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The Relationship between Atmospheric Temperature and Carbon Dioxide Concentration

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Abstract

Human-produced CO_2 by fossil fuel combustion, combined with the rising atmospheric CO_2 concentration and the observed temperature increase, enabled a compelling narrative to be constructed, in which these three facts, in that order, formed a chain of causality. The narrative has been embraced by global political elites to promote their interests. It has also become dominant in public perception, by means of issuing threats for all aspects of life due to alleged climate impacts. My recent work has challenged the alleged causal relationships that form the narrative. A stochastic method for detecting causality showed that temperature change can potentially cause changes in CO_2 concentration, but not vice versa. Temperature increase causes the biosphere to expand and, in turn, produce more naturally emitted CO_2, which accounts for 96% of total emissions. All relevant data sets confirm these findings. In particular, instrumental and proxy data support the natural origin of the change in the isotopic composition of atmospheric CO_2, and century-long longwave radiation data show no discernible effect of increased CO_2 concentration on the greenhouse effect.

Keywords: Causality; stochastics; greenhouse effect; longwave radiation; water vapour; carbon dioxide

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Τι να μάς πει η φυσική / Οι νόμοι δε μετράνε / Σε φάση μεταφυσική / Τα πάθη κυβερνάνε
(What's the need for physics / The laws don't count / In a metaphysical phase / The passions rule)
Lavrentis Machairitsas, from the lyrics of «Πεθαίνω για σένα» ("Dying for you")

1. Introduction

Powerful elites, assuming the role of the planet saviours, blame human CO_2 emissions for every evil that befalls the Earth. In this, they are assisted by so-called climate science, which has constructed the causal chain, "a", "b", "c", shown in Figure 1 (upper row) as its core. Not only is this chain promoted by IPCC and the political and economic interests, but is also supported by mainstream "sceptics". However, in my view, it is naïve, as climate is too complex to be represented in such a simplistic sequence with a single cause. Besides, the causality direction is mostly opposite to the prevailing assumption and is represented by the lower row in Figure 1, which is a result of my recent research publications that are summarised below. In particular, causal links "b" and "c" are replaced by "β" and "α", respectively, which have opposite direction, while "a" is of minor importance as other factors trump it. These are examined in the next sections of this paper.

2. Assumed causal link "a": Is the increase in atmospheric CO_2 caused by human emissions?

One of the arguments in support of the popular affirmative reply to the above question has been the decrease of the abundance of the ^{13}C isotope, represented by the standard metric $\delta^{13}C$, in the atmosphere, which has been attributed to the burning of fossil fuels, and has been known as the *Suess* (1955) *effect*. Indeed, the time series of the atmospheric $\delta^{13}C$, seen in the lower graph of

Figure 2, shows a decreasing trend.

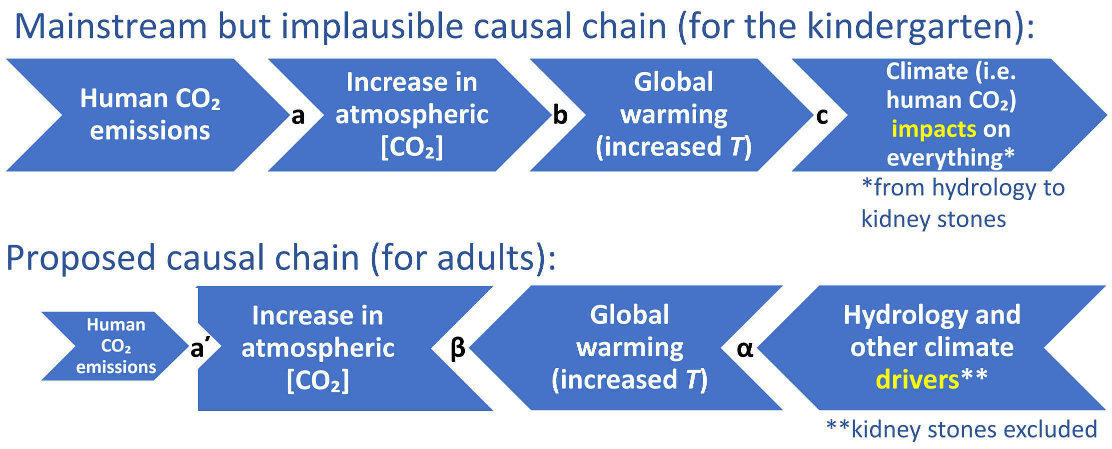


Figure 1: Graphical depiction of the subject of this paper, with the upper row of arrows showing the mainstream causal chain that is popular among climate zealots and mainstream climate sceptics, and the lower row showing the proposed alternative based on my recent publications. The smaller arrow for the human CO_2 emissions in the lower row corresponds to the fact that they only contribute 17% to the increase of [CO_2] (causal link "a′"), while natural emissions by the expanded biosphere due to increased T contribute 83% (causal link "β"; see Section 2). The footnotes are included for illustration and are documented as follows: A Google Scholar search for the terms "climate impacts" and "hydrology" yields 34 200 publications[1] and a search for the terms "climate change" and "kidney stones" yields 3710 publications[2].

