The Physics of the Carbon Cycle: About the Origin of CO_2 in the Atmosphere

ABSTRACT

Aims: Examination of the correctness of some assumptions of IPCC regarding climate. Discussion of consequences.

Methodology: Explanation of terms used by IPCC and clarification of consequences, identification of prerequisites for the validity/applicability of these terms and scrutiny of their fulfillment under real-world conditions, discussion of consequences.

Results: Based on the laws of physics and logic, two central terms used by IPCC, i.e. the fixed "airborne fraction", and the constant "CO_2-budget” cannot exist in reality. The first states that about 50 % of the CO_2 emitted by humans (the “airborne fraction”) stay in the atmosphere for centuries or longer (the other about 50 % leaving it within maximum a few years), the latter is the maximum value of cumulative net global anthropogenic emissions that is allowed, if global warming should be kept below a given level, for example 2 °C. According to their definition, both values are independent of the temporal distribution of the anthropogenic emissions. But physics speaks against their existence. And also the “Bern Cabon Cycle Model”, used by IPCC as an alternative method to analyze the carbon cycle, cannot be correct, because it is based on incorrect physical boundary conditions. The inadmissibility of the two terms is also supported by observations of the fast decay of $^{14}CO_2$ after the atomic bomb test stop agreement.

Conclusion: If the considerations made here are correct, IPCC's assessment of the sharp increase in CO_2 concentration being a consequence of anthropogenic releases implodes. Consequently, the assessment of global warming to be man-made is justified no more, and the necessity to terminate all anthropogenic releases of CO_2 for climate protection reasons becomes superfluous. The considerations made here appear to be very reliable, but in view of the far-reaching consequences, a careful review by the scientific community seems to be urgently needed.

Key Words: Global warming, anthropogenic emissions, carbon cycle, carbon budget, CO_2-budget, airborne fraction, climate sensitivity, Bern carbon Cycle Model.

1. INTRODUCTION

The current global warming is usually assessed to be the result of anthropogenic emissions of CO_2 and is assumed to progress faster and faster if we were to continue with business as usual. Only terminating all our emissions within the next few years will see us taking the last exit ofthe “highway to climate hell” (UN Chief Antonio Guterres, Nov. 07, 2022). But there are also dissenters. They point out inconsistencies and emphasize existing gaps in our understanding of climate science. For example, it is hard to understand why the enormous research effort over the past half century has not led to a satisfactory clarification of the influence of CO_2 on the climate. This influence is measured by the “climate sensitivity of CO_2”, which quantifies the global averaged warming in case of a doubling of CO_2concentration. In its latest report, AR6, IPCC specifies the bandwidth of uncertainty as 2.5 to 4 °C, almost a factor of 2 [1]! Others claim higher or lower numbers, with some far away from IPCC’s bandwidth. And since CO_2 has positive consequences as well, especially through its undeniableboost of plant growth and thus improved food supply, CO_2 can be categorized as ranging from extremely dangerous to beneficial. An end of the dispute is not in sight. This impossibility to adequately narrow the uncertainty could perhaps be due to scientists focusing too much on the interactions of CO_2 and climate, without sufficiently validating the starting point of their considerations, the assumption that the increase in CO_2 concentration is manmade. It might even be truly impossible to achieve definitive results if the basis is erroneous. This article scrutinizes the reliability of the basisof IPCC’s reports.

2. MATERIALS AND METHODS

This article does not present new experiments or measurements. Rather, it checks selected relevant statements from literature, especially from IPCC, against the rules of physics and logic: Which prerequisites must be fulfilled, so that these statements may be correct and support IPCC's opinion of the climate being determined by the anthropogenic CO_2-emissions? Are these prerequisites actually fulfilled under real-world conditions? The individual results are discussed and brought together to achieve an overarching assessment.

3. THE ELEMENT CARBON AND ITS CYCLE

In its organic form, carbon is the basis of all life: *Without carbon, no life!* And in its chemical form CO_2, it again is the basis of all life: *Without CO_2, no photosynthesis*, no plants, no animals, no humans. The lower its concentration, the lower the photosynthetic performance. And whenever the concentration falls below about 150 ppm, photosynthesis would stop altogether and all life, as we know it, would be terminated.

In the early days of the earth, CO_2 was the main component of the atmosphere. But meanwhile, most of it has been transferred to rocks, reducing it to a trace gas in the atmosphere with a concentration of only 0.04%(400 ppm). However, this was not a straightforward process, rather large amounts of rocks with all their carbon captured have been subducted into the earth mantle by plate tectonic processes, a part of this carbonhas been reemitted into the atmosphere as CO_2 by volcanoes,and then these processes repeated. This leads to the concept of a "*carbon cycle*".

Usually, scientists distinguish between the "*geological*" (or "slow", or " long-term") and the "*biological*" (or "fast", or "short-term") carbon cycle [2]. The "geological" cycle includes processes such as sedimentation, weathering of rocks, plate tectonics, etc., running on time scales of millions of years or longer. Therefore, this cycle is irrelevant regarding manmade climate changes. In contrast, the "biological" cycle comprises all exchange processes between atmosphere and biosphere, respectively ocean. These processes are generally performed on short time scales, from days to several thousand years. Therefore, this cycle does play a role in climate discussions.

However, for a better understanding, it seems appropriate to subdivide the "biological" cycle even further, depending on the speed of the processes [3-6], see Fig. 1. In this article, the term "*small cycle*" is used for all fast-running processes (high exchange rates, time scales up to several decades), and the term "*large cycle*" is used for all slower-running processes (lower exchange rates, longer time scales). The "small cycle" comprises all exchange processes between the atmosphere and the *near-surface ocean layer* and the *short-lived terrestrial biomass*, which all run at high exchange rates. The near-surface ocean layer is roughly about 50 to 100 m deep, it is well mixed by wind and waves, it includes organic material in different forms, it is sunlit (photosynthesis!), and it exchanges carbon with the atmosphere on the one side and with the deep ocean on the other side. The short-lived terrestrial biomass includesannual plants, leaves, needles, etc. It takes out CO_2 from the atmosphere by photosynthesis and gives it back by respiration and rotting.

The "large cycle" then comprises all slower exchange processes of the atmosphere, respectively the "small cycle", with the *deep ocean* and with *long-lived terrestrial biomass* **(**long-lived woods, humus, peat, etc., including permafrost). "Small cycle" and "large cycle" together form the "biological cycle" (Fig. 1) [3-6].

