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Atmospheric CO_2: What Physics Dictates

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Abstract

Despite dramatic temperature changes of more than 10°C over the Phanerozoic and 15x higher CO_2 concentrations than today**,** with the inception of the Industrial Era for many climate scientists**,** in first position for the IPCC, but also for some climate sceptics, natural impacts no longer exist**.** Instead, we hear, almost only fossil fuels and land uptake are responsible for an increasing atmospheric CO_2 concentration, and the IPCC additionally alleges, 90 % of the temperature increase is only caused by this greenhouse gas**,** which makes this discussion so important.

In this contribution, we only concentrate on the first claim and examine to what extent anthropogenic emissions alone can be made responsible for the observed CO_2 increase over the Industrial Era and how far this thesis contradicts basic physics, especially the Conservation Law.

Keywords: Atmospheric CO_2; native and anthropogenic CO_2 emissions; airborne fraction

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1. Introduction

All climate experts agree that the basis for calculating changes of the CO_2 concentration in the atmosphere is the balance equation or Conservation Law, which sums up all in- and outfluxes of the atmosphere. However, significant differences exist, how strongly fluxes from anthropogenic sources affect this balance and how far also natural emissions have to be considered. One central claim is, as long as the growth rate of CO_2 in the atmosphere is less than human emissions and thus, their ratio as so-called Airborne Fraction AF is smaller one, there is zero net contribution from natural sources and sinks to the increase in the atmosphere.

This lecture summarizes, how far such suppositions are substantiated or must be made responsible for significant misinterpretations. Based on the Conservation Law, own calculations will be presented, reproducing all details of the measured atmospheric CO_2 concentration over the Mauna Loa Era, including the seasonal cycles. They allow to deduce an upper limit of 15 % for the anthropogenic contribution to the observed increase of CO_2 over the Industrial Era, and under conditions of an increasing imbalance between troposphere and extraneous reservoirs of only 9%, which are not more than 3 % of the atmospheric CO_2 concentration. The importance of only one unitary time scale for the removal of anthropogenic and natural CO_2 emissions from the atmosphere, characterized by an effective absorption time, is discussed.

2. IPCC's Explanation of Increasing CO_2

The IPCC [1]and the CO_2 Coalition team (CO_2-C) [2], assume, before 1850 the carbon cycle was in balance with an atmospheric concentration of about 280 ppm and in- and outfluxes of approximately 80 ppm/yr. But over the Industrial Era this cycle has come out of balance, actually with 425ppm and with an additional flux of 32 ppm/yr, only caused by fossil fuels and land uptake.

Meanwhile human emissions $e_A(t)$ increased to 5.7 ppm/yr (Global Carbon Budget, GCB-2024 [3]), which are 5.1 % of the total emissions. From these emissions 54 % are directly absorbed by the oceans and land, the rest, the Airborne Fraction (*AF*) with about 46 % is cumulating in the atmosphere. This is made responsible for the rapidly rising CO_2 concentrations C_{CO2} over the Industrial Era with about 145 ppm.

IPCC assumes, the removal of this additional CO_2 from the atmosphere takes up to a few hundred thousand years and is described by different adjustment times τ_A. On the other hand, the turnover time, we call this the residence time τ_R, as ratio of the concentration to the total emission or absorption, is only 3.8 yrs. What IPCC uses as a simplified description, and well suited for policy makers, is summarized again in Fig. 1a by the so-called Airborne Fraction Model.

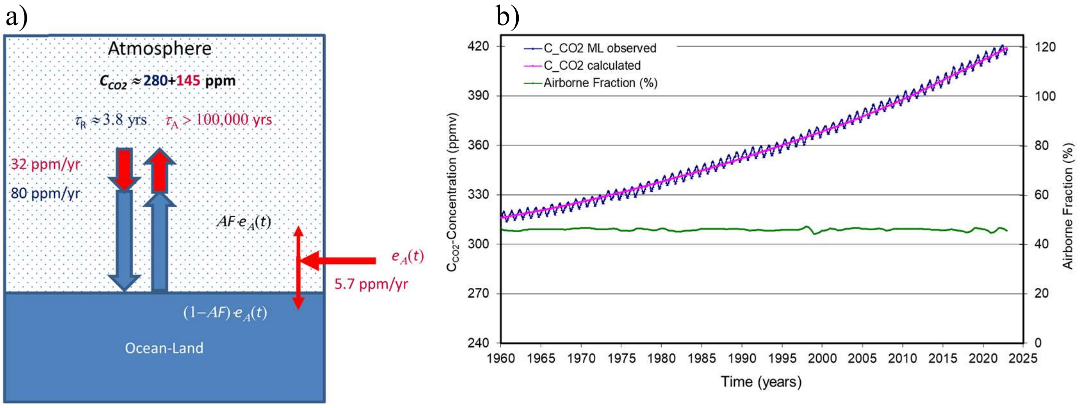

Fig. 1: a) Airborne Fraction Model and b) comparison of calculated CO_2 concentration over time (Magenta graph) with observations at Mauna Loa [4].

Somewhat strange is that the constant natural contribution of 280 ppm and the continuously increasing human injections of 145 ppm together are circulating with the residence time of 3.8 yrs and at the same time 54 % of the new anthropogenic emissions are directly sequestrated, while the other part is accumulating in the atmosphere for ever. Some people even believe, only the natural part is oscillating as a closed cycle [2], and the anthropogenic emissions are not involved.

