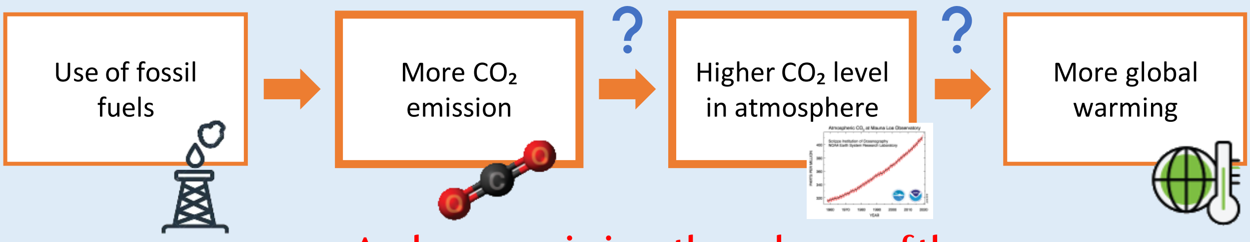
Why is the CO_2 level in the atmosphere rising?

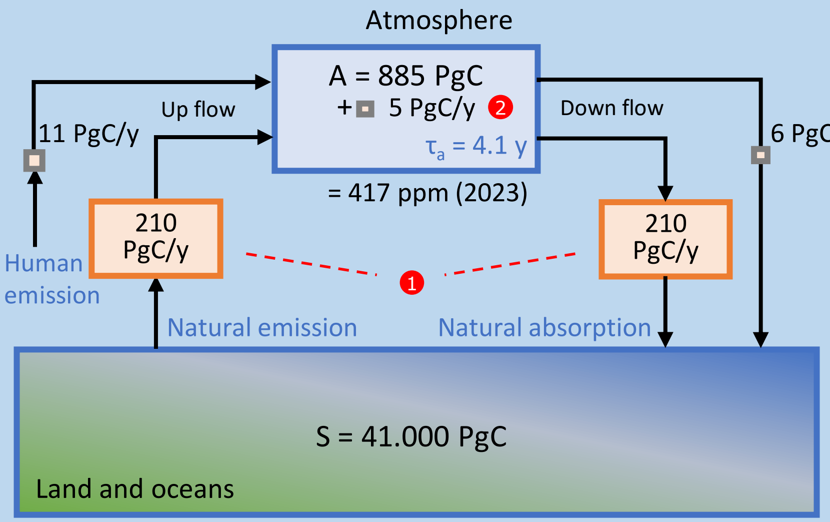
15 min read

This is what most people believe



Are human emissions the real cause of the increasing CO_2 concentration in the atmosphere?

Assumptions to blame human CO_2



Source: Global Carbon Budget 2023

Global Carbon Budget

1. The **natural flows are in perfect balance** and can't be the cause of the CO_2 rise. The Residence Time of CO_2 is around **4.1 years** (i.e. the average time CO_2 remains in atmosphere).
2. Almost half of the **human CO_2 accumulates in the atmosphere** and is the sole cause of the yearly CO_2 rise. It remains almost indefinitely in the atmosphere (>100,000 instead of 4.1 years). Source: IPCC-AR5

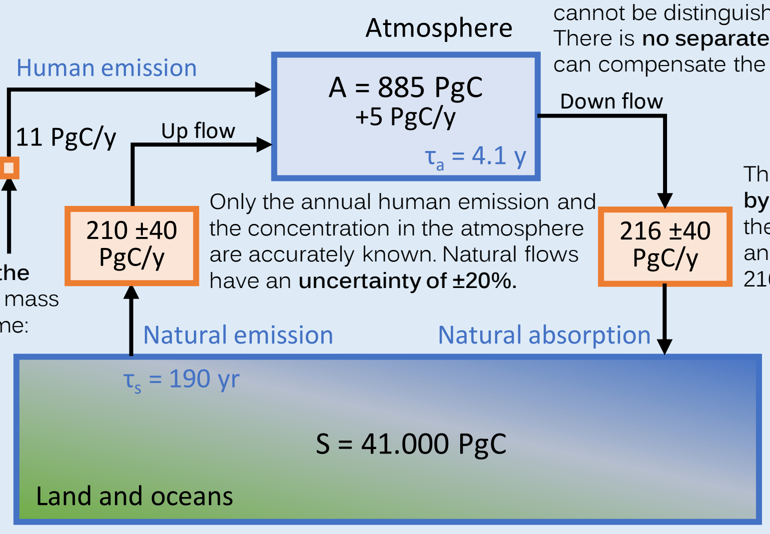
Ice core data

3. The **ice core data** from Antarctica suggest that the CO_2 levels in the past 800,000 years were **much lower** (<300 ppmv) than the present level

1 ppm = 1 part per million
1 ppm = 2.12 PgC = 2.12 Petagram Carbon
1 Petagram = 1 Gigaton = 1 billion tons

The Global Carbon Budget: this is what we know

In the well-mixed atmosphere human CO_2 cannot be distinguished from natural CO_2. There is **no separate natural down flow** that can compensate the natural up flow.



The down flow is **not defined by the natural emission**, but by the mass in the atmosphere and its residence time: 216 = 885 / 4.1.

The up flow is **not defined by the natural absorption**, but by the mass in the sink and its residence time: 210 = 41,000 / 190.