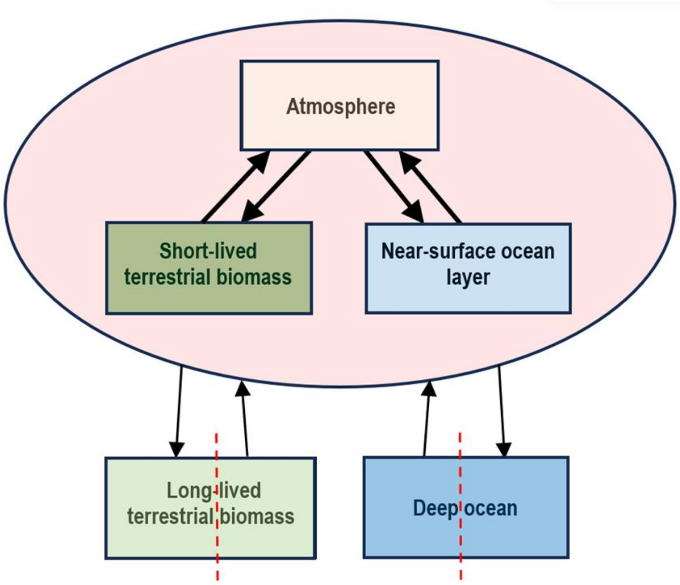

Fig. 1: Carbon Cycle, schematic. The "small cycle" occurs inside the ellipse, the "large cycle" is all together. Arrows symbolize CO_2-exchanges, dashed red lines indicate decoupling of inflow and backflow in that reservoir.

4. WHAT HAPPENS WHEN CO_2 IS EMITTED?

The events following emission of CO_2 into the atmosphere can be described in *3 consecutive steps* (Fig. 1):

- First, distribution of "new" CO_2 within the atmosphere: This is performed very effectively by wind and weather, and a homogenous concentration is reached on a large scale within a few months. On a small scale, local and temporal variations do exist but may be neglected for the discussions here.

- Second, further distribution within the "small cycle": This is performed by high exchange rates (about a quarter of the atmospheric inventory per year! [1, 7-9]), and an equilibrium is reached within a few years (same partial pressure all over the "small cycle").

- Third, transfer of carbon from the "small cycle" into the deep ocean, respectively into long-lived terrestrial biomass: This is performed by considerably slower processes.Due to the large carbon inventories [1, 7-9], equilibrium will be reached only after thousands of years (roughly) (equilibrium within the "large cycle").

To understand the carbon cycle correctly, it is essential to take note that the process proceeds in these successive steps.

5. "CARBON BUDGET", "AIRBORNE FRACTION", AND "CLIMATE SENSITIVITY"

IPCC claims that anthropogenic CO_2 emissions are the only cause of global warming [1, 7-9]. To avoid a catastrophe, we must completely stop all these emissions. IPCC assumes the existence of a "maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level", IPCC calls this the "*carbon budget*" or "*CO_2-budget*" [1]. This "CO_2-budget" is stated to be almost exhausted, so time is pressing for countermeasures. According to its definition, the "CO_2-budget" is independent from the temporal distribution of our emissions.

IPCC deduces the existence of this fixed "CO_2-budget" from *two assumptions*:

1. The rise in atmospheric CO_2-concentration is (exclusively!) the consequence ofthe anthropogenic emissions, which is in turn deduced from the assumption that

approximately 50 % of these emissions remain in the atmosphere (quantitatively, not necessarily the individual molecules emitted), independent of the height of these emissions and independent of the concentration already reached; IPCC speaks of a constant "*airborne fraction*" [1, 7-9].

2. The concentration increases the temperature by a fixed amount for each doubling of the concentration. This amount is labelled the "*climate sensitivity of CO_2*" [1, 7-9].

Focus of the considerations here is a careful check whether a constant "airborne fraction" and a fixed "CO_2-budget" be conclusive. It will be shown that both concepts contradict physical rules with high confidence. If this is confirmed, anthropogenic emissions *cannot be* the main cause of the rising CO_2-concentration, and therefore also not of the rising temperature, regardless the "climate sensitivity" of CO_2. Consequentially, this "climate sensitivity" is only of secondary importance here. It should only be mentioned that its exact value is scientifically highly controversial; and for those interested, a few helpful publications are listed [10-19].

6. PREREQUISITES

Physics and logic require three prerequisites to be fulfilled, if the fixed "CO_2-budget" and the constant "airborne fraction" were to exist:

1. All other sources of CO_2 *must have remained constant*. Otherwise, they would contribute to the growing concentration, perhaps they could even dominate it.
2. The short-term partners of the atmosphere must store the *same amount*of CO_2as the atmosphere itself. Otherwise, it would not be possible that always 50 % of the anthropogenic emissions remain in the atmosphere.
3. The atmosphere together with its short-term partners (the "short cycle") *must be a closed system*.Otherwise, CO_2would be taken out of this system, reducing the concentration, the more, the higher the concentration.

It will be shown that all three prerequisites are not fulfilled with a high level of confidence.

7. PREREQUISITE 1: CONSTANT NATURAL SOURCES

Inside the atmosphere, CO_2 reacts as an inert gas: There is no CO_2 produced and none vanishes. All CO_2-molecules inside have been emittedfrom an external source, and all will be transferred into an external sink. This outflow starts when the first molecules accumulate, it is *the stronger the higher the concentration is*, and it'll theoretically lastuntil the last molecule is transferred.

For clarification: This outflow is the *gross* outflow. It must be strictly distinguished from the *net* outflow, which is the difference to the simultaneous gross inflow into the atmosphere. The net flow between two reservoirs always goes from higher to lower concentration, but this net flow is always the *superposition of two countercurrent gross flows*, back and forth, both driven by the concentration in the respective emitting reservoir (exceptions: emissions due to human activities or from volcanos do not depend on concentration, but on entirely different effects!). In equilibrium, the net flow is always zero, but the two countercurrent flows depend on concentration.

The dependency of the gross outflow from the atmosphere on atmospheric concentration follows inevitably from the main processes involved, dissolution in water and photosynthesis: Both are diffusion-processes, and diffusion depends on concentration! This has an immediate consequence: Whenever the emissions into the atmosphere remain constant, the concentration in it *adjusts itself to a fixed value*: that value, where *outflow equals inflow!* Hereafter, the concentration remains constant, despite of ongoing emissions! This alone*contradicts the existence of a fixed "CO_2-budget" and of a constant "airborne fraction" inevitably!* That's rather all that needs to be said.

But two further consequences of (gross) outflow rising with concentration should be mentioned:

1. When the total emissions into the atmosphere rise by x %, then the concentration in it can rise *at most by x %* too (in equilibrium, before even less)!

2. All sources contribute to the concentration according to their relative strength. *No one can contribute disproportionately!*

These two consequences always exist whenever the (gross) outflow from a reservoir increases with the concentration in it, regardless of the exact shape of this dependency. But because the outflow from the atmosphere runs mainly via diffusion (dissolution in ocean water and photosynthesis in plants!), this shape *must be proportionality!* Well, not necessarily exact from zero concentration up to 100 %, but within the range of interest here, from about 280 ppm (before the industrial revolution) to about 420 ppm (today) or 560 ppm (perhaps tomorrow), proportionality applies at least in good approximation! As shown above, physics demands this to be true.This is an essential assumption in the discussions here (Attention: this is the gross outflow, the net outflow is proportional to the *difference* in concentration!).