The respective balance equation for the yearly changes $\Delta C_{CO2}/\Delta t$ then takes the form:

$$\frac{\Delta C_{CO2}}{\Delta t} = e_A(t) - (1 - AF) \cdot e_A(t) = AF \cdot e_A(t) \tag{1}$$

The incident human emissions are reduced by the absorbed part, and the concentration is increasing with the airborne fraction *AF*. Year-to-year summation gives the rising concentration over time (Fig. 1b, Magenta graph), which is in good agreement with the averaged measurements at Mauna Loa (ML) [4] for an airborne fraction of 46 %.

A more advanced model, the so-called Bern Model [5] and especially favoured by the IPCC, considers a time dependent airborne fraction, now called pulse response function *R*(t) with 5 different adjustment times between 3.4 yrs and infinity. Each emission e_A is supposed to contribute with that pulse response, yielding a convolution integral. Year-to-year summation – with a smaller correction – also shows good agreement with the measurements at Mauna Loa (see: Harde 2019 [6], Fig. 6). But apparently, there are some inconsistencies in this interpretation with observations:

- A constant natural cycle and neglection of additional native emissions contradicts paleoclimatic and actual observations.
- 46 % of all new emissions – in the Bern model 18 % – are cumulating for ever in the atmosphere, the other fraction is instantaneously absorbed, but no uptake of previously cumulated emissions. This violates the Equivalence Principle; and for a constant emission rate the system never reaches a previous or new equilibrium.
- The absorption is considered to be proportional to the emission, not to the concentration. This is in dissent to native decay processes and the ^{14}C-decay after the Nuclear Test Ban Treaty.

- The total CO_2 content in the atmosphere, or only the native part, is exchanged within about 4 yrs like an inert gas, but no real absorption and emission is considered at the surface; this contradicts observations with different compounds in sea water or in the biosphere. On the other hand, 54 % of new anthropogenic emissions disappear instantaneously.
- The more elaborate Bern-Model considers even 5 different absorption channels, again proportional to the emission, and even worth, working at least partially in series. It contradicts the observed parallel uptake by different reservoirs (see Harde 2019 [6], Subsec. 5.5)

3. Approach of the CO_2 Coalition Team

The model favoured by the CO_2-C team [2] and some others overcome some of these deficits, now indeed presuming an absorption proportional to the concentration, but still separated into a closed native cycle as in preindustrial times with native emissions e_{N0} and a concentration C_{N0}, on the other hand the anthropogenic emissions e_A(t) and an excess concentration $C_A = C_{CO2} - C_{N0}$. The respective balance equation (Conservation Law) assumes the form:

$$\frac{\Delta C_{\mathrm{CO2}}}{\Delta t} = e_{\mathrm{N0}} - \frac{C_{\mathrm{N0}}}{\tau_{\mathrm{N}}} + e_{\mathrm{A}}(t) - \frac{(C_{\mathrm{CO2}} - C_{\mathrm{N0}})}{\tau_{\mathrm{A}}}. \qquad (2)$$

The first two terms in the balance, representing the native cycle, compensate each other for e_{N0} = 77 ppm/yr, C_{N0} = 270 ppm and a native residence time of τ_N = 3.5 yrs. Thus, again only human emissions determine the balance, which now is controlled by the anthropogenically caused concentration C_A and a second, independent time scale τ_A. Some people call τ_A adjustment time, but in reality, it is nothing else than a second residence time, separated from the native cycle to explain all atmospheric changes only by anthropogenic emissions of CO_2.

Now, instead of an infinite accumulation, the excess concentration is decaying with the e-folding time τ_A, or at a constant emission rate approaches an equilibrium level $C_{N0} + e_A \cdot \tau_A$.

Also, this gives good agreement with the averaged ML measurements (Harde 2019 [6], Fig. 7; Harde 2023 [7], Fig. 2b), but native emissions are circulating with 3.5 yrs, the rest stays for 50 yrs and longer? This also violates the equivalence principle; and claiming only anthropogenic emissions contribute to an increasing concentration, while assuming a closed native cycle, looks like circular reasoning.

4. Own Approach to the Carbon-Cycle

So, there are different reasons for a more realistic approach to the carbon cycle, which is in agreement with all observations and physical causalities. First own studies go back to 2017 [8] and 2019 [6]. In succeeding years there was established a close cooperation with the late Murry Salby from Macquarie University Sidney (see Harde & Salby [9]; Salby & Harde [10 – 12].

4.1 The Modified Balance Equation

Our approach includes temperature dependent natural emissions $e_N(T, t)$ and anthropogenic emissions $e_A(t)$ over the Industrial Era. The absorption rate $a(t)$ is proportional to the CO_2-concentration C_{CO2} in the atmosphere, not the difference to pre-industrial times, and is characterized by a unitary residence time, or here further called *effective absorption time* τ_{eff}. This gives the balance equation or the Conservation Law as CO_2–changes per yr, caused by the native and anthropogenic emission rates, minus the absorption rate (for a similar approach, see also Berry [13, 14]):

$$\frac{\Delta C_{\mathrm{CO2}}(t)}{\Delta t} = e_{\mathrm{N}}(T,t) + e_{\mathrm{A}}(t) - \frac{C_{\mathrm{CO2}}(t)}{\tau_{\mathrm{eff}}} = e_{\mathrm{N}}(T,t) - \frac{C_{\mathrm{N}}(t)}{\tau_{\mathrm{eff}}} + e_{\mathrm{A}}(t) - \frac{C_{\mathrm{CO2}}(t) - C_{\mathrm{N}}(t)}{\tau_{\mathrm{eff}}} \qquad (3)$$

As confirmation of this Law and a deeper understanding of increasing CO_2 it is worthwhile to look closer to measurements of radiocarbon, which is an ideal tracer for the uptake of atmospheric CO_2 by the biosphere and oceans.