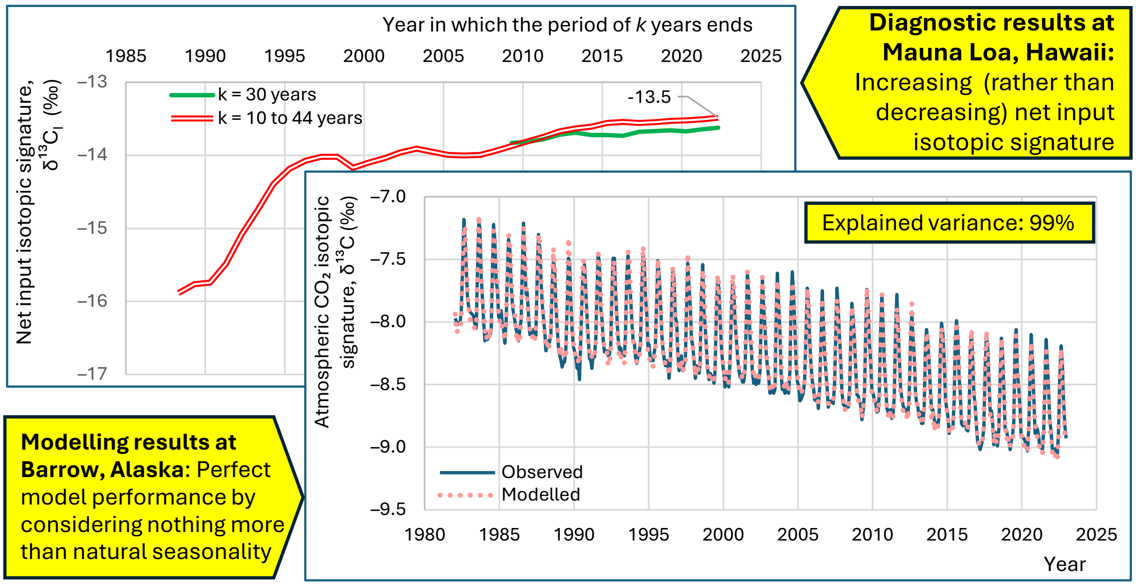


Figure 2: Reproduction of the graphical abstract of Koutsoyiannis (2024a).

[1] https://scholar.google.com/scholar?q=%22climate+impacts%22+%22hydrology%22.

[2] https://scholar.google.com/scholar?q=%22climate+change%22+%22kidney+stones%22.

However, as shown in the study by Koutsoyiannis (2024a), which fully reproduced the observations with a simple model (lower graph of Figure 2), the net input signal of the atmospheric, $\delta^{13}C_I$, is not decreasing—in some cases, it is increasing (upper graph of Figure 2). A constant $\delta^{13}C_I$ of slightly less than –13‰ at an overannual time scale is representative across the entire globe for the entire period of measurements. The same value holds for the entire period after the Little Ice Age, as confirmed by proxy data. These results support the conclusion that natural causes drove the increase of CO_2 concentration ([CO_2]). A human-caused signature (Suess effect) is non-discernible.

Besides, while fossil fuels have indeed a small $\delta^{13}C$ signature, down to –26‰, and hence their input $\delta^{13}C_I$ is low, C3 plants (e.g., evergreen trees, deciduous trees and weedy plants) have much lower $\delta^{13}C$ values than fossil fuels, down to –34‰, and thus their input $\delta^{13}C_I$ is even lower (Koutsoyiannis, 2024b). Lower values than in fossil fuels, also appear in other CO_2 sources. When the C3 plants (and many other organisms) respire, they emit to the atmosphere low $\delta^{13}C_I$, decreasing the atmospheric $\delta^{13}C$ content. It is therefore absurd to suggest that it is the emission from burning fossil fuels (4% of the total) that causes the atmospheric $\delta^{13}C$ value to fall.

A more detailed account of the atmospheric CO_2 balance was presented by Koutsoyiannis (2024c). That study fully overturned the IPCC's weird claims of different behaviour of the anthropogenic from the natural CO_2, where the former allegedly has a multi-millennial lifetime in the atmosphere. Contrary to this, Koutsoyiannis (2024c), showed that the CO_2 mean residence time in the atmosphere is: (a) independent of the origin (human or natural), (a) about 4 years on overannual basis, and (c) seasonally varying with lowest value < 2 years (see Figure 3, upper right).