Another important feature is that this gross outflow from the atmosphere is completely independent of what happens subsequently to the molecules that have left the atmosphere (for example, whether they are circulated back into the atmosphere or not, asthis only influences the emissions into the atmosphere and not the outflow from it), and it is also completely independent of how many molecules are emitted into the atmosphere simultaneously (and from which source they are emitted)! Therefore, if we know how much the concentration has changed (the only parameter we really can measure!), we can calculatehow much *the (gross) outflow must have changed* as a consequence. And if we know the gross outflow from the atmosphere, we can calculate *which inflow must have taken place* to let the concentration develop as it did, independent of the cause of this inflow [3-6, 20-24]!

Short supplement: As already said, the gross flowrate from the atmosphere into the ocean does not depend on what happens to the molecules afterwards. This also holds true for possible chemical transformations of those CO_2 molecules in the ocean water. But the (gross) flowrate back into the atmosphere does depend on those transformations. This isbecause the transformation-products, carbonate and bicarbonate, do not contribute to the CO_2 partial-pressure, which drives the flow back into the atmosphere. A further complication arises from the fact that the solution equilibrium between these transformation-products and CO_2 depends on concentration. For more details see the discussion in section 13.4.

To summarize: Because the concentration in the atmosphere has risen by 50 %, the total gross outflow from the atmosphere *must have risen by 50 % as well*, at least approximately! That seems to be what physics requires. And since the concentration has risen, the total inflow *must have risen by a greater amount!* That seems to be what the mass balance requires. In other words: According to these considerations, the total inflow into the atmosphere *must have risen by about 50 %!* The 5 % share of anthropogenic emissions is *far too small* in any case.

Interim result: This confirms the result already found: To explain the observations, other sources of CO_2 must have been enhanced substantially, prerequisite 1 *cannot be fulfilled!*

Which sources have been enhanced is of secondary importance for the discussions here, but clearly very interesting. One contribution inevitably comes as a*respond*to the higher concentration in the atmosphere, whatever the cause: Because of the rather small inventory inthe immediate reaction partners of the atmosphere, the near-surface ocean layer and the short-lived terrestrial biomass (Fig. 1), the concentration in them will always *rise markedly* when they receive further CO_2. Consequently, they must *deliver more* CO_2 back to the atmosphere! Therefore, when emissions into the atmosphere increase, the emissions back into the atmosphere from these two reservoirs *increase as well*, with only a short time lag. (Note: This is the response the *atmosphere* receives from its direct reaction partners, for the response the “*small cycle*” receives from its partners, see section 9).

This feedback to increased emissions into the atmosphere exists without doubt, but there must be other enhancements of emissions too: At least the *higher temperature***,** whatever the cause, must have increased the emissions from ocean and biomass! Reasoning: Higher temperatures emit more CO_2 from the ocean (temperature dependent solubility of gases in liquids!), and they also enhance the exchange rates between atmosphere and biomass, the latter boosted even further by the growing of biomass (“global greening”, see e. g. [25-27]). One can discuss the size of this temperature-driven enhancement, but not its existence. Higher temperatures always increase emissions!

Supplemental remark: It is always the emissions that determine the concentration (to that value, where outflow equals inflow). Therefore, a higher temperature always leads to a higher concentration (as would a lower temperature to a lower concentration). According to [28], this is shown throughout the whole history of the earth: The CO_2 concentration has always followed the temperature.

Summarizing the fulfillment of prerequisite 1: Anthropogenic emissions are *much too small*, and increased temperatures *must have enhanced* emissions too! Further enhancement might come from relocations of ocean currents with different carbon content or from volcanoes (on land or submarine) and there are some more possibilities. The rules of physics *seem to require* substantially enhanced emissions from natural sources, but they also *provide possibilities* for that to happen. There is no need to assume any unknown physical effect.

8. PREREQUISITE 2: EQUAL STORAGE CAPACITY

If the "small cycle" were a closed system,and if the storage capacities in the atmosphere itself and in the rest of the "small cycle" were the same, all CO_2 taken up in that cycle would distribute itself with *half of it* remaining in the atmosphere. That is exactly what IPCC assumes regarding the anthropogenic emissions [1, 7-9]! But that only works in a closed system with equally large storage capacities!

In its Fig. 5.12, [1] gives numbers for carboninventories. Their interpretation is complex because most of the CO_2 dissolved in the ocean is converted into carbonate and bicarbonate, which do not contribute to the partial pressure. Regarding biomass, IPCC does not differentiate between short-lived and long-lived biomass. But the numbers given in Fig. 5.12of [1]strongly suggest that there is considerably less CO_2 in the atmosphere than in the rest of the "small cycle". If correct, *less* than half of anthropogenic releases remain in the atmosphere!

However, this "equal capacity" is only valid anyway if no other sources are enhanced. Otherwise, the atmosphere's carbon inventory must be larger than that of the other components to retain 50 % of CO_2 emitted into the small cycle. Obviously, according to the numbers given in Fig. 5.12 of [1]this is even *less likely*. Hence, the fulfillment of prerequisite No. 2 is *seriously in doubt.*

But perhaps other observations can help: There is a radioactive variant of CO_2, $^{14}CO_2$ (8 neutrons in the carbon-nucleus, $T_{1/2}$ of about 6000 years), with a very low natural atmospheric concentration (equilibrium between production via cosmic rays and radioactive decay). Following last century's atomic bomb tests, its concentration almost doubled (Fig. 2). It can be clearly seen that after the test stop agreement in 1963, the concentration of $^{14}CO_2$ decreased rapidly, essentially *reaching its previous value* from before the bomb tests. In this case, clearly, *less than 50 %* of the $^{14}CO_2$ released anthropogenically remained in the atmosphere, much less!

And in this regard "normal" CO_2 *cannot behave differently!* It must distribute itself in the "small cycle" analogue to the distribution of $^{14}CO_2$(the chemical behavior of different isotopes is basically the same!). Even with "normal" CO_2, only *significantly less than 50 %* can remain in the atmosphere! This confirms that today's observed increase of the concentration by 2.5 ppm/y most probably *is not* the result of half of anthropogenic emissions remaining in the atmosphere (as IPCC assumes), but rather the result of *much stronger sources* combined with *substantially increased outflow* of CO_2 from the "small cycle" into the deep ocean, respectively into long-lived biomass.