4.2 Radiocarbon

Carbon 14 is formed in the upper atmosphere by incident cosmic rays, when a neutron is colliding with a nitrogen nucleus and kicks out a proton. ^{14}C is rapidly oxidized and has a concentration of about 1.2×10^{-10} % relative to the stable isotopologues. Its radioactive decay time as e-folding time is 8 265 yrs and thus, much longer than our considered observation times.

Due to nuclear bomb tests up to 1963 this concentration was doubled, but with the stop of these tests it was possible to measure the uptake by the extraneous reservoirs. Typically measured is the ^{14}C-anomaly $\Delta^{14}C$ as relative deviation from a reference $(^{14}C - {}^{14}C_R)/{}^{14}C_R\times1000$ [‰], called the Δ-permille value. This is a direct check of the Conservation Law.

Fig. 2 shows the normalized ^{14}C-anomaly at Vermunt-Austria (Levin et al. 1994 [15]) as Yellow Graph. It is characterized by an exponential decay with seasonal emissions over the first 5 to 6 years due to the Brewer-Dobson circulation from the stratosphere to the troposphere, particularly at boreal winters. Often these oscillations are neglected, but they give a much deeper insight for the fast absorption behavior.

We consider a 3-volume system with the stratosphere as the source of ^{14}C [10]. When a mass fraction Δm^{14} is injected to the troposphere, the concentration in the stratosphere reduces by $\Delta C_{\mathrm{St}}^{14}$ as the ratio of this fraction to the total mass in the stratosphere m_{St}. At the same time the tropospheric concentration increases by $\Delta C_{\mathrm{T}}^{14}$as the ration of this fraction to the mass in the troposphere m_{T}. Something similar happens between the surface and troposphere with the respective mass ratio.

The solution for the concentrations in the stratosphere, shown as Gray Graph, for the troposphere displayed in Blue, and for the surface in Red, gives good agreement for the troposphere with the observation. It shows a very fast uptake with a direct absorption time τ by the surface of only 8 months and slows down with increasing observation to an effective absorption time τ_{eff} = 8 yrs.

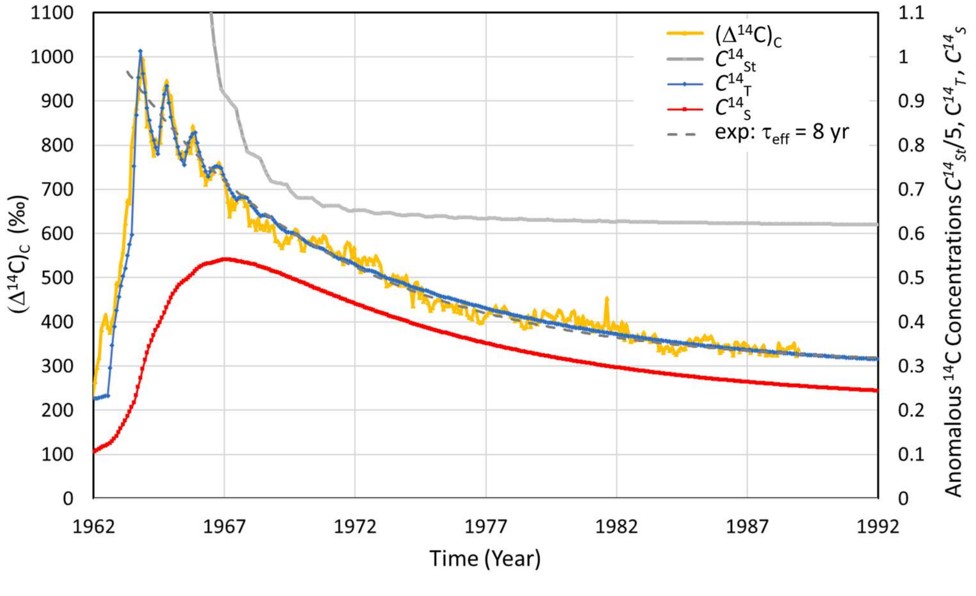

Fig. 2: Comparison of $\Delta^{14}C$ (normalized) at Vermunt-Austria (Yellow) with calculations of anomalous ^{14}C concentrations in the stratosphere (Gray), in the troposphere (Blue) and in the surface (Red).

This effective absorption considers that with increasing ^{14}C-concentration in the surface layer re-emission from the surface to the troposphere takes place, which is proportional to the actual surface layer concentration and can be expressed in good approximation as a fraction β of the tropospheric concentration, yielding an effective absorption time $\tau_{\mathrm{eff}} = \tau/(1-\beta)$ [7, 9 – 12].

The final decay is determined by the surface concentration and the removal of ^{14}C to the final stores. What we find for ^{14}C as tracer also holds for the total CO_2 cycle.

4.3 Anthropogenic Emissions

Applying the same 3-volume calculation for anthropogenic emissions over the Mauna Loa Era, we can calculate the concentrations caused by anthropogenic emissions (see Fig. 3) in the stratosphere C^a_{St}, displayed as Orange graph, in the troposphere C^a_{T} as Blue, and in the surface C^a_{S} as Red, and how they develop over time. The emission $e_{\mathrm{A}}(t)$ is based on the GCB-2024 data [3].

