past	H_2O	CO_2	Total	Future	H_2O	CO_2	Total
T_e in °C	9.5	4.1	13.6	T_e in °C	10.0	4.3	14.3
$10^{-6}(\text{v})$	3876	295	1900	$10^{-6}(\text{v})$	3921	351	Author Scenario 2050*
$10^{-6}(\text{wt})$	2431	452		$10^{-6}(\text{wt})$	2427	538	
Gigaton	13397	2493		Gigaton	13374	2967	

* 250 million years ago - see refs. [14–17]

Fig. 5 CO_2 and H_2O in the atmosphere and associated T_e in the past, current and future.

15.5 °C by 2050 and about 17.0 °C by 2100, extrapolating the T_e increased from 1980–2019 by 0.0231 °C/year (see Table 1). These T_e estimates are lower than mentioned above in section 2.1 based on IPCC data, but it is more important that we agree with many scientists that everything should be done to keep the T_e increase at about 1.5–2.0 °C, including most of the participants of the IPCC². However, it is well known that not everybody agrees with the IPCC objective (see, e.g., Refs. 5, 6, 18, 21 as typical examples).

The most effective way to manage anthropologic CO_2 emissions is to avoid the formation of CO_2 . Furthermore, carbon-neutral technologies may assist in greening the world. Also, photosynthesis is an essential natural method to reduce CO_2 from the atmosphere, and technologies that remove CO_2 from the atmosphere may also become viable in the future. In the following paragraphs, we will present summaries of what can be achieved.

3.2.1 Electrical power generation

It is apparent that CO_2 reduction options for electrical power generation are being pursued around the world. By 2050, we estimate that 215 gigatons of CO_2 can be avoided mainly by applying wind and solar technology.

3.2.2 Agriculture including forestry

CO_2 reduction in the agriculture sector is also possible^{22,23}. In the next 30 years 471.5 gigatons of CO_2 emissions could be avoided. Forestry management, new agriculture technologies, and reducing food waste are likely the key areas with the most significant impact. Around the world, large scale reforestation projects are in progress, like in China, Brazil, USA, Morocco, and other countries.

3.2.3 Building

Better maintenance of air conditioning equipment could potentially reduce CO_2 emissions by 89.4 gigatons between 2020 and 2050²². Additionally, another 54.5 gigatons CO_2 reductions are possible using, for instance, district heating, better insulation, and LED lighting.

3.2.4 Transportation

The transportation sector can potentially reduce CO_2 emissions by 134 gigatons during the period from 2020 to 2050. This may be achieved using a variety of technologies. Around

the world, hydrogen fueled cars, electric cars, hybrid cars and mass transportation are already actively pursued and improved ships, trucks, and airplanes will follow as well. Biomass can be converted to transportation fuels, enabling carbon neutral recycling^{24,25}.

3.2.5 Industry

In the industry sector, fuels, and chemicals from sustainable resources²⁴ can lead to reductions in CO₂ emissions. Biomass, municipal solid waste, and other carbon-containing streams can be used to produce bio-SNG, bio-jet fuel, green methanol, and green ammonia²⁵. It may take some time to transform the industry sector to greener technologies, but several companies are already working on this.

3.2.6 Other CO₂ reduction methods

Education and family planning are highlighted to reverse the global temperature increase²⁵, reducing CO₂ emissions by 109.2 Gigatons during the next 30 years. One hopes that with education and family planning, the total world population will not increase as fast as projected.

In addition to the methods reviewed above, one can remove CO₂ from the atmosphere to lower the T_e . The following approaches may be suitable.

3.2.7 Photosynthesis

Photosynthesis is a natural way to remove CO₂ from the atmosphere. This requires that the atmosphere contains at least $150 (\times 10^{-6}(v))$ CO₂ with an optimum CO₂ level of $1500 (\times 10^{-6}(v))$. For this reason, farmers and gardeners add CO₂ to their greenhouses.

3.2.8 Biochar

Biochar is an emerging carbon material derived from renewable resources. This has triggered great interest in a variety of areas, including carbon sequestration and potential soil amendments²⁶. Trees and plants do grow faster in sandy soil mixed with clay, biochar, and mycorrhizae fungi if one has enough water. This had been demonstrated successfully, for instance, in the Gobi Desert in China and around the Sahara for the Great Green Wall initiative.

3.2.9 CO₂ mineralization

To date, the most widely accepted method of carbon capture and storage (CCS) is the injection of CO₂ into underground

geological formations and reservoirs. However, the risk remains that potentially suitable reservoirs may turn out to be insufficient, uneconomic, or impractical²⁷.

Carbon capture and mineral carbonation (CCMC), also called CO₂ mineralization, has been identified by the IPCC as a possible promising additional technology to remove CO₂ from the atmosphere. CCMC is a process whereby CO₂ is chemically reacted with calcium- and/or magnesium-containing minerals to form stable carbonate materials which do not incur any long-term liability or monitoring commitments. CCMC is highly verifiable and permanent in nature. Companies are pursuing CCMC, and demonstration pilot plants have already been in operation²⁸. Australia recently discovered large deposits of halloysite-kaolin clay that can be used for CCMC²⁹.

