Essay

On the Residence Time of CO_2 in the Atmosphere and the Carbon Mass Balance

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Abstract

The impression is gained that there is still no conclusive physical description of the global behavior of CO_2 absorption/emission in the various reservoirs. There is a growing group that is convinced, the residence time of CO_2 in the atmosphere is approximately 4 years. Another group assumes a significantly longer residence time of 30 years or more. Finding a common consensus between both sides appears difficult.

An attempt is made here to provide an approach. It can be viewed as a complement to other articles recently published in Science of Climate Change. We assume that there is a regular exchange of CO_2 between the reservoirs, both in terms of absorption and emission. Without anthropogenic emissions, absorption and emission balance each other.

The approach assumes an equilibrium of CO_2 concentrations between the various reservoirs. Any additional amount of CO_2 introduced into the system is distributed in a constant ratio among the reservoirs.

Keywords: e-time τ; global carbon cycle; absorption S_{LAND} and $S_{OCEAN.}$; CO_2-equilibrium and equivalence principle, communication tubes

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1. Introduction

Most scientists represented by the IPCC believe that the CO_2 increase from 280 ppmv to 420 ppmv is solely anthropogenic, justifying this with a residence time according to the Bern Model.

However, in recent years, a growing number of scientists (Roth [1], Berry [2], Schrijver [3]) have cast doubt on this view, especially since the Bern Model contradicts the Equivalence Principle [12] and has no physical basis. The IPCC's previous predictions have never come true.

Prof. Feynman once taught: If the prediction is wrong, the assumption is necessarily wrong. The assumption that 50% of anthropogenic emissions remain in the atmosphere must therefore also be questioned.

This statement addresses two points.

1. The evidence provided by Mueller [5] that the absorption of the oceans and land areas relative to the CO_2 concentration has been constant for 270 years, has several implications. Firstly, according to the Equivalence Principle [12], anthropogenically produced CO_2 has the same residence time as natural CO_2. Secondly, the result can be determined as a state of equilibrium between the Earth's reservoirs.
2. Due to this state of equilibrium between the atmosphere, the ocean, and biomass, the assumption that a stable atmospheric CO_2 concentration can be maintained if anthropogenic CO_2 emissions are halved is untenable. Any additional amount of CO_2 introduced into the system is distributed in a constant ratio among the reservoirs.

In this article, I base my analysis on the statistical analysis of the constancy of ocean absorption and land biomass according to Müller [5]. This demonstrates the equilibrium state in the Earth's CO_2 system. On the other hand, since CO_2 concentrations have increased by 50% since 1850, but the equilibrium has been maintained, it must be possible to draw conclusions from this.

2. On the Absorption of Reservoirs

The absorption of CO_2 in the ocean and in biomass is constant relative to the respective CO_2 concentration in the atmosphere. This demonstrates the validity of Henry's Law for the ocean and the linearity of plant growth with atmospheric CO_2 concentrations up to 450 ppmv (Hamburg Education Server [6]) (see Fig. 2).