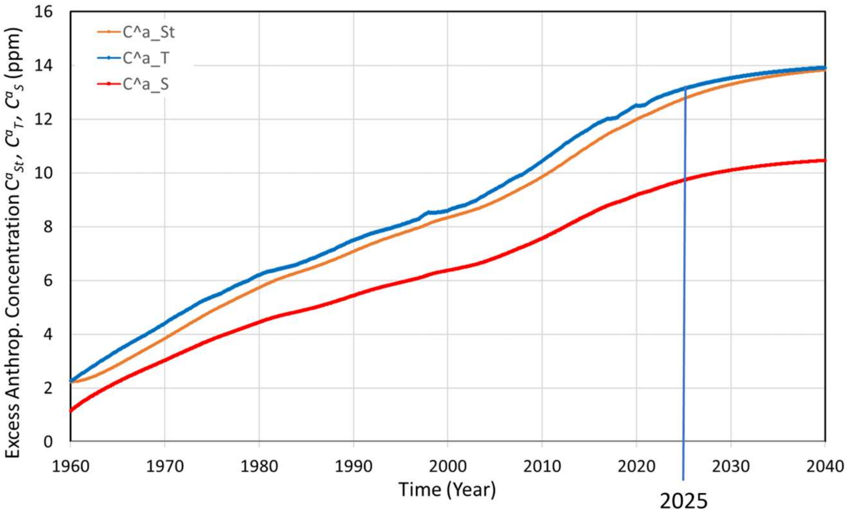

Fig. 3: Calculated anthropogenic excess concentrations in the stratosphere (Orange), in the troposphere (Blue) and the surface (Red).

Different to ^{14}C the slightly increasing emission occurs continuously and directly in the troposphere. While the troposphere and stratosphere are close to equilibrium, this magnifies the disequilibrium between the troposphere and surface, and thus, inhibits a larger offset of direct absorption by re-emission.

This results in effective absorption, that can even be faster than the mean decline of ^{14}C. With a quite conservative mass ratio of the troposphere to the surface layer with one quarter, up to now anthropogenic emissions wouldn't have contributed more than 13 ppm to the atmospheric concentration, which is only 9 % of the increase over the Industrial Era and not more than 3 % of the total CO_2 concentration. A further constant emission over successive years can only increase the concentration by one additional ppm.

4.4 Thermally Induced CO_2 Emissions

But how can the much larger increase of CO_2 over recent decades be explained? From many observations we know: Surface processes like emission and absorption of CO_2 depend intrinsically upon the temperature. This is documented:

- in seasonal emissions and uptake, almost 6x larger than anthropogenic emissions,
- in soil respiration - even increasing exponentially with temperature, or
- in the emission and uptake by the oceans.

Therefore, different to the IPCC we don't ignore such temperature dependent processes, not in the biosphere, not in the oceans or by permafrost. And we remind to the volcanic activities under water. Experts estimate, there are about 1 Mio. submarine volcanoes, thousands of them are expected to be active.

Looking closer to the CO_2 concentration at Mauna Loa as a worldwide reference, the seasonal modulations are obvious (see Fig. 1b). They are more or less regular from one year to the next and not systematically changing. This is different for emissions over longer time periods, as they become visible, when inspecting the derivative of the deseasonalized concentration C'_{CO2}, low-pass filtered as average over one season. This gives the well-known Conservation Law, determined by the natural and anthropogenic emissions and their uptake:

$$\frac{dC'_{\mathrm{CO2}}}{dt} = e_{\mathrm{N}}(T,t) + e_{\mathrm{A}}(t) - \frac{C'_{\mathrm{CO2}}}{\tau_{\mathrm{eff}}} = E_{\mathrm{net}}(t) \tag{4}$$

The difference we call the net emission (Fig. 4, Blue graph), which shows characteristic spikes over 2 – 7 yrs that coincide well with El Niño events.

The mean increase of this net emission rate with about 2 ppm/yr over 65 years seems very small and is even less than the anthropogenic emissions with about 3.5 ppm/yr over this period. But this should not be mixed with the direct emission rates – native or anthropogenic –, as the net emission rate represents the difference between the total emission rate and absorption. And with a fast absorption rate this only gives a relatively small incline over time.

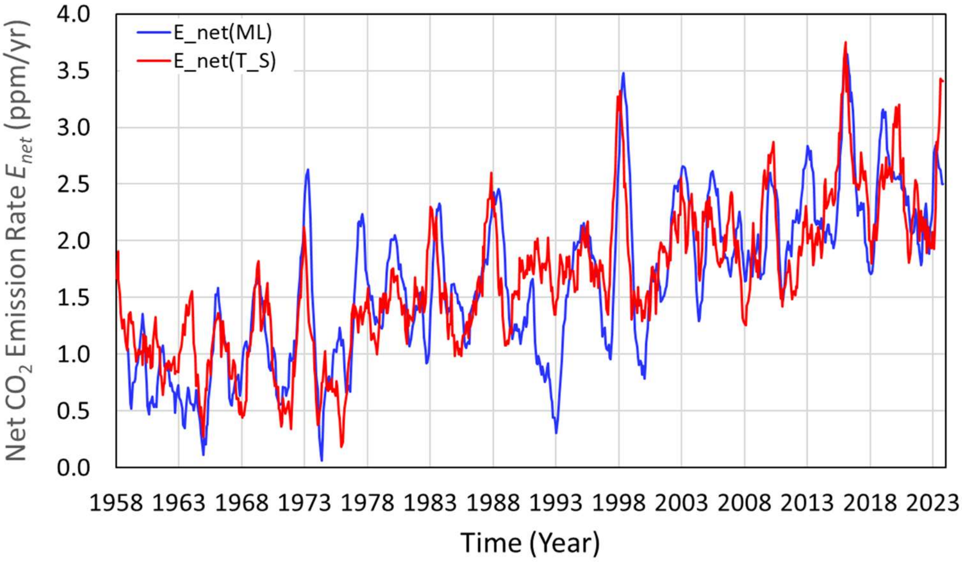

Fig. 4: Net CO_2 emission observed (Blue), low-pass filtered to periods longer than a year, along with its thermally-induced component (Red), calculated from the observed record of tropical temperature.