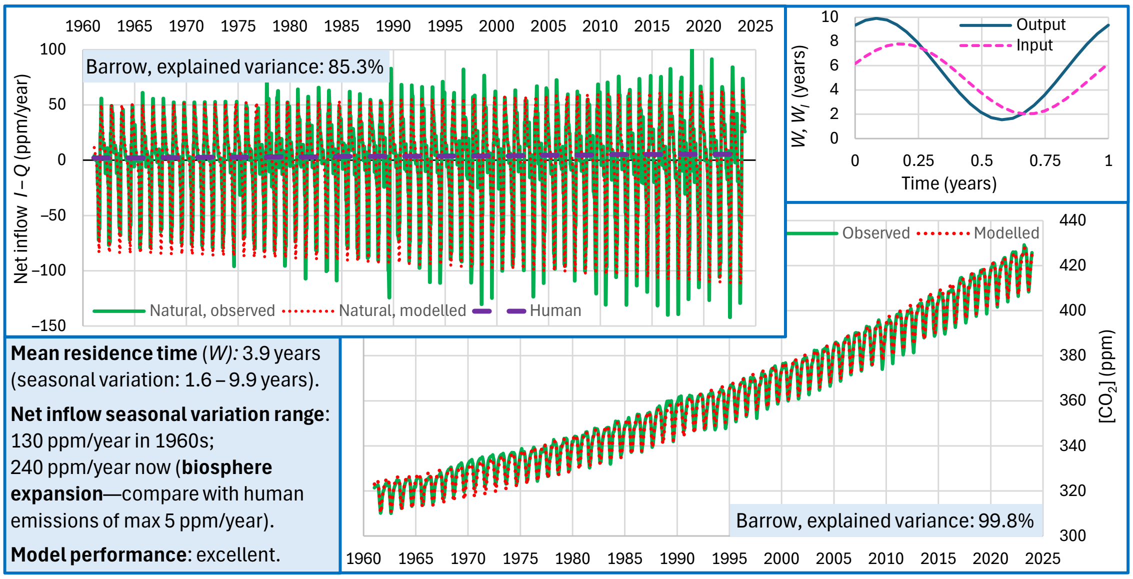


Figure 3: Reproduction of the graphical abstract of Koutsoyiannis (2024c).

The same study highlighted the fact that since the 1960s the biosphere has substantially expanded, as seen from the observations of net natural inflow of CO_2 (see Figure 3, upper left). The expansion was caused by the increase of temperature. Indeed, living organisms love warm conditions and increase their respiration R with temperature T exponentially, following the empirically proved relationship, known as the Q10 model (Patel et al., 2022):

$$R(T) = R(T_0)Q_{10}^{(T-T_0)/10} \tag{1}$$

where Q_{10} is a dimensionless parameter and T_0 and $R(T_0)$ are reference values. From the model results, we infer that the biosphere expansion from 1958 to 2023 resulted in an upsurge, Δ(EN), of the natural emission, EN, equal to 26.1 ppm CO_2/year. For comparison, the human emissions in this period varied from 2.1 to 5.4 ppm CO_2/year at the beginning and end of this period, respectively. The related time series are seen in Figure 4. From the entire figure, it can be inferred that the standard practice of both IPCC and mainstream sceptics to focus on the lower part of the graph (the two curves below 10 ppm/year in Figure 4) is inappropriate as it misses the "forest", i.e., the entire biosphere. This IPCC's practice is reflected in the following quotation (IPCC, 2021, p. 54): "*Emissions from natural sources, such as the ocean and the land biosphere, are usually assumed to be constant, or to evolve in response to changes in anthropogenic forcings or to projected climate change*." The inappropriateness of this practice can be inferred from the facts that the biosphere: (a) has its own dynamics that is not governed by human emissions, and (b) quantitatively has 25 times higher contribution than human emissions, even according to IPCC estimates (see Figure 5). If more recent estimates are considered, the human contribution becomes even less important. Specifically, in the recent publication by Lai et al. (2024) the estimates of gross photosynthesis and respiration are higher than the IPCC's, namely 157 and 149 Gt C/year, respectively (instead of the IPCC's estimates of 142.0 and 136.7 Gt C/year, shown in Figure 5).