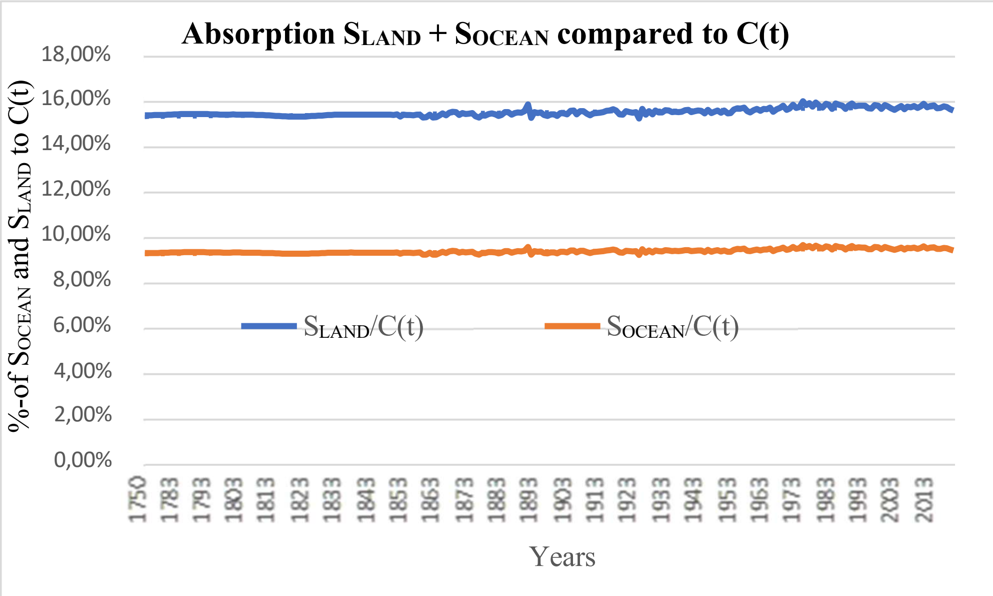

Fig. 1: The relative total absorption on ocean and on land stays constant over 270 years [5].

According to the IPCC AR6 [7] Chapter 5 Fig. 5.12, at the beginning of industrialization, the CO_2 concentration was 278 ppmv or 591 GtC. IPCC says, the e-time (equal to residence time) is about 4 years, corresponding to a total annual emission of approximately 165.9 GtC/a. Today, we have 50% more CO_2, which is 420 ppmv or 890 GtC. In IPCC AR5, WG1 Chapter 6, p. 472, Box 6.1 the residence time for the anthropogenic component is within several decades and a few thousands of years. Many scientific theories propose an e-time of 30 years.

This means, however, if the 591 GtC in 1750 have a residence time of less than 4 years in the atmosphere (165.9 GtC/a according to the IPCC [7]), the anthropogenic 298 GtC (889 GtC – 591 GtC) remain with a residence time of 30 years, i.e., an annual absorption of 11 GtC/a. We should therefore have a total annual absorption of 165,9 GtC/a from the old stock and 11 GtC/a from the anthropogenic 289 GtC, a total of 176,9 GtC/a plus new emissions. (According to the IPCC, the emission in 2020 is approximately 216.2 GtC. With this value, the residence time would have to be approximately 4 years.)

This contradicts the proportionality of Henry's Law and the measured higher biomass, which is also approximately proportional to CO_2 concentration. Despite a 50% higher partial pressure, absorption would be almost constant (from 165,9 GtC to 176,9 GtC) over 30 years with residence time $\tau = 30$ years. The assertion that the anthropogenic CO_2 content remains in the atmosphere longer than the natural CO_2 content thus rejects Henry's Law, as well as the linearity of CO_2 absorption by plants in relation to CO_2 partial pressure. However, both phenomena are scientifically recognized.

With a 50% higher partial pressure, according to Henry's Law, the oceans would have to emit and absorb 50% more. The oceans account for approximately 32% of global emissions. In 1750, the oceans (S_{OCEAN}) absorbed approximately 54.8 GtC/a, and the biomass/land (S_{LAND}) absorbed 111.1 GtC/a. (see IPCC Chapter 5 Figure 5.12 [7]). For reasons of proportionality, an additional CO_2 exchange of approximately 27.4 GtC/a would have to occur from the oceans (the IPCC is correct here), resulting in a total CO_2 exchange of the ocean of approximately 82.2 GtC/a.

Table:1 Absorption by S_{OCEAN} and S_{LAND} according to the principle of proportionality.

Absorption (GtC)	1750	2020
S_{OCEAN}	54,8	82,2
S_{LAND}	111,1	166,6
Total	165,9	248,8

Due to the higher biomass according to NASA and Tiexi [8] of at least 44% by 2016, an additional S_{LAND} emission of 48.8 GtC/a would have to occur. For 2020, we also assume 50% for proportionality reasons, which would then be 55.5 GtC (although the IPCC only reports 29 GtC) – together with the current figure, this would amount to 166.6 GtC/a. Therefore, S_{LAND} + S_{OCEAN} is 166.6 GtC/a + 82.2 GtC/a = 248.8 GtC/a.

If these assumptions are incorrect, the following is true: Since the biomass has clearly increased significantly according to several scientific reports, the only option is a correction of Henry's Law – or the residence time is not constant. In this case, the measurement data from the Global Carbon Budget must be questioned. For example, if biomass did not increase by 50% but only by 35% with a 50% increase in CO_2, then in Fig. 1 S_{LAND} would have to decrease by 1.5% to about 14% - which is obviously not the case.