With this net emission in mind we also look closer to the monthly Sea Surface Temperature Anomaly (SSTA–HadSST4 [16]). While over mid and high latitudes there is almost no systematic temperature increase, in the tropics we find a continuous increase over land and sea (see, Salby & Harde 2022 [12], Fig. 2), and also the spikes coincide with El Niños. These are good reasons to explain the observed emissions by an increasing temperature.

Generally these emissions are expected to originate from sea and land. But outgassing of CO_2 with temperature from oceans is relatively low with a temperature sensitivity of only 3 %/°C. This is more than one order of magnitude lower than soil respiration, which is particularly large in tropic areas, where we also observe the largest temperature increase over the last decades.

So, when calculating the net emission from the temperature record and soil respiration of tropical areas, additionally considering a slightly exponential increase with temperature, the simulation (Red) tracks the observation quite well with a correlation of 80 %.

Note: the emission is in phase with temperature, while the concentration as integral of the emissions has a phase delay of 90°. This has already been described by Humlum et al. [17] and Salby [18] in 2013. Therefore, CO_2 , at least for this warming, cannot be the reason for a T-increase.

4.5 Comparison of Calculation and Measurement

Finally, to compare the measured CO_2 concentration at Mauna Loa (Fig. 5, Blue Triangles) directly with the respective calculation, we have to integrate the total emission, consisting of the thermally induced and anthropogenic contributions and also including the seasonal oscillations:

$$C_{\mathrm{CO2}} = \int \left(E^{s}_{\mathrm{net}}\,(T,t) + e_{\mathrm{A}}\right)dt \tag{5}$$

The calculation as Magenta Diamonds almost exactly tracks the measurement. The Green Dots represent the natural fraction to the concentration, and the Aqua Triangles display the anthropogenic fraction for a tropospheric to surface mass ratio of 1:4 (see right ordinate).

As considered earlier, this corresponds to 13 ppm, caused by human emissions and is not more than 9 % of the increase over the Industrial Era, or compared to the total concentration only 3 %.

The lower Violet line shows the anthropogenic emissions, actually with 5.1 % of the total flux; and we see from these graphs that for a further constant emission the atmospheric CO_2 concentration is only further increasing by about 10 ppm within less than one decade. This is our personal Representative Concentration Pathway.

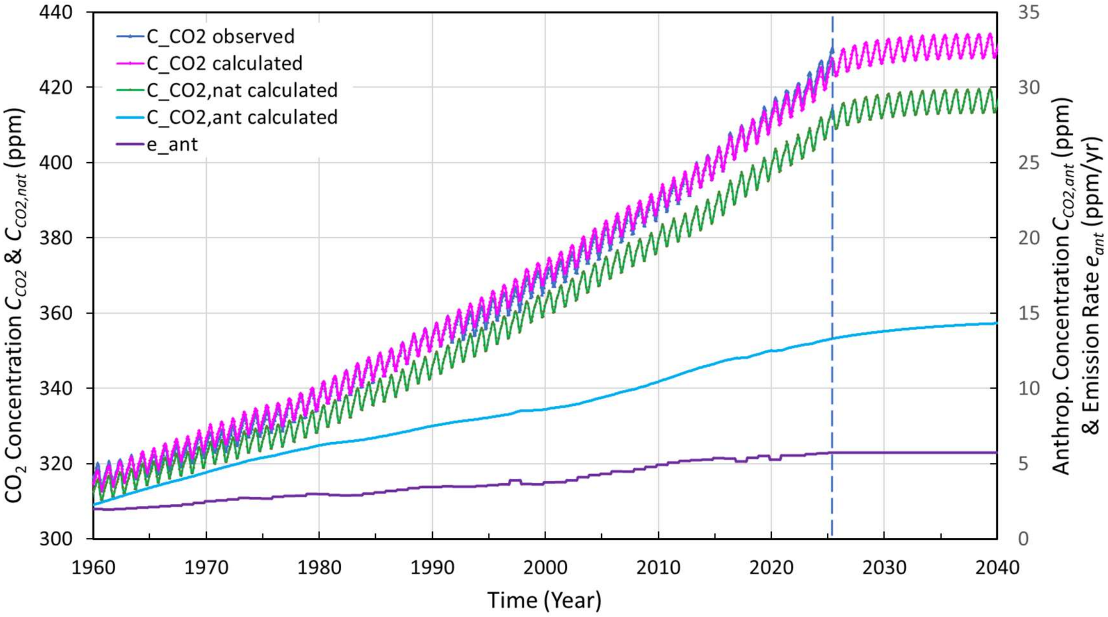

Fig. 5: Observed monthly CO_2 concentration at Mauna Loa (Blue Triangles) together with a calculation for anthropogenic and thermal emissions at a tropospheric to surface CO_2 mass ratio of 1:4 (Magenta Diamonds). Also plotted is the concentration $C_{CO2,nat}$ (Green Dots) only caused by natural emissions $e_N(t)$, and $C_{CO2,ant}$ (Aqua Triangles) caused by the anthropogenic emissions $e_A(t)$ (Violet).