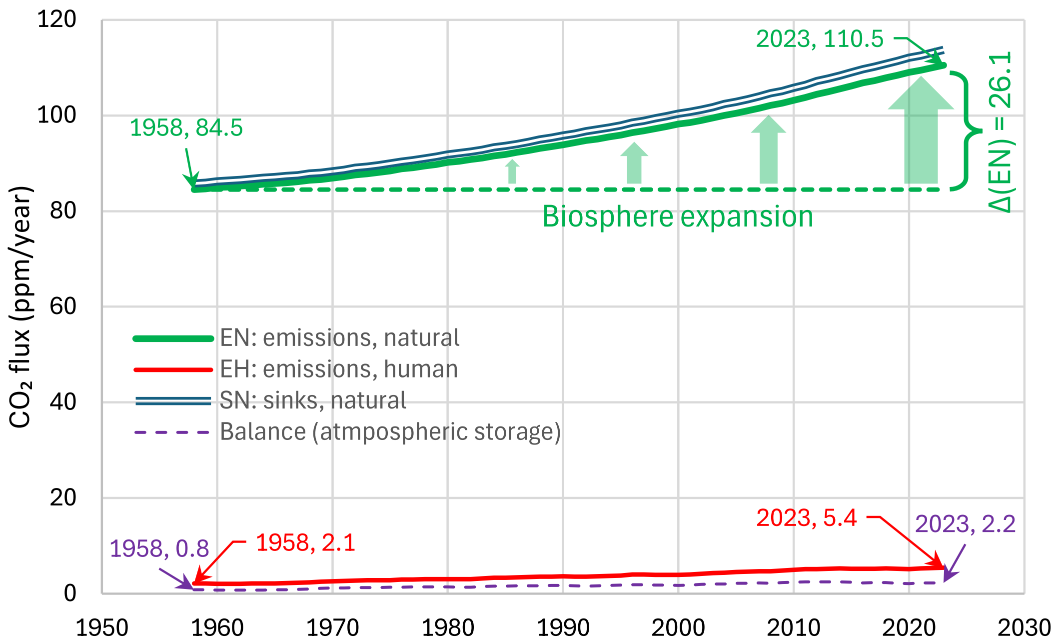


Figure 4: CO_2 fluxes in the atmosphere for the period 1958-2023, as inferred by human emission estimates, CO_2 concentration data, and the model by Koutsoyiannis (2024c) (for EN and SN).

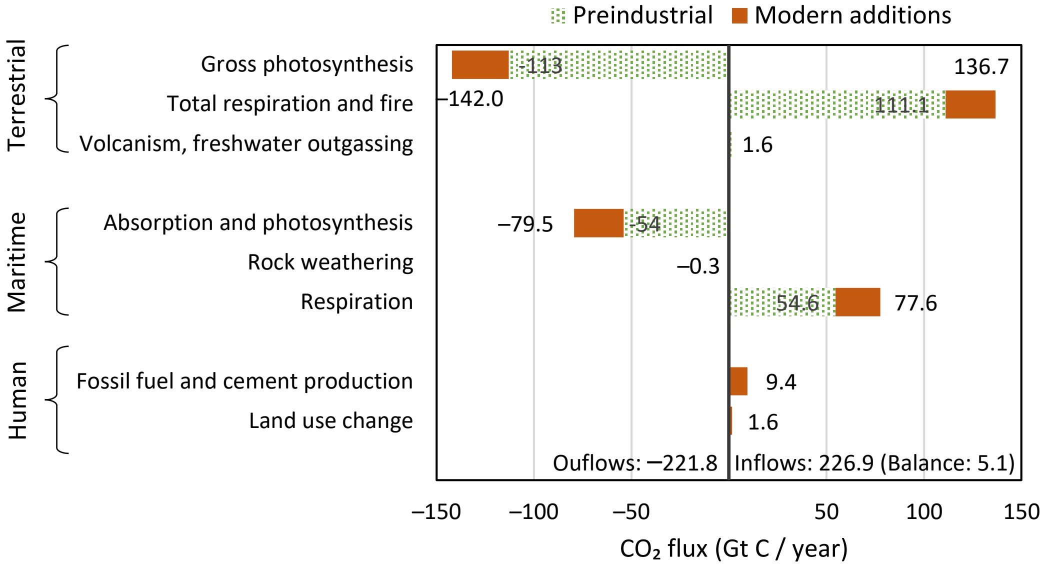


Figure 5: "Official" IPCC's (2021; Fig. 5.12) estimates of CO_2 fluxes, in an "unofficial" presentation adapted from Koutsoyiannis (2024c).

Even keeping the IPCC's estimates shown in Figure 5, we can make the following observations that are in line with the proposed interpretation of CO_2 fluxes:

1. Humans are responsible for only 4% of carbon emissions.
2. The vast majority of changes in the atmosphere since 1750 (red bars in the graph) are due to natural processes, respiration and photosynthesis.
3. The increases in both CO_2 emissions and sinks are due to the temperature increase, which expands the biosphere and makes it more productive.
4. The terrestrial biosphere processes are much more powerful than the maritime ones in terms of CO_2 production and absorption.
5. The increase of natural CO_2 emissions by the ocean biosphere alone is much larger than human emissions.
6. The modern (post-1750) CO_2 additions to pre-industrial quantities (red bars in the right half of the graph) exceed the human emissions by a factor of ~4.5.

Furthermore, by combining Figure 4 and Figure 5 we can see that the vast majority of the [CO_2] increase in 2023 is due to the increased natural emissions. Namely, the percentage from this increase for 2023 is 26.1 / (26.1+5.4) = 83%, leaving 17% to human emissions (cf. caption of Figure 1 and also Koutsoyiannis, 2024f, section 5.3).