In summary, even if there is no real proof, there is strong evidence that prerequisite 2 *is not fulfilled!*

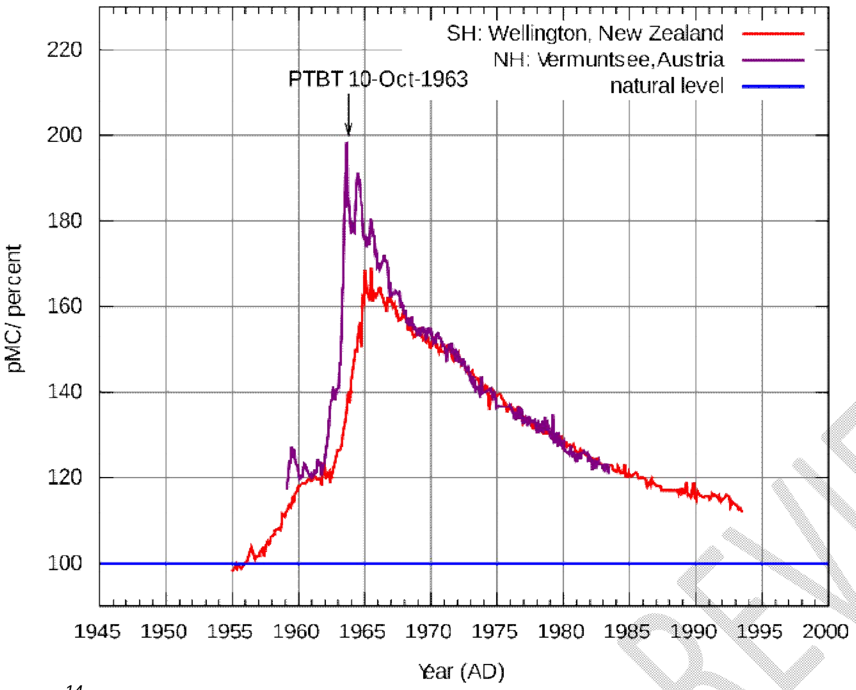

Fig. 2: $^{14}CO_2$ concentration in the atmosphere: Pulse and decay after the atomic bomb tests [29].

9. PREREQUISITE 3: CLOSED SYSTEM

In a closed system, all CO_2 emitted into it remains in it. Therefore, constant emissions increase the concentration indefinitely. But in an open system, this is completely different: Because of gross outflow rising with concentration, constant emissions enhance concentration *only until outflow equals inflow*. Afterwards, concentration *remains constant*, despite of ongoing emissions. Because the "small cycle" is an open system (see below), prerequisite 3 *cannot be fulfilled.* Therefore, the fixed "CO_2-budget" and the constant "airborne fraction" *cannot exist!*

Reasoning: The only parameter really measured is CO_2-concentration. And to correctly interpret these measurements, a special feature of the carbon-exchange with the deep ocean is of particular importance: Forward flow and return flow *can diverge substantially!* The downward flow into the deep ocean increases with the atmospheric concentration (more accurate: with the concentration in the near surface ocean layer, but the two are always similar), because the two effects that bring about this transport,the biological pump (sinking of dead organisms with calcareous shells) and the physical pump (sinking of entire water packages with their whole contents) run proportional to concentration, at least approximately. However, due to the sheer size of the deep ocean andits slow currents, the return flow back from the deep ocean remains basically *unchanged* for about 1000 years! The response of the deep ocean to an increasing atmospheric concentration simply takes this long. Therefore, whenever the concentration in the atmosphere changes, the exchange with the deep ocean is *imbalanced* for a significantly long period!

[1] gives the downflow into the deep ocean with 275 PgC/y. Previously, it was about 100 PgC/y [7-9]. Nothing shows clearer than this surprising sudden jump that we are *far away from knowing everything for sure* in the carbon cycle! But whatever the real value, it doubtless proves that the "small cycle" *is an open system!*

Regarding long-lived terrestrial biomass, similar conditions apply: Here, too, the storage time is very long and therefore the exchange between atmosphere and long-lived biomass is *imbalanced* for a long period. IPCC only gives combined numbers for the short-lived and the long-lived terrestrial biomass [1], but a substantial part of the ~~respond~~responseof the terrestrial biomass to rising atmospheric concentration is considerably delayed unambiguously, contributing to the openness of the system.

For clarification: It is the *size* of the direct reaction partners that determines the time delay of a response to increased emissions of CO_2: The atmosphere as such has small partners, resulting in a *quick* response, within at most a few years, the partners of the “small cycle” in total are much larger, resulting in a delay of about *1000 years*. During this time, the “small cycle” definitely *is an open system!*

10. DEPENDENCE ON TEMPORAL DISTRIBUTION

As already said, according to the definitions of the fixed “CO_2-budget” and the constant “airborne fraction”, these two terms must be *independent of the temporal distribution* of the anthropogenic emissions. For example, emitting the whole “CO_2-budget” evenly distributed over 100 years must have the *same consequences* as an abrupt emission of the same total amount in a single pulse. And the consequences must be the same, independent of the time of this pulse, be it e. g. in year 1 or 100, or in any other year.

But if, for example, 50 % of that amount are emitted in year 1 and the other 50 % are emitted in year 100, and if that should have the *same consequences* as the larger single pulse in year 100, *no* CO_2 must be taken out of the atmosphere for 100 years despite substantially increased concentration! Likewise, in the case of equally distributed emission over 100 years, no share of these emissions must be taken out before year 100. That *contradicts* physics, which requires outflow to increase with concentration, and it also *contradicts* the fixed “airborne fraction” of 50 %, which, if correct, would mean that 50 % of any amount emitted are withdrawn within a few years at most! The two concepts, the fixed “CO_2-budget”, and the constant “airborne fraction”, *contradict each other!*

Appraisal: Both assumptions, the fixed “CO_2-budget” and the fixed “airborne fraction”, are key components in IPCC’s attribution of the rise in CO_2-concentration solely to human emissions [1, 7-9]. Both seem to *contradict physics*, and they *cannot coexist*, because they are mutually exclusive! Probably, both assumptions are incorrect. Most likely, the rise in CO_2-concentration is a *mood of nature with only a small human contribution!*

11. WHAT HAPPENSTO THE CLIMATE WHEN WE TERMINATE OUR EMISSIONS?

Presumably not very much. On the basis of the considerations here, the development of the concentration has been determined by changes of natural emissions, and this will also hold true for the future! Anthropogenic emissions are much too low to impose large changes. If natural emissions were to continue to rise, the concentration would rise as well, and if nature were to reduce its emissions, the concentration would fall as well, whatever we do. The influence humankind can exert by its emissions of CO_2 seems to be too small to matter.

12. RESULT

If the above considerations hold true, the main result is that the two central terms of IPCC, the fixed “carbon budget” and the constant “airborne fraction”, *do not exist* in reality. If they were to break away, then the emissions from natural sources *must have increased substantially* for the concentration to rise as it did. And as a consequence of this, the anthropogenic emissions of CO_2 *cannot be responsible* for the ongoing global warming, whatever the climate sensitivity of CO_2. Finally, there would be *no need to reduce* these emissions, at least not due to climate concerns. We could spend the money and effort on other, more urgent issues.

13. DISCUSSION

The results developed in this article deviate from the mainstream. In such cases, extreme caution is always urgently required, because a treacherous error may have crept in somewhere. Therefore, the author of this article has tried to discuss all the findings as detailed as possible with people that agree, and especially with people that don’t agree. Some of the counterarguments put forward have already been rejected in the sections above, others are discussed in more detail in this section 13. It will turn out that they will not hold up either, the results found here seem to be robust. The scientific community should bring about a final clarification.