But even excluding an increasing disequilibrium between troposphere and surface due to continuous human emissions, as an upper limit we can expect that the anthropogenic contribution is determined by this ratio, actually 5.1 % or 22 ppm of the total concentration of 425 ppm.

5. Nature as a Net Sink

As already outlined in Sec. 3, the CO_2 Coalition Team assumes a closed cycle for native emissions, thus only anthropogenic emissions contribute to an increasing CO_2 level C_{CO2}. Any uptake is only determined by the excess concentration to 1750 with $C_{CO2} - C_{N0}$, and with an adjustment time τ_A = 45 yrs this is in good agreement with observations (Ref. 7, Fig. 2b). Dividing (2) by e_A(t) gives the *AF*:

$$AF = 1 - \frac{(C_{\mathrm{CO2}} - C_{\mathrm{N0}})}{\tau_{\mathrm{A}} \cdot e_{\mathrm{A}}(t)} \tag{6}$$

From this the CO_2-C research team follows:

For AF < 1, nature cannot have contributed to any rise, nature is a net sink.

But first excluding native emissions and then such conclusion looks like circular reasoning.

We consider the whole balance equation with one unitary cycle for native and anthropogenic emissions and with one absorption time τ_{eff} of 3 - 4 yrs.

To demonstrate the discrepancy to the CO_2-C's statement ($AF < 1 \Rightarrow$ no native emissions), for a moment, we assume constant anthropogenic emissions e_{A0}. Then, the last two terms in (3) cancel, and any changes can only be determined by nature. For a linear increase $e_N(t) = e_{NO} + \delta \cdot t$ from quasi-equilibrium conditions e_{NO} and with $e'_N = \delta$ as derivative of $e_N(t)$ this gives:

$$\frac{\Delta C_{CO2}}{\Delta t} = e_{N0} - \frac{C_{N0}}{\tau_{eff}} + \delta \cdot t - \frac{C_{CO2} - C_{N0}}{\tau_{eff}} \leq \delta \cdot \tau_{eff} \qquad (7)$$

The first two terms on the right side compensate each other, and bearing in mind a delayed uptake of the previous emissions over the residence time, as good approximation and upper limit of the growth rate the last two terms can be expressed as $\delta \cdot \tau_{eff}$. This can be derived from the response of the Earth-Atmosphere-System to some perturbation Δe_N to attain a new equilibrium at an increased level $\Delta C_{CO2}^{eq} = \Delta e_N \cdot e_{eff}$ as solution of the balance equation (see also [12], eq. (B4)).

With $\delta = 0.443$ ppm/yr^2 and $\tau_{eff} = 3.8$ yrs integration of (7) over the Mauna Loa Era gives a straight line, shown in Fig. 6 as Magenta Diamonds. As average it fits with the observations (Blue Triangles). Dividing (7) by e_{A0}, gives the airborne fraction $AF = \delta \cdot \tau_{eff}/e_{A0}$, which for $e_{A0} = 3.7$ ppm/yr as average over the ML Era, becomes 45 % (Orange Dots). The natural emissions are rising from 80 to 110 ppm/yr (Green Squares), while the anthropogenic emissions stay constant.

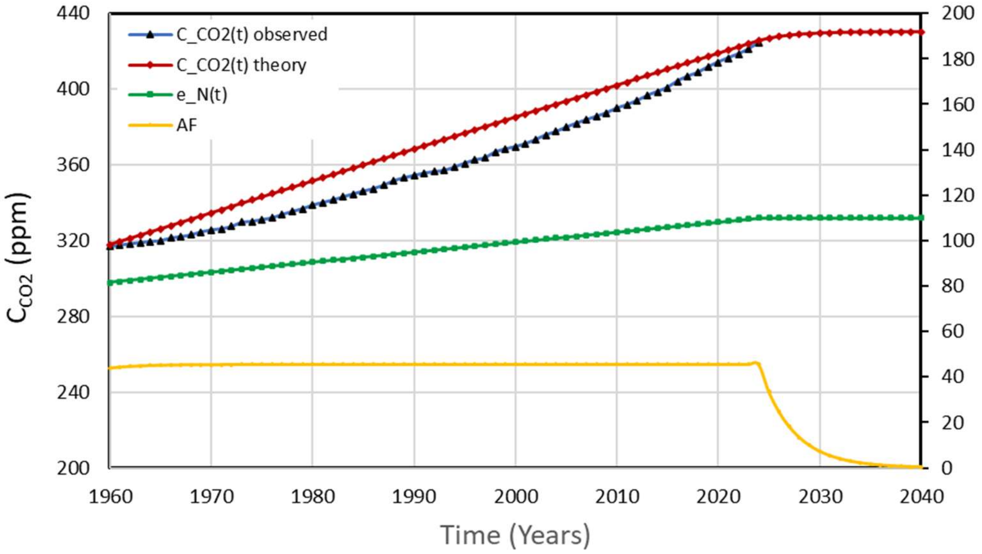

Fig. 6: Measured CO_2 concentration at ML (Blue Triangles) and calculation (Magenta Diamonds) for a linearly increasing natural emission rate e_N (Green Squares) and a constant human emission rate. The airborne fraction is shown as Orange Dots.

This example demonstrates: The CO_2 increase per year is controlled by the derivative $e'_N(t) = \delta$ of the native emission rate (see eq. (7)), and AF as ratio of this increase to the anthropogenic emission rate e_{A0} is smaller 1, this despite growing natural emissions over this period of 30 ppm/yr. So, apparently a statement: *For AF <1 nature cannot have contributed to any rise*, can no longer be held upright, and is falsified.