3. Assumed causal link "b": Does the increase in atmospheric CO_2 cause temperature increase?

An initial investigation of the potential causality in atmospheric [CO_2] and temperature based on observations, rather than models, was undertaken by Koutsoyiannis and Kundzewicz (2020), prompted by the fact that the increasing pattern of atmospheric CO_2 concentration remained unaffected by the decrease of human CO_2 emissions due to the covid lockdowns. It was followed by the development of a new stochastic method by Koutsoyiannis et al. (2022a,b). This began with a review of approaches to causality over the entire knowledge tree, from philosophy to science and to technological and socio-political application, and identified the major unresolved problems. The developed methodology posited a modest objective: To determine necessary conditions that are operationally useful in identifying or falsifying causality claims; sufficient conditions were not sought. The necessary conditions are important in two respects:

- In a deductive setting, to falsify a hypothesized causality relationship by showing that it violates a necessary condition.
- In an inductive setting, to add evidence in favour of the plausibility of a causality hypothesis.

The methodology replaced events with stochastic processes. It is fully based on stochastics—a superset of probability and statistics, with time playing an essential role. Specifically, it is based on a reconsideration of the concept of the impulse response function (IRF). Real-world data, namely time series of observations, constitute the only basis of the method application. Model results and so-called *in silico experimentation* are categorically excluded. On the contrary, the method provides a test bed to identify whether or not models are consistent with reality.

The general setting of the method is for the Hen-Or-Egg case, i.e., bidirectional causality, while the unidirectional cases of a causal system (causality direction according to the hypothesis) or an anticausal system (causality direction opposite to the hypothesis) are derived as special cases.

The method was formulated as a general stochastic method, while a more extensive analysis of the climate-related causality chains was made in a follow-up paper by Koutsoyiannis et al. (2023), which extended the approach to multiple scales and applied it to the longest period covered by instrumental data. Subsequently, Koutsoyiannis (2024d) further refined the methodology and also used proxy data covering the entire Phanerozoic.

The results have always been the same: The common perception that increasing [CO_2] causes increased T can be excluded as it violates the necessary condition for this causality direction. In contrast, the causality direction $T \rightarrow [CO_2]$ is plausible. An illustration of such results is provided in Figure 6, where the fact that [CO_2] changes follow those in T is evident even visually. The graph uses a lag of 6 months (0.5 years) for illustration. Detailed application of the stochastic method results in a median and mean time lag slightly higher, 0.6 and 0.7 years, respectively, as shown in Figure 7. This is for an annual time scale of analysis and for the instrumental data. If we consider a decadal time scale for the same data, the causality direction remains the same and the lags increase to 3.2 and 3.3 years, respectively. If we use proxy data for time scales up to a million years, again the causality direction is the same (the time lags are positive) as seen in Figure 7.

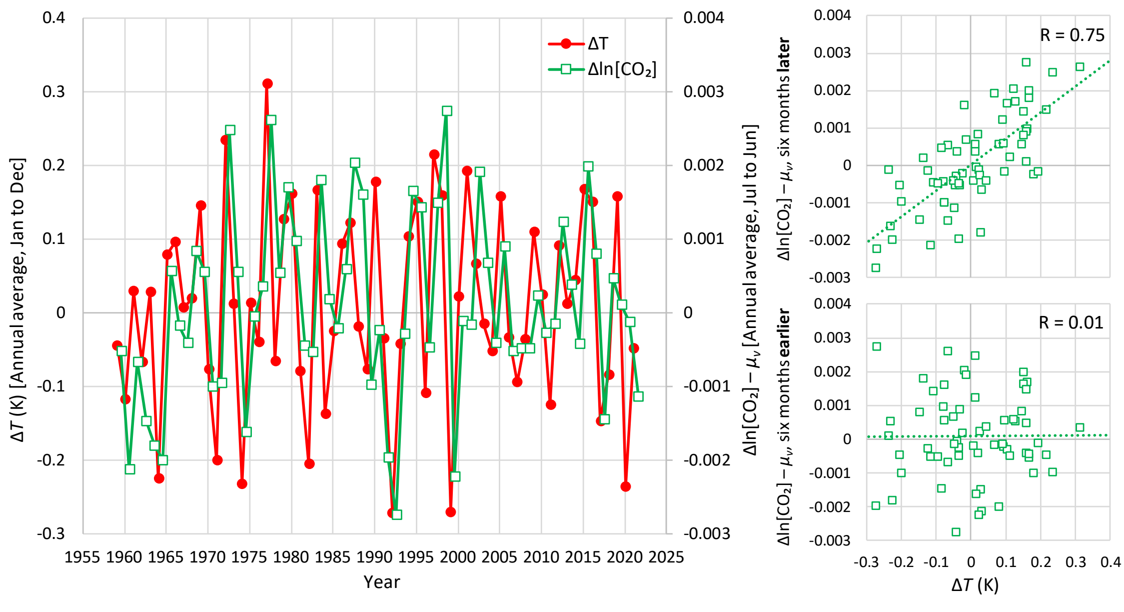


Figure 6: Reproduction of the graphical abstract of Koutsoyiannis et al. (2023), showing different plots of the annual averages of differenced time series of temperature (ΔT) and the logarithm of [CO_2] ($\Delta ln[CO_2]$) for a differencing time step of one year and a lag of six months. On the left graph, each point represents the time average for a duration of one year ending at the time of its abscissa.