13.1 Incorrectness

Many objections were only general claims of incorrectness without clearly stating the attested failure. This is hard to understand, because it is always stated precisely how the considerations made follow the rules of physics and logic (at least, the author sees it that way). And the result is not just marginal, but the natural flows must have grown by a multiple of the anthropogenic emissions. Therefore, minor inaccuracies are not enough to reject the preponderance of natural emissions. This is supported by the fact that the two CO_2-cycles, the one between atmosphere and ocean, and the other between atmosphere and biomass, are totally independent of each other (except for the atmosphere being part of both), and that they operate by essentially different physical processes. Therefore, failure in one does not mean failure in the other. Additionally, each of the two cycles is strong enough on its own to maintain the central statement "nature dominates", even if the argumentation should break down in the other cycle. The preponderance of nature would be less, but it would still apply, rejecting IPCC's view "only the anthropogenic emissions". Of course, two independent failures are possible, but unlikely. The central statement "nature is stronger than humankind" cannot be so easily overthrown.

The correctness of the results found here can also be checked by comparing them with numbers given by IPCC: According to [1], AR 6, Fig. 3, the CO_2 inventory in the atmosphere rose from 591 PgC in 1750 to 870 PgC in 2019, that is an increase in concentration by 47 %. During the same time period (more precisely, up to the average from 2010 to 2019), the outflow from the atmosphere rose from 167 to 221,5 PgC/yr, that is an increase by 33 %. This is a rather *good confirmation* of approximated proportionality, and it clearly shows that natural flows have been enhanced *much more* than the anthropogenic emissions. IPCC does not seem to be aware of the contradiction of numbers published by themselves.

13.2 Driving force of 120 ppm

Today, the concentration in the atmosphere is about 120 ppm higher than it was 150 years ago. And today the net outflow from the atmosphere into the ocean and into the terrestrial biomass is about 2.5 ppm/y. Sometimes, this is interpreted as the 120 ppm being the *driving force* to emit the 2.5 ppm/y from the atmosphere [19, 30-33]. On that basis, it is calculated: If we reduce our emissions to 50 %, the concentration remains constant immediately, and if we freeze our emissions at today's value, the concentration increases only up to a new equilibrium at about 500 ppm, and if we terminate our emissions, the concentration falls rapidly, exponentially with a time constant of about 55 years down to the old equilibrium 150 years ago.

This view also clearly deviates from IPCC's view, but it also contradicts the results found here. But it seems to be *wrong for two reasons:*

- First, the driving force for the actual net outflow is the *actual* difference in concentration between the atmosphere and its sinks, not the *mathematically calculated* difference between today's concentration and that 150 years ago. This difference does not exist as a real-world state, and the atmosphere does not even have a "memory" for any past concentration, it only "knows" today's boundaries.
- And second, an imbalance with a driving force of 120 ppm appears to be *totally impossible* in a system with an exchange rate roughly the same size (about a quarter of the inventory per year!) and a gross outflow depending on concentration. More precisely: "Totally impossible" is at least true for slow transients, and real transients always have been very slow, below 1 % of the inventory per year! Such a high imbalance, if it should ever come about at all, would be eliminated completely within maximum a few years.

Today's net flow of 2.5 ppm/y from the atmosphere into the near surface ocean layer and into the terrestrial biomass is tantamount to the statement that these two reservoirs emit 2.5 ppm/y less than they receive from the atmosphere. What they receive, we know, is driven proportionally by the total concentration in the atmosphere, and regarding their emissions, we do not know the strength of the driving forces (temperatures, ocean currents, volcanoes, etc.), but we can calculate the (gross) flux by observing the mass balance. These simple physical relationships show that an excess concentration of 120 ppm above the equilibrium does not exist in nature and could never be the driving force for the 2.5 ppm/y of net flow. The argument is simply not tenable.

13.3 Bern Carbon Cycle Model

Some scientists admit that the “airborne fraction” and the “CO_2-budget” have some shortcomings, but IPCC would only use them for rough descriptions and general statements anyway. For precise calculations, IPCC would rather use the “Bern Carbon Cycle Model”, which does not have such shortcomings. However, the Bern Carbon Cycle Model is fundamentally flawed, as will be shown below.

This model was originally developed to consider different sinks by calculating the removal of CO_2 from the atmosphere as a sum of negative exponential functions, one for each sink [34]. This should make the results more accurate. The model uses the same formula as describes the radioactive decay of a mixture of unstable isotopes.

But the removal of CO_2 is quite different: While in the case of radioactivity the decaying isotopes determine the course of events, in the case of CO_2-removal, it is the sinks into which the CO_2 flows (all CO_2-molecules are the same!). With radioactivity, each isotope decays with its specific half-life, independent of the presence of other isotopes.Isotopes with the highest radioactivity disappear first, so that after some time only the weaker ones have remained andthen they determine what happens. With CO_2-removal, all sinks work together, like a single large sink, and the strongest sinks remain the determining ones, until the very end, the small ones never become relevant.The CO_2-molecules justdo not wait for a small sink to catch them, rather they disappear in a fast sink before.

To sum it up: The Bern Carbon Cycle Model is based on a false physical basis. It cannot correctly describe the outflow of CO_2 from the atmosphere. It cannot repair the shortcomings of the “airborne fraction” and the “CO_2-budget”.

13.4 Revelle-Effect

When CO_2-molecules enter the ocean, most of them are transformed into other chemical compounds. This effect is called the “*Revelle-Effect*”, named after the researcher Roger Revelle. It is often said that it reduces the capacity of the ocean to take up additional CO_2 considerably, contradicting proportionality between concentration in the atmosphere and outflow from it.

The chemistry of carbon in the ocean water is complex. The so-called Bjerrum-plot shows significant changes of the solution equilibrium of the different species with the pH-value. At today’s typical value of 8.1 (and all other parameters as they are today), about 99 % of the total dissolved inorganic carbon content (DIC) is made up of carbonate and bicarbonate, neither of which contribute to the partial pressure. Therefore, this pressure is determined by only about 1 % of the DIC, the part that exists as dissolved CO_2. But this solution equilibrium not only depends on the pH-value, but also on the DIC-concentration and on other parameters. Accordingly, if there were a change, the ratio of the relative change in CO_2 concentration to the relative change in total DIC concentration would also depend on all these parameters. This ratio is called the “*Revelle-Factor*” (RF), sometimes also referred to as the “*Buffer-Factor*”, because it indicates how much a certain amount of CO_2, transferred from the atmosphere to the ocean, increases the CO_2 concentration in the oceanwater. A typical value of the RF is about 10. This value means that when the CO_2-concentration in the near-surface ocean layer rises by x %, the DIC-concentration rises only by a tenth of x % (the reciprocal value of the RF).