Fig. 7 displays a simulation (Magenta Diamonds) with anthropogenic emissions $e_A(t)$ according to the GCB-2024 data, and the thermally induced emissions $e_N(T,t)$, as derived from the tropical SSTA data, similar to Fig. 5, but averaged over the seasons. We find excellent agreement with the ML measurements (Blue Triangles) and again an AF around 45 % (Orange Dots), which now is well approximated by the sum of the derivatives $e'_N + e'_A$ over the residence time.

The increase of the native emissions (Green Squares) with 27 ppm/yr over this period is almost 8x larger than the increase of human emissions (Lilac dots). So, again, despite a substantial increase of the natural contribution, AF remains smaller 1. Nevertheless is nature a net sink.

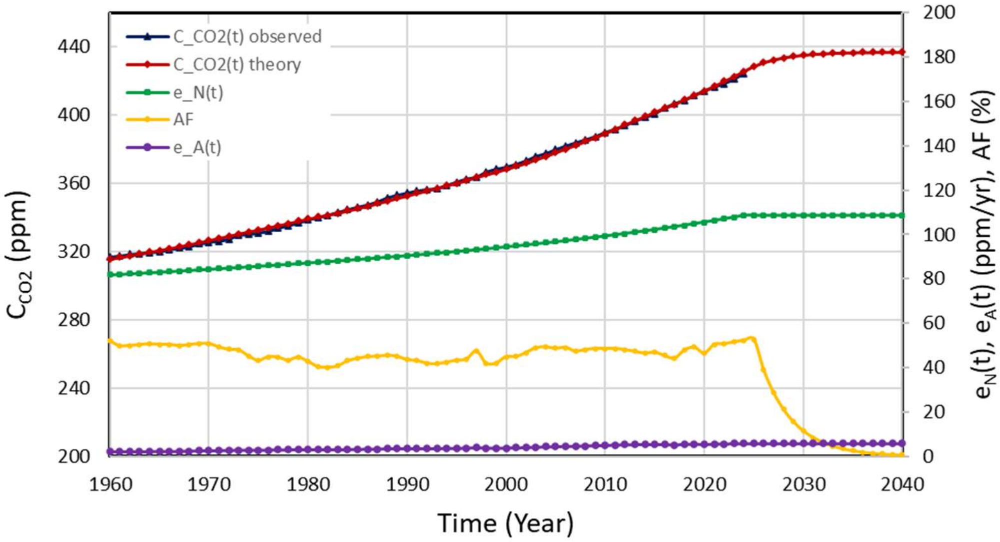

Fig. 7: Measured CO$_2$ concentration at ML (Blue Triangles) and calculation (Magenta Diamonds) for increasing natural (Green Squares) and anthropogenic (Lilac Dots) emission rates. The airborne fraction is shown as Orange Dots.

This is obvious, as often considered in this context, when shifting $e_A(t)$ in (3) to the left side. With the native impact again expressed as $e'_N(t) \cdot \tau_{eff}$, and with $C_A = C_{CO2} - C_N$ as the anthropogenically caused fraction to the concentration, the balance equation becomes:

$$\frac{\Delta C_{CO2}}{\Delta t} - e_A(t) = e_N(t) - \frac{C_N(t)}{\tau_{eff}} - \frac{C_{CO2}(t) - C_N(t)}{\tau_{eff}} = e'_N(t) \cdot \tau_{eff} - \frac{C_A(t)}{\tau_{eff}} \qquad (8)$$

So, as long as the native growth rate $e'_N(t) \cdot \tau_{eff}$ is smaller than the uptake of anthropogenic emissions with $C_A/\tau_{eff} = e_A(t) - e'_A(t) \cdot \tau_{eff}$, or in other words, when $e_A(t) > \{e'_N(t) + e'_A(t)\} \cdot \tau_{eff}$, both sides of (8) are negative. Since up to now any uptake is a pure native process – including the human emissions –, under these conditions *Nature is a net sink.* This, and an airborne fraction smaller 1, is the case despite increasing natural emissions.

Critics often forget that with the increasing CO$_2$ level in the atmosphere also the uptake is rising to adapt to a new quasi equilibrium; and due to the short residence time, there is only some smaller gap, which even under growing native emissions is less than the anthropogenically caused concentration C_A. Without anthropogenic emissions and their respective uptake nature would be a net source. *Thus, this human fraction finally determines, if Nature is a net sink or source.*

6. Conclusion

In this contribution we oppose the IPCC's and CO$_2$-C's interpretation of the carbon cycle to our own approach, in particular we discuss the mass balance of atmospheric CO$_2$ and show that by no means this is such a "*compelling and easily understood line of evidence"* as assumed by the CO$_2$-C research team [2]. Only looking to the yearly CO$_2$ increase relative to the anthropogenic emission rate and to conclude, as long as this ratio—the so-called airborne fraction—is smaller one, "*there is zero net contribution from natural sources and sinks to the increase in the atmosphere",* leads to wrong conclusions.

With one unitary residence time for native and anthropogenic emissions of 3 – 4 yrs and based on both, the thermally induced soil respiration in the tropics as well as human emissions according to the GCB-2024 data, the observed CO$_2$ increase over the Mauna Loa Era can be reproduced in all details. Despite an 8 times larger native increase than the human growth rate over this period the airborne fraction stays around 45 %, and the anthropogenic fraction contributing to the CO$_2$ increase over the Industrial Era, is only 5 % or even less of the actual total CO$_2$ concentration.