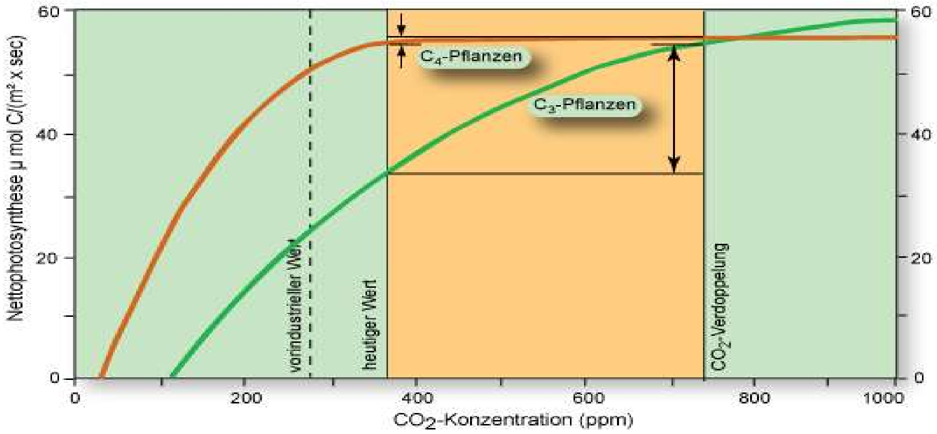

Fig. 2 the increase of C3-plants for 280 ppmv to 400 ppmv is up to 35% C4-Plants up to 55%, proofed by Taylor et al.[9].

This results in an average residence time, including the 298 GtC from anthropogenic emissions, of less than four years. A residence time of anthropogenic emissions of 30 years or more is therefore invalid.

Let's examine the sources of anthropogenic emissions in more detail. If the anthropogenic share is defined as E_{FF}(10 GtC) + E_{LUC}(3 GtC) + E_{BMV}(14 GtC), then this requires an additional annual emission of 27 GtC/a for 2020, or a total of 248.8 GtC/a + 27 GtC/a = 275.8 GtC/a. Fossil emissions therefore account for 4% of total emissions, while total anthropogenic emissions amount to 10.8% of total emissions.

Definition and Datasource – Skrable [4], Global Carbon Budget, 2021[10]:

E_{FF}: Human Carbon is from burning carbon fuels and producing cement
E_{LUC}: Land Carbon is from human-caused land-use-change
E_{BMV}: Burned Biomass caused by human activity
E_{OT}: Emission by ocean temperature increase

As explained in Müller [5], the absorption rate relative to the partial pressure has remained constant for 270 years in both the ocean and the land. We therefore have a constant equilibrium between ocean, land, and atmosphere, similar to communicating tubes. Of the 27 GtC/a emissions, 4.4 GtC/a remain in the atmosphere, 7.3 GtC/a enter the ocean, and 15.3 GtC enters the biomass/land. However, according to the Mauna Loa database, an average of 5.2 GtC remained in the atmosphere annually between 2010 and 2020.

The claim that the airborne fraction of approximately 50% of anthropogenic emissions remain in the atmosphere is misleading. Compared to the natural equilibrium, in addition to purely fossil emissions E_{FF}, there are additional emissions (E_{LUC} + E_{BMV}). Strictly speaking, this also includes E_{OT}, the additional outgassing of CO_2 from the ocean due to its warming according to Henry's Law (approximately 5 GtC in 2020). With the same ratio, the theoretically remaining portion in the atmosphere agrees with the measured values from Mauna Loa.

3. The Net-Zero Thesis

If – as preferred in public debate – E_{OT}, E_{LUC}, and E_{BMV} are attributed to natural CO_2 sources (as is the 1 GtC produced by the respiration of 8 billion people), and only fossil emissions are considered as an increase in CO_2 concentration, one could argue:

The annual increase in atmospheric CO_2 concentration (assuming fossil emissions of 10 GtC/a) in recent years has been 2.44 ppmv, or 5.2 GtC/a. It is claimed that keeping the current carbon concentration constant would be possible, if we reduced fossil emissions from 10 GtC/a by 5.2 GtC/a. Total anthropogenic emissions should therefore remain at 4.8 GtC/a. The current CO_2 concentration in the atmosphere would then remain constant, with the excess being absorbed by the ocean and the biosphere.