3.2.10 Direct air capture of CO₂

Biochar plus CO₂ mineralization can potentially remove about 78 gigatons of CO₂ in 30 years, as estimated in Ref. 22. By 2050, direct air capture of CO₂ could become an additional viable technology, if the captured CO₂ is used for CCS and/or CCMC.

3.2.11 Geoengineering

Star Technology and Research³⁰ has designed a system of space mirrors that blocks sunlight from reaching the earth and provides another source of clean energy for the earth. These spacecraft mirrors are remotely controlled and equipped with solar panels that collect some of the sunlight and send the captured energy back down to earth. However, geoengineering has many potential pitfalls that have not made it popular with scientists, whose climate platforms focus instead on ways to reduce the earth away from fossil fuels³¹.

3.3 Applying scenarios to reduce CO₂ emissions

Five scenarios have been developed (see Fig. 6), using similar calculations to assess the CO₂ in the atmosphere from 1998 to 2018, shown in Section 3.2. The first scenario, called “Business-as-usable” (BAU), extrapolates the current CO₂ emissions data¹³ until 2050, leading to an increase of 531 gigatons CO₂ in the atmosphere. The Shell scenario³² is a little better than the BAU scenario but still increases the CO₂ in the atmosphere of 351 gigatons. The most aggressive scenarios are called “Plausible” and “Drawdown” based on Ref. 22. The input of 192 well-known environmental experts, scientists, engineers, architects, lawyers

Fig. 6 Various scenarios for CO₂ in the atmosphere by 2050.

Fig. 7 CO₂ in gigaton in the atmosphere, based on authors' scenario and data from Ref. 11.

and writers have contributed to the formulation of the Plausible and Drawdown scenarios. The Plausible scenario is an optimistic, feasible frame work and forecast of CO₂ reduction activities that could impact the global climate with a total CO₂ reduction of 1051 gigatons in 30 years. The Drawdown scenario describes the most comprehensive plan to reverse global warming. It shows what would happen when the more conservative assumptions of the Plausible scenario are removed. In this case, a total CO₂ reduction of 1747 gigatons in 30 years could be realized. The proposed authors' scenario is selected as an achievable compromise approach, predicting a CO₂ reduction potential of 513 gigatons. Fig. 6 also lists corresponding global T_e in °C and the expected CO₂ in 10⁻⁶(v). The Plausible and the Drawdown scenarios would affect global food production since the CO₂ would drop to 240 ($\times 10^{-6}$ (v)) and 205 ($\times 10^{-6}$ (v)), lower than in 1850.

The anthropologic CO₂ emission in 2020 is estimated to lead to 3458 gigatons of CO₂ in the atmosphere, applying the trends shown on Ref. 19. According to the author's scenario, the CO₂ in the atmosphere would reduce to 2945 gigatons. The distribution of this amount by sectors of activity is shown in Fig. 7. The data indicates that relative to 2020, the most important CO₂ reductions by 2050 are expected to be achieved mainly in the electricity, agriculture, and transportation sectors.

4 Conclusion and discussion

It is a fact that the mean temperature of the earth has been increasing slightly during the past 60 years, which is supported by numerous data. Referring to Section 3.1, the a and b coefficients are based on observational data such as the T_e , the CO₂ in the atmosphere, and water in the atmosphere derived from rainfall records. The thermodynamic calculated a and b coefficients are in line with the experimental values. Furthermore, the 0.918 CO₂ decrease rate per year used in Section 3.1 shows that CO₂ remains in the atmosphere for many years, while water in the atmosphere only stays about 9 days. The amount of water in the atmosphere is, however, more dominant in terms of the earth's temperature than the contribution of CO₂. The amount of water hardly changed from 1850 till 2020, independent of the increasing CO₂ amount. Fig.

2 illustrates the expected T_e according to the IPCC ² and the author's scenario. If "Business as usual" is happening, the IPCC projects that the T_e could increase to 16.4 °C by 2050. Applying the correlations describes in Section 3.2, we estimate that the T_e may increase to 15.5 °C for a "Business as usual" scenario. According to the author's scenario, a T_e of 14.2 °C seems to be achievable by 2050. Using the proposed simple model to calculate T_e may seem to be an oversimplification, since it does not predict other important climate events, which were not part of the paper's objective.

Indeed, several questions regarding physical processes associated with global warming remain unanswered. That means that the causes and prediction of the global warming trend should be considered as open scientific questions. For instance, the roles of sun activities coupled with Milankovitch cycles, are not fully understood yet. Also, other factors like ocean CO₂ uptake and volcanic activities, may not be negligible.

Basing the multi-factor earth's climate system to CO₂ in the atmosphere as the only variable causing the observed temperature anomaly is most likely an oversimplification, because one should at least consider the presence of water in the atmosphere. That does not mean that efforts to lower CO₂ emissions should not be pursued because getting to a fossil-free world is ultimately unavoidable and will create progress in many ways.

Conflict of interest: The authors declare that they have no conflict of interest.

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