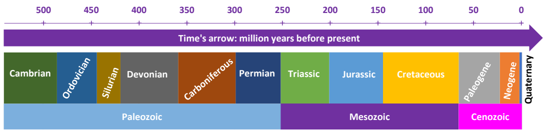
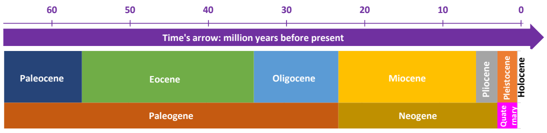
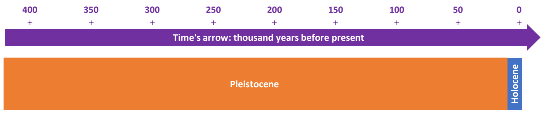
Period		**Analyzed timescale**	**Time lags, $h_{1/2}, \mu_h$**
Phanerozoic		10^6	2.3×10^6, 6.4×10^6
Cenozoic		10^5	7.6×10^5, 9.1×10^5
Late Quaternary		500 1000	1200, 3300 1200, 4500
Common Era		1 10	25, 33 26, 33
Modern (instrumental)		1 10	0.6, 0.7 3.2, 3.3

Figure 7: Summary of time lags (in years) of the T → [CO_2] potentially causal relationship (positive in all cases, meaning that [CO_2] change lags behind T change); $h_{1/2}$ and μ_h denote the median and mean time lag, respectively.

4. Assumed causal link "c": Are there climate impacts, or ultimately, do human CO_2 emissions affect everything?

While "climate science" babbles on about CO_2 as the determinant greenhouse gas (calling it the "principal control knob"), hydrology has routinely quantified the greenhouse effect for 70 years. This is necessary in evaporation calculations and the related formulae are based on data of atmospheric moisture. Koutsoyiannis and Vournas (2023) used a century-long collection of data on downwelling longwave radiation at the ground level. The analysis of this data set showed that there is no discernible effect on the greenhouse effect intensity, despite the increase of atmospheric [CO_2] from 300 to >400 ppm in a century (see Figure 8).