A few calculation examples to demonstrate the effect: Let us take a small volume element of ocean water, just large enough to contain 10 dissolved CO_2-molecules. According to today’s situation with a DIC-to-CO_2-ratio of 100, the total number of DIC-molecules in that volume element must be 1000. For doubling the CO_2-concentration (increase by 100 %), another 10 dissolved CO_2-molecules would be necessary in that volume element. And if the RF were 10, the typical value of today, the DIC-concentration would simultaneously rise by 1/10 of 100 %, that is 10 %. This brings the total number of DIC-molecules to 1100. With other words, to store additional CO_2-molecules as dissolved CO_2 in the ocean water, today the *10-fold* number of CO_2-molecules must be taken out from the atmosphere (most of it gets transferred to other chemical compounds)! If, hypothetically, the RF were 20, the DIC-concentration would rise by only 5 %, requiring only a total of 50 CO_2-molecules to pass over into the water phase, the 5-fold amount of the newly stored dissolved CO_2. And if the RF where 5, 200 CO_2-

molecules would be required, the 20-fold amount. Finely the borderline case: If the RF where zero, all transferred CO_2 would go into the other chemical compounds, none would be stored as dissolved CO_2, its concentration could not increase.

These examples show: The higher the RF, the less CO_2-molecules pass over into the water phase until a given increase in dissolved CO_2-concentration is reached (equalizing the partial pressures). IPCC's claim that this strongly limits the ability of the ocean to absorb CO_2 from the atmosphere is principally correct, but it is sometimes used in what might be considered a misleading way, exaggerating the limitations of this absorption: First, the examples above show that large quantities of CO_2 are still transferred to the water-phase, second, the RF has not changed very much in recent times(in the last 150 or so years, the RF has increased by roughly 10 % [35]), its change can therefore not have exerted any great influence, and third, regarding the climate-problematic, the Revelle-Effect seems to be massively overrated anyway: The exchange between atmosphere and ocean is not a one-way-transport, but rather a cycle with CO_2 flowing back and forth. In equilibrium (in the "small cycle", only here we have a transfer between the gaseous and the liquid phase), both flows are equally strong, and the influences of the Revelle-Effect on outflow and inflow of CO_2 should cancel one another out.

Altogether, the Revelle-Effect *does not prevent* approximated proportionality between fluxes and concentration, nature still must have increased much stronger than man.

13.5 Observations contradict

Critics argue that observations contradict the results found here.According to IPCC,observations show that the concentration of CO_2has always grown at half the rate of the anthropogenic emissions [1, 7-9].Thatseems right at the first glance, but could also be pure coincidence (as is also shown here in this work). After all, IPCC does not specify a physical process that could explain this cause/effect relationship.Unsurprisingly, because it contradicts the laws of physics, according to whichthe removal of CO_2 from the atmosphere must depend on the concentration and must be independent of how much CO_2 is released at the same time.

And if you take a closer look, even the observations speak against it: The anthropogenic releases have grown much more slowly in the last 10 years or so than before (perhaps because of efforts to contain them?), and in 2020 there was even a temporary decline of about 7% due to the coronavirus. If the anthropogenic releases really were the driving force, the slowdown in its increase should be noticeable as a kink in the concentration curve and the recession in 2020 should result in a dent in that curve.But there is no sign of that.On the contrary, as shown in Fig 3 the concentration has continued to rise completely unaffected by the two events, it perhaps has even increased somewhat.It simply does notseem to be true that the anthropogenic releases determine the concentration by half of them remaining in the atmosphere.

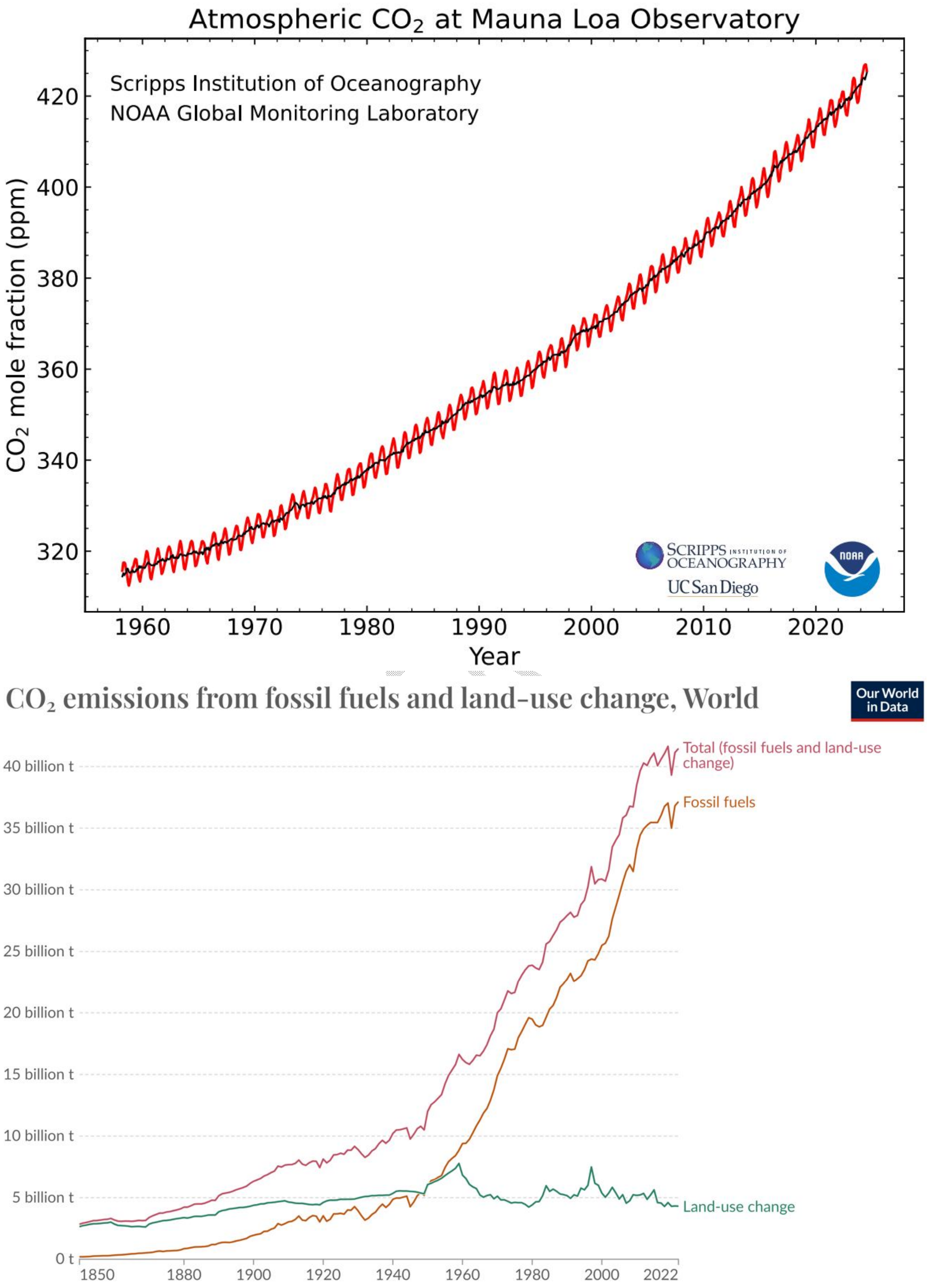

Fig. 3:Atmospheric CO_2-Concentration (top) and anthropogenic CO_2-Emissions (bottom). Source: NOAA, Global Monitoring Laboratory,and Our World Data.