For any changes, both the anthropogenic and natural emission rates, are responsible and are summing up over time. As long as the native increase $e'_N(t)$ over the absorption time τ_{eff} is smaller than the uptake C_A/τ_{eff} of the anthropogenically caused emissions, *the Earth is still a net sink*.

Therefore, a statement as expressed in [2]:

> *Anthropogenic emissions of fossil CO_2 are much larger than the measured increase in the amount of CO_2 in the atmosphere. Therefore, the natural CO_2 "sinks" are nearly always larger than natural CO_2 "sources."*

can well be accepted, as only natural sinks exist, which also absorb any contributions of human emissions. But a further conclusion:

> *Any theory that leads to a substantial increase of CO_2 in the atmosphere due to natural factors violates the mass balance and thus cannot be correct.*

is more than questionable and is falsified. A more differentiated interpretation and integration of the mass balance just shows the opposite.

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References

1. Sixth Assessment Report (AR6), IPCC, 2021: V. Masson-Delmotte, P. Zhai, A. Pirani et al.: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press.
2. F. Engelbeen, R. Hannon, D. Burton, 2024: *The Human Contribution to Atmospheric Carbon Dioxide*, CO_2-Coalition, https://co2coalition.org/wp-content/uploads/2024/12/Human-Contribution-to-Atmospheric-CO2-digital-compressed.pdf
3. P. Friedlingstein et al., 2025: *Global Carbon Budget 2024*, Earth Syst. Sci. Data, 17, pp. 965–1039, https://doi.org/10.5194/essd-17-965-2025, https://www.statista.com/statistics/276629/global-co2-emissions/
4. X. Lan, P. Tans, K. W. Thoning, 2024: *Trends in globally averaged CO_2 determined from NOAA Global Monitoring Laboratory measurements, Version 2024-09*, https://gml.noaa.gov/ccgg/trends/global.html.
5. F. Joos, M. Bruno, R. Fink, U. Siegenthaler, T. F. Stocker, C. Le Quéré, J. L. Sarmiento, 1996: *An efficient and accurate representation of complex oceanic and biospheric models of anthropogenic carbon uptake*, Tellus B 48, pp. 397–417, https://doi.org/10.1034/j.1600-0889.1996.t01-2-00006.x.
6. H. Harde, 2019: *What Humans Contribute to Atmospheric CO_2: Comparison of Carbon Cycle Models with Observations*. Earth Sciences, Vol. 8, No. 3, pp. 139-158, https://doi.org/10.11648/j.earth.20190803.13.
7. H. Harde, 2023: *Understanding Increasing Atmospheric CO_2*, Science of Climate Change, Vol. 3.1, pp. 46 – 67, https://doi.org/10.53234/scc202301/23
8. H. Harde, 2017: *Scrutinizing the carbon cycle and CO_2 residence time in the atmosphere*, Global and Planetary Change 152, pp. 19-26, http://dx.doi.org/10.1016/j.gloplacha.2017.02.009.
9. H. Harde, M. L. Salby, 2021: *What Controls the Atmospheric CO_2 Level?* Science of Climate Change, Vol. 1, No.1, pp. 54 - 69, https://doi.org/10.53234/scc202106/22.
10. M. L. Salby, H. Harde, 2021 (SH1): *Control of Atmospheric CO_2 - Part I: Relation of Carbon 14 to Removal of CO_2*, Science of Climate Change, Vol. 1, No.2, pp. 177 - 195, https://doi.org/10.53234/SCC202112/30.

11. M. L. Salby, H. Harde, 2021 (SH2): *Control of Atmospheric CO_2 - Part II: Influence of Tropical Warming*, Science of Climate Change, Vol. 1, No.2, pp. 196 - 212, https://doi.org/10.53234/scc202112/12.
12. M. L. Salby, H. Harde, 2022 (SH3): *Theory of Increasing Greenhouse Gases*, Science of Climate Change, Vol. 2, No.3, pp 212 - 238, https://doi.org/10.53234/scc202212/17.
13. E. Berry, 2019: *Human CO_2 has little effect on atmospheric CO_2*, International Journal of Atmospheric and Oceanic Sciences, Vol. 3.1, pp. 13-26, https://doi.org/10.11648/j.ijaos.20190301.13.
14. E. Berry, 2023: *Nature controls the CO_2 increase,* Science of Climate Change, Vol. 3.1, pp. 68 – 91, https://doi.org/10.53234/scc202301/21
15. I. Levin, B. Krömer, H. Schoch-Fischer, M. Bruns, M. Münnich, D. Berdau, J.C. Vogel, K.O. Münnich, 1994: *Atmospheric $^{14}CO_2$ measurements from Vermunt, Austria, extended data up to 1983*, https://cdiac.ess-dive.lbl.gov/ftp/trends/co2/vermunt.c14.
16. J. J. Kennedy, N. A. Rayner, C. P. Atkinson and R. E. Killick, 2019: *An Ensemble Data Set of Sea Surface Temperature Change From 1850: The Met Office Hadley Centre HadSST.4.0.0.0 Data Set,* Journal of Geophysical Research: Atmospheres 124, pp. 7719–63.
17. O. Humlum, K. Stordahl, J.-E. Solheim, 2013: *The phase relation between atmospheric carbon dioxide and global temperature*, Global and Planetary Change, Vol. 100, pp. 51–69. https://doi.org/10.1016/j.gloplacha.2012.08.008.
18. M. L. Salby, 2013: *Relationship between Greenhouse Gases and Global Temperature*, Video presentation, Hamburg, Germany, https://www.youtube.com/watch?v=2ROw cDKwc0.