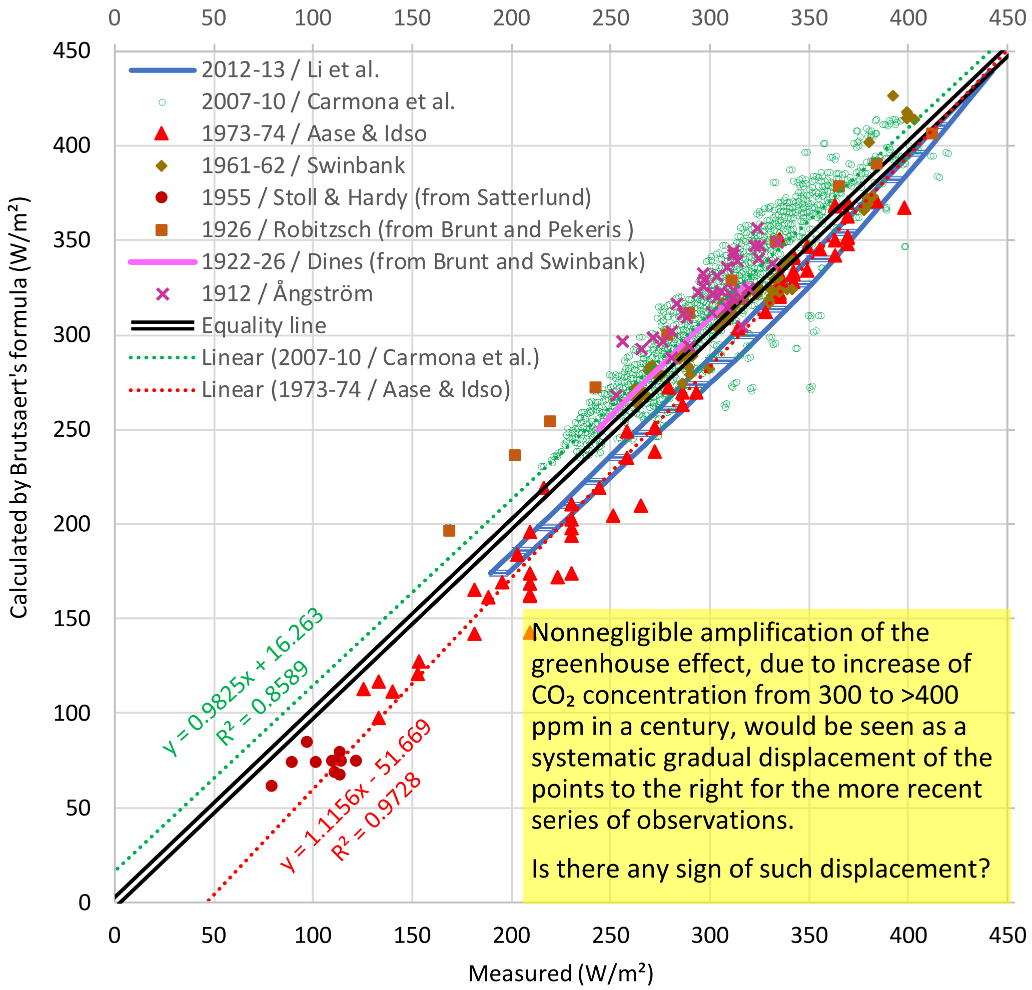


Figure 8: Reproduction (with kind permission of IAHS) of Figure 2 from Koutsoyiannis and Vournas (2023; after adaptation) showing plots of downward radiation of the atmosphere, measured vs. calculated (by the Brutsaert's, 1975, formula, which accounts for water vapour pressure only), in eight data sets used in the study. For the two data sets with the largest number of points, the linear regression lines are also shown, along with their equations.

Explanation of this result and quantification of relevant importance of greenhouse drivers were performed by the follow-up study by Koutsoyiannis (2024e). This was based on the standard theory and an established model of radiation in the atmosphere (MODTRAN), as well as on satellite radiation data. Using MODTRAN results and data from NASA's ongoing project Clouds and the Earth's Radiant Energy System (CERES, 2021), the study constructed a macroscopic relationship for longwave radiation, i.e.:

$$L_{\mathrm{D,O}} = L^* \left(1 + \left(\frac{T}{T^*}\right)^{\eta_T} \pm \left(\frac{e_a}{e_a^*}\right)^{\eta_e}\right)\left(1 \pm a_{CO_2} \ln \frac{[\mathrm{CO_2}]}{[\mathrm{CO_2}]_0}\right)(1 \pm a_C C) \tag{2}$$

where $L_{\mathrm{D,O}}$ denotes the downwelling (D) and outgoing (O) longwave radiation flux; T is the temperature near the ground level; e_a is the water vapour pressure near the ground level; $[\mathrm{CO_2}]$ is the atmospheric $\mathrm{CO_2}$ concentration with a reference value $[\mathrm{CO_2}]_0$ = 400 ppm; C is the cloud area fraction; L^*, T^*, e_a^* are dimensional parameters, with units $[L]$, $[T]$, and $[e_\mathrm{a}]$, respectively; and η_T, η_e, $a_{\mathrm{CO_2}}$, a_C are dimensionless parameters. The parameter values were optimized based on clear-sky MODTRAN results, except a_C, which was estimated from CERES satellite data.

This relationship was applied to find the relative importance of each of the factors $F_i \in \{T, e_\mathrm{a}, [\mathrm{CO_2}], C\}$ on the longwave radiation by means of the total differential:

$$\mathrm{d}(\ln L) = \frac{\mathrm{d}L}{L} = \sum_i \frac{\partial L}{\partial F_i}\frac{F_i}{L}\frac{\mathrm{d}F_i}{F_i} = \sum_i L^{\#}_{F_i}\frac{\mathrm{d}F_i}{F_i} = \sum_i L^{\#}_{F_i}\,\mathrm{d}\ln F_i \tag{3}$$

where $L^{\#}_{F_i}$ denotes the log-log derivative, i.e. (Koutsoyiannis, 2023):

$$L^{\#}_{F_i} := \frac{\partial \ln L}{\partial \ln F_i} = \frac{\partial L}{\partial F_i}\,\frac{F_i}{L} \tag{4}$$

The importance of other greenhouse gases was also assessed by direct numerical evaluation with MODTRAN. The final results are depicted in Figure 9. The chart on the left explains the findings of the study by Koutsoyiannis and Vournas (2023): given that the contribution of CO_2 is only 4% there could be no discernible effect of the [CO_2] increase in a century on the downwelling longwave (LW) radiation. The chart on the right suggests that the same should have been the case (macroscopically) with the outgoing LW radiation if data of similar length existed.