This means that there is no equilibrium between all three reservoirs. This, however, contradicts the equilibrium principle between the three reservoirs described above, as well as Henry's Law and the linearity principle of biomass growth. The equilibrium principle implies that a portion of each additional emission remains in the atmosphere.

Summary:

The following statement is false:

With an annual additional anthropogenic emission of 10 GtC, 5.2 GtC/a remains in the atmosphere, 3.3 GtC is absorbed on land, and 1.5 GtC in the ocean.

The correct statement would be: the total non-natural emissions from the disturbed equilibrium are the above 27 GtC + 5 GtC from E_{OT}. So 32 GtC. Of this, 5.2 GtC remains in the atmosphere, 18.2 GtC on land, and 8.6 GtC in the ocean.

The constant ratio of the distribution is thus 16.25% : 56.87% : 26.88%.

The soil's CO_2 budget has not yet been taken into account. As of 2020, it contains 1500 $GtCO_2$ (410 GtC).

4. Carbon Balance Compared with Data from the IPCC and Global Carbon Budget

If we combine Tayler's study[9] for a 30% increase in biomass from 1850 to 2000 with Tiexi's [8] new study of a 14% increase between 2000 and 2016, we have a biomass increase of at least 44%. (1% per year). For 2020 – here the data apply to the ocean, and C(2020) = 420 – we propose a 50% increase with a linear absorption in the ocean and land.

With the following assumptions, according to the IPCC:

In 1750: The atmosphere had 591 GtC. For respiration, see Table 1. Biomass was 520 GtC (IPCC indicates between 450 GtC and 650 GtC), and the residence time is less than 4 years. The surface ocean had 900 GtC in 1750.

In 2020: The atmosphere had 889 GtC. The land biosphere probably has 780 GtC today (+50%). Since absorption remained constant at S_{LAND} (see Figure 1), it follows that land biomass must have increased by 50%, i.e., by 260 GtC.

According to the author's theory, the surface ocean has absorbed 50% more, or 450 GtC, of which a portion has entered the deep sea. A calculation based on the respective Revelle factor (Müller [5]) gives approximately 110 GtC (24%). This leaves 1250 GtC in the surface ocean. The total increase in all four reservoirs by 2020 was 298 GtC + 260 GtC + 340 GtC + 110 GtC = 1008 GtC.

However, only 463 GtC were emitted anthropogenically from fossil fuels by 2019. This is 45% of the carbon balance.

Table 2: C-Budget

Absorption GtC	C-Budget 1750	*Sur Plus* 2020
S_{Ocean}	900	340
S_{Land}	520	260
S_{Air}	591	298
$S_{Deep\ Sea}$	37100	110
Total	39111	1008

The IPCC and Global Carbon Budget provide different figures:

IPCC:
Atmosphere +279 GtC, Biosphere +239 GtC, and Deep Sea +173 GtC equals 691 GtC.
No data is available on absorption in the ocean.

Global Carbon Budget:
The Global Carbon Budget reports total emissions from E_{FF} and E_{LUC} as 463 GtC + 195 GtC = 658 GtC. This results in a deficit of 350 GtC to 545 GtC.

5. Summary

Both the total CO_2 emissions reported by the IPCC for 2020, as well as the biomass increase and increased CO_2 absorption by the oceans, rule out a residence time of anthropogenic CO_2 of more than four years.

The principle of equilibrium between reservoirs does not allow for the net-zero thesis. Any additional CO_2 inputs are distributed among the reservoirs in a fixed ratio.

The question also arises as to why, according to the Global Carbon Budget 2023, the ocean has absorbed so little CO_2, which contradicts Henry's Law.

Furthermore, the above considerations raise the question, where 500 GtC come from. This does not take into account the change of CO_2 stored in the upper soil layer. E_{BMV} and E_{OT} could explain a part of it.

We therefore know that the IPCC's assumptions and fundamentals are wrong. But we also know that many unanswered questions remain.

The share of biomass in atmospheric CO_2 in 1850 was approximately 66%, or 182 ppmv. A 50% increase would add up to an additional 90 ppmv. A 1°C warming of the ocean as well as soil respiration could explain the shortfall to 140 ppmv. The discussion about CO_2 would then be irrelevant.

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