13.6 A sink cannot be a source

Finally, one more counterargument, allegedly even a very fundamental one: *A sink cannot be a source!*it runs. Ocean and biomass have always been a sink for CO_2, taking up about half as much as the anthropogenic emissions amount to. And as a sink, they cannot have contributed to the increase in the concentration.From this follows the common argument, that this increase must have been brought about *exclusively by anthropogenic emissions*.

This counterargument is defended vehemently, however, it still seems to be wrong. It simply ignores the fact that the (gross) outflow from the atmosphere always *increases* with rising concentration, whatever the cause. Let’s start with external emissions. These are emissions into the atmosphere from outside the “small cycle” (e. g. anthropogenic emissions from burning fossil fuel or from cement production, or emissions from volcanoes, etc.): In all such cases the concentration in the atmosphere rises, and as a consequence, the (gross) outflow from the atmosphere rises too, but lags a little bit behind the (gross) inflow, it is simply a (delayed) response to the increased inflow. Consequently, ocean and terrestrial biomass now receive more CO_2 and *act as a net sink*! (Note: Strictly speaking, this is true for transients only; when the external emissions are held constant, equilibrium will be reached in short time, with the outflow being the same as the inflow). This applies for all external emissions.

Regarding internal emissions, at first, there appears to be analogous behavior. Internal emissions are all emissions into the atmosphere from within the small or the large cycle, e.g. emissions from the ocean or from the terrestrial biomass (note: anthropogenic emissions due to land use changes are largely internal emissions!). Internal emissions are nothing new, they already existed in the preindustrial equilibrium, but they can be enhanced, for example by rising temperatures or by changes in ocean currents. Here, too, when the internal emissions rise, the concentration in the atmosphere rises, and consequently, the (gross) outflow from the atmosphere rises too, and again this increased outflow lags a little bit behind the increased inflow. But with one important difference: In the case of enhanced internal emissions, ocean and terrestrial biomass go ahead, and they emit more than they take up. They now *act as a net source!* That applies for all internal emissions. (Again, this is true only for transients, if for example the temperature stops to rise, we again reach equilibrium in short time).

To make the difference clear: External emissions *increase the inventory* in the cycle and this additional inventory is distributed in the cycle, increasing the inventory (and by that the concentration) in all affected reservoirs. All reservoirs except the atmosphere act as net sinks. Enhanced internal emissions on the other hand *leave the total inventory unchanged* and just redistribute it between the reservoirs. This means that the increase in the inventory in the atmosphere comes about at the expense of the inventory in the ocean and/or the terrestrial biomass, they act as a net source.

One more note: In both cases the extent of ocean and biomass as net sink or net source is always the *momentary difference* between total input and total output to/from ocean and terrestrial biomass.

So far for the separated consideration. If both external and internal emissions are increased simultaneously their effects superimpose each other. Both increase the concentration in the atmosphere, and, following, both increase the (gross) outflow from the atmosphere. As long as the internal emissions rise somewhat fast and the external emissions are low, the latter enhance the (gross) outflow only a little bit, and ocean and biomass remain a net source. But when the external emissions get high enough, they can enhance the (gross) outflow sufficiently in order to become larger than the emissions from ocean and terrestrial biomass. Then the latter two switch to be a net sink. They now act as *a net sink and as a net source at the same time!* This is no contradiction, they are a net sink with regard to all emissions combined, and they are a net source simultaneously with regard to just what they do alone, without the external emissions!

That fits well with the findings in [36] in that ocean and biomass had been a *net source* of CO_2 for 200 years, with only very small anthropogenic emissions during that time, but switched to be a *net sink* around 1956, when the anthropogenic emissions became strong enough. For clarification: They became strong enough to enable that switch, however, that does not tell *which one* of the two emissions has contributed more to the observed rise in concentration. But this is an easy question: Since the emissions from natural sources have increased about *tenfold* compared to the anthropogenic emissions (about 50 % versus about 5 %), the answer is clear-cut (and there is even plenty of room left for possible inaccuracies, see above): Natural emissions have contributed *much* more!

To sum it up: Ocean and terrestrial biomass can be sink and source simultaneously. As a source, they enhance the concentration in the atmosphere significantly, and,consequently, the outflow from the atmosphere rises too, but with a slight delay. And when then anthropogenic emissions are added and when they are strong enough to enhance the concentration so much that the (gross) outflow from the atmosphere surpasses the (gross) inflow from the ocean and the terrestrial biomass, then the ocean and the terrestrial biomass *become a net sink, while still being a net source* for their own.

14. CONCLUSION

The main result of the considerations here is that both, the fixed “carbon budget” and the constant “airborne fraction”, *do not exist,* and that consequently the emissions from natural sources *must have been enhanced substantially* to increase the concentration in the atmosphere as has been observed! If confirmed, this has consequences: There are *only two possibilities left:* Either the climate is determined by CO_2, then it is *natural* CO_2 that determines, or other factors dominate, then CO_2 plays only a *subordinate role* at most! In both cases, there is *no need to reduce anthropogenic emissions,* at least not for climate protections sake. We can benefit from cheap energy from fossil fuels and from CO_2-improved plant growth without any remorse. And we have to accept the climate, as it develops on its own, and if necessary, we have to implement mitgating measures!

The results shown here clearly *contradict the mainstream view.* This is a good reason for caution, but the results seem to be backed by physics and by logic, and counterarguments do not seem to be sustainable. Therefore, a careful review of the results found here is required urgently. This article aims to push the discussion

Competing interest

Authorhereby declares that he has not received any funding or similar benefits for this work, that no competing interest exists,

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3..

REFERRENCES

1. IPCC (2021): AR6, Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, MI. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. *Cambridge University Press*, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. https://doi.org/10.1017/9781009157896

2. Harrison, J., (2024): http://visionlearning.com/en/library Earth Science/Earth Cycles/The Carbon Cycle.

3. Roth, E. (2019): Probleme beim Klimaproblem – Ein Mythos zerbricht. *BoD-Verlag Norderstedt* 2019, ISBN 978-3-7481-8275-7, E-Book 978-3-7494-0328-8.

4. Roth, E. (2020): Abgesagt! Dem Klimanotstand bricht die Basis weg. *BoD-Verlag Norderstedt* 2020, ISBN 978-3-7526-4764-8, E-Book 978-3-7526-55308-8.

5. Roth, E. (2022): Das große Klimarätsel: Woher kommt das viele CO_2? *BoD-Verlag Norderstedt* 2022, ISBN 978-3-7562-2033-5, E-Book 978-3-7562-5347-0.