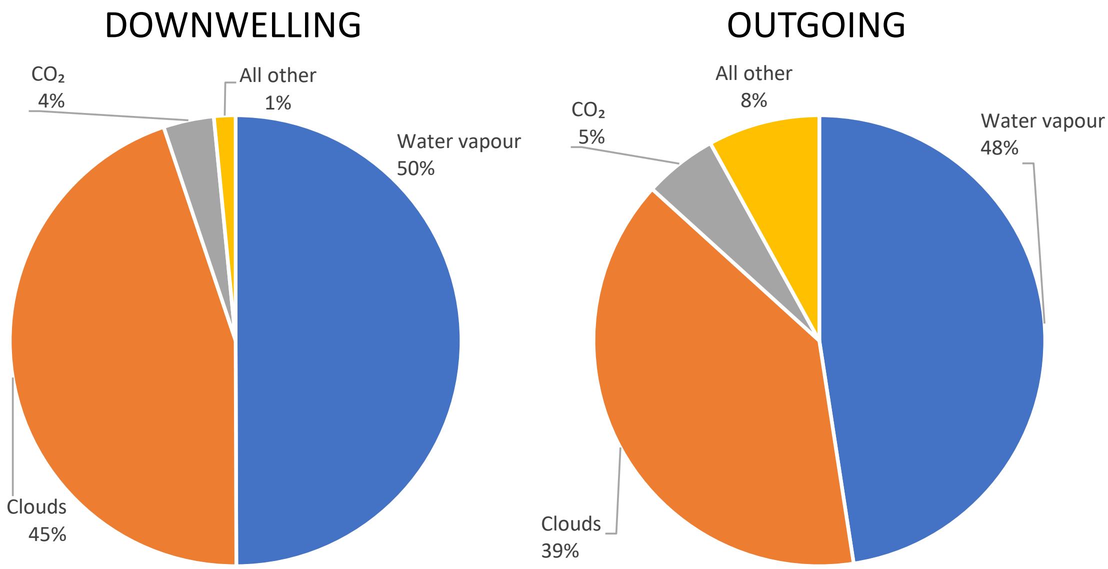


Figure 9: Reproduction of Figure 24 from Koutsoyiannis (2024e) showing the contribution of the greenhouse drivers to the LW radiation fluxes.

All evidence suggests that the recent increase in atmospheric temperature was not caused by the [CO_2] increase. The question of what might have caused it is not easy to answer as numerous factors influence climate, both internal and external to the climatic system. Before trying to answer it, one would think of additional questions such as:

1. Do complex dynamical systems need external agents to change their state?
2. Should we expect the temperature to be stable?
3. What caused a cause?
4. Have the huge changes in global temperature during the Phanerozoic been explained?

None of these additional questions has an affirmative answer. In particular, the negative answer to question 1 has been extensively studied in Koutsoyiannis (2006, 2010, 2013).

Nevertheless, Koutsoyiannis et al. (2023) examined some possible mechanisms internal to the climatic system, namely albedo, ENSO and ocean heat, in which the change was found to precede that of temperature (and a fortiori of CO_2). The change of the albedo based on CERES data is shown in Figure 10 (left). A decline of the albedo of about 0.004 is seen for the entire observation period, which translates to 1.4 W/m^2. This is much greater than the average imbalance (net absorbed energy) of the Earth, which, if calculated from the ocean heat content data, is about 0.4 W/m^2 (Koutsoyiannis, 2021).

Apparently, the albedo decline has no relationship with the increase of [CO_2]. Rather it has been caused by (or at least it is consistent with) a decline in cloud area fraction, also seen in Figure 10 (right). Notably, this explanation does not enable predictability of future climate. Rather, it raises additional questions, e.g., what caused the decline in clouds? Yet it highlights the importance of H_2O and the insignificance of CO_2 in climate.

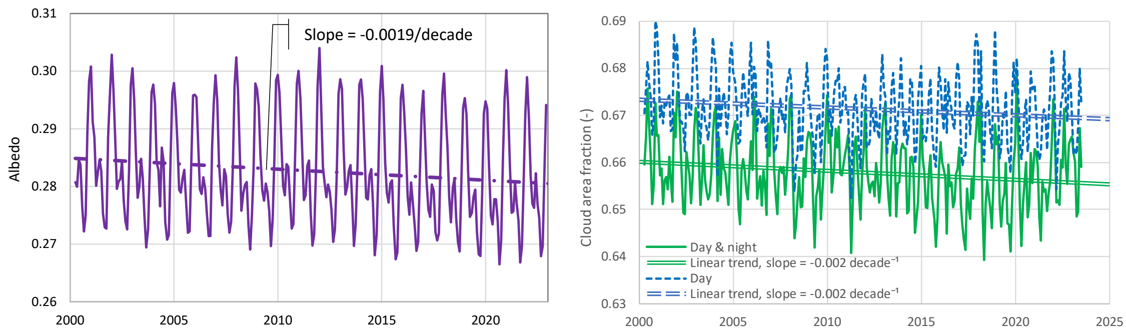


*Figure 10: (**left**) Top-of-atmosphere albedo time series (continuous line) from NASA's CERES data set, along with linear trend (dashed line); source Koutsoyiannis et al. (2023). (**right**) Total cloud area fraction (single lines) from NASA's CERES data set, along with linear trends (double lines); source Koutsoyiannis and Vournas (2024) (with kind permission of IAHS).*

5. Concluding remarks

- The foundation of the modern climate edifice is afflicted by erroneous assumptions and speculations.
- The causal chain promoted by mainstream science is naïve and wrong.
- In scientific terms, the case of the magnified importance of CO_2, the focus on human emissions thereof, and the neglect of the ~25 times greater natural CO_2 emissions constitute a historical accident.
- This accident was exploited in non-scientific (politico-economic) terms.
- For complex systems, observational data are the only scientific test bed for making hypotheses and assessing their validity.
- The real-world data do not agree with the "mainstream science" (a euphemism for sophistry).
- The results I have presented are scientific and therefore may not be relevant to the climate narrative, which has a non-scientific aim.

Guest Editor: Stein Storlie Bergsmark

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