6. Roth, E. (2023): Climate: Man or Nature? A Contribution to the Discussion. *Science of Climate Change*, Vol. 3.5 (2023), pp. 521-542, https://doi.org/10.53234/scc202310/40

7. IPCC (2007): AR4, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. *Cambridge University Press*, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

8. IPCC (2013): AR5, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, [Stocker, TF, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. *Cambridge University Press*, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

9. IPCC (2018): SR1.5, Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. *Cambridge University Press*, Cambridge, UK and New York, NY, USA, 616 pp. https://doi.org/10.1017/9781009157940

10. Beemt, F. (2019): https://www.sciencetalks.nl/the-physics-of-doubling-co2-full-version

11. Curry. J. (2023): Climate Uncertainty and Risk – Rethinking Our Response. *Anthem Press*, 2023, 290 p; ISBN 9781839989254

12. Koutsoyiannis, D., Onof, C., Kundzewicz, Z.W., Christofides, A. (2023): On Hens, Eggs, Temperatures and CO_2: Causal Links in Earth's Atmosphere. *Sci* 2023, 5, 35. https://doi.org/10.3390/sci5030035

13. Lewis, N. (2023): Objectively combining climate sensitivity evidence. *Climate Dynamics* 60, 3139–3165 (2023). https://doi.org/10.1007/s00382-022-06468-x

14. McKitrick, R., Christy, J. (2020): Pervasive Warming Bias in CMIP6 Tropospheric Layers. *Earth and Space Science*, Vol. 7, Issue 9, Sept. 2020, e2020EA001281. https://doi.org/10.1029/2020EA001281

15. Scafetta, N. (2022): CMIP6 GCM ensemble members versus global surface temperatures. *Climate Dynamics* 60, 3091–3120 (2023). https://doi.org/10.1007/s00382-022-06493-w

16. Scafetta, N. (2024): Impacts and risks of “realistic” global warming projections for the 21st century. *Geoscience Frontiers* Vol. 15, Issue 2, March 2024, 101774. https://doi.org/10.1016/j.gsf.2023.101774

17. Spencer, R. (2024): Global Warming: Observations vs. Climate Models. *The Heritage Foundation*, Backgrounder No. 3809, Jan. 24, 2024, https://report.heritage.org/bg3809

18. Spencer, R., Christy, J.R. (2024): Effective climate sensitivity distributions from a 1D model of global ocean and land temperature trends, 1970–2021. *Theoretical and Applied Climatology* **155**, 299–308 (2024). https://doi.org/10.1007/s00704-023-04634-7

19. Vahrenholt, F., Lüning S. (2020): Unerwünschte Wahrheiten, was Sie über den Klimawandel wissen sollten, 2. Auflage. *Langen Müller Verlag GmbH*, München 2020, ISBN 978-3-7844-3553-4.

20. Berry, E. X: (2019): Human CO$_2$-Emissions Have Little Effect on Atmospheric CO$_2$”, *International Journal of Atmospheric and Oceanic Sciences,* Vol. 3, No. 1, 2019, pp. 13-26; doi: 10.11648/j.ijaos.20190301.13.

21. Harde, H. (2017): Scrutinizing the carbon cycle and CO$_2$ residence time in the atmosphere. *Global and Planetary Change* 152, 19–26. https://doi.org/10.1016/j.gloplacha.2017.02.009

22. Harde, H. (2019): What Humans Contribute to Atmospheric CO$_2$: Comparison of Carbon Cycle Models with Observations, *Earth Sciences*, Vol. 8, No. 3, 2019, pp. 139-159. doi: 10.11648/j.earth.20190803.13.

23. Harde, H. & Salby, M. (2021): What Controls the Atmospheric CO$_2$-Level?, *Science of Climate Change*, Vol. 1, No. 1, August 30, 2021, pp. 54-69, DOI: 10.53234/scc202106/22

24. Salby, M. (2018): What is Really Behind the Increase of Atmospheric CO$_2$?, *Lecture at Helmut Schmidt Universität, Hamburg,* 10.10.2018. https://youtu.be/b1cGqL9y548?feature=shared

25. Chen, X., Chen, T., He, B., Liu, S., Zhou, S., Shi, T. (2024): The global greening continues despite increased drought stress since 2000. *Global Ecology and Conservation*, Volume 49, 2024, https://doi.org/10.1016/j.gecco.2023.e02791, https://www.sciencedirect.com/science/article/pii/S2351989423004262

26. Scinexx (2016): Unser blauer Planet wird grüner – Steigender Kohlendioxidgehalt der Luft fördert das Pflanzenwachstum. https://www.scinexx.de/news/geowissen/unser-blauer-planet-wird-gruener/

27. Zhu, Z., Piao, S., Myneni, R. et al. (2016): Greening of the Earth and its drivers. *Nature Climate Change* 6, 791–795 (2016). https://doi.org/10.1038/nclimate3004

28. Koutsoyiannis, D.: Stochastic assessment of temperature–CO$_2$ causal relationship in climate from the Phanerozoic through modern times[J]. *Mathematical Biosciences and Engineering*, 2024, 21(7): 6560-6602. doi: 10.3934/mbe.2024287

29. Hokanomono, (2015): *Wikimedia Commons* 2009-08-09: https://commons.wikimedia.org/wiki/File:Radiocarbon_bomb_spike.svg

30. Halperin, A., (2015): Atmospheric CO2 Change: Simple Equation of Multi-Decadal Atmospheric Carbon Concentration Change. *Science Defies Politics*, defyccc.com/docs/se/MDACC-Halperin.pdf

31. Spencer, R. (2019): A Simple Model of the Atmospheric CO$_2$ Budget. http://www.drroyspencer.com/2019/04/a-simple-model-of-the-atmospheric-co2-budget

32. Dietze, P. (2021): Der “Restbudget”-Unsinn, https://www.fachinfo.eu/dietze2021.pdf

33. Ganteför, G. (2024): Das KLIMAPROBLEM und seine LÖSUNG in 20 MINUTEN, *YouTube Kanal Grenzen des Wissens*, https://www.youtube.com/ganteförklima

34. UNFCCC (2002): Parameters for tuning a simple carbon cycle model, *United Nations Framework Convention on Climate Change*, https://unfccc.int/response/brazil/carbon.html

35. Egleston, E. S., Sabine, C. L., & Morel, F. M. M. (2010). Revelle Revisited: Buffer Factors that Quantify the Response of Ocean Chemistry to Changes in DIC and Alkalinity. *Global Biogeochemical Cycles*, 24, GB1002. https://doi.org/10.1029/2008GB003407

36. Ollila, A. (2016): Timescales of Anthropogenic and Total Carbon Dioxide (CO_2) in the Atmosphere. *Physical Science International Journal* 11(3), 1-19, 2016, Article no. PSIJ.27004, https://doi.org/10.9734/PSIJ/2016/27004