The carbon mass in the sink (land/oceans) is around **50 times larger** than in the atmosphere.

The assumptions to blame human CO_2 are incorrect

1 Are natural flows in perfect balance?

- In the land and ocean sinks most of the **CO_2 is transformed** into other carbon compounds, such as carbohydrates, (bi)carbonates, calcium carbonates, etc.
- The physical, chemical and biological processes that define the amount of carbon that is stored or released to/from these sinks, are **complex** and **chaotic**.
- The carbon sinks are **very large** compared to the atmosphere.
- A small **imbalance**, even for many years, is quite possible and would have no noticeable impact on the sub-surface reservoirs.
- Due to their **great uncertainty**, we do not know whether the up and down flows are equal.

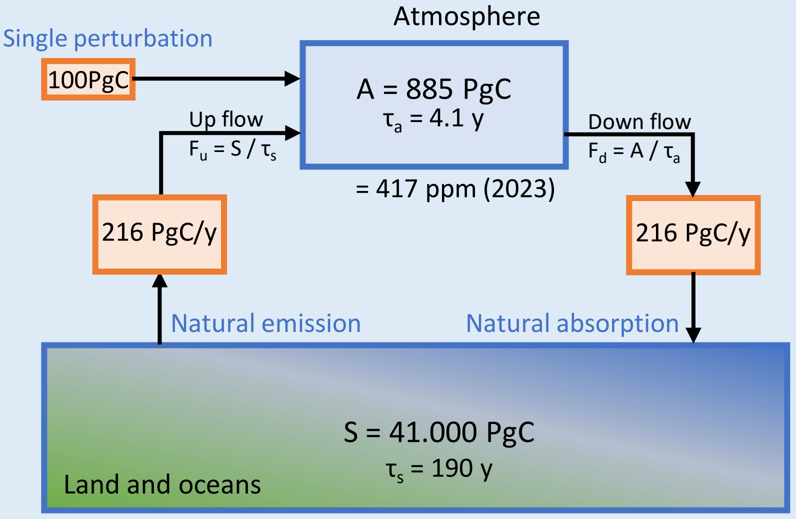
➜ We cannot conclude that natural up and down flow are in balance

2 Does human CO_2 accumulate in the atmosphere, due to a much longer residence time?

- The surface layer of the oceans and other waters is **not saturated** with CO_2. Due to Henry's Law a higher concentration than normal will therefore lead to more absorption into the oceans.
- The removal of carbon from the surface layer into the deeper layers is **not restricted**.
  - Due to the higher CO_2 concentration, the biological pump (storing of carbon) has increased significantly (Steele, 2017).
  - The **upwelling and downwelling** of carbon to and from the deeper ocean is around 270 PgC/y, so ~100 times more than the net air-sea flows, maintaining the waters undersaturated (Levy, 2013).

➜ **The oceans and other waters can easily absorb the relatively small surplus of CO_2, which makes a large residence time nonsensical.**

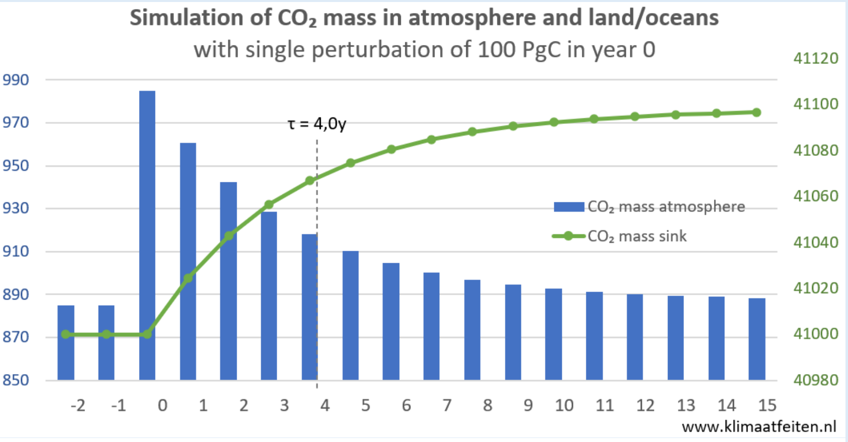
What happens in the event of a perturbation?



Simulation with single perturbation

- Imagin up and down flow are in balance.
- At one moment in time 100 PgC is added to the atmosphere.
- The mass in the atmosphere increases to 985 PgC.
- The down flow is proportional to the mass, so will increase to 240 PgC/yr (= 985 / 4.1).
- This reduces the mass in the atmosphere and increases the mass in the sink.
- A year-by-year calculation is given in the Excel-table.
- The mass in the atmosphere decreases to almost the old level (2% remains after 10 years), blue bars in the chart.
- Most of the added CO_2 (98%) ends up in the sink, green line.
- The adjustment time (= time to re-equilibrate) is 4.0 years, slightly smaller than the residence time.

year	Pert.	A	S	Fu	Fd	Fd-Fu
-2		885	41000	216,0	216,0	0,00
-1		885	41000	216,0	216,0	0,00
0	100	**985**	41000	216,0	**240,4**	24,40
1		961	41024	216,1	234,4	18,32
2		942	41043	216,2	229,9	13,75
3		929	41056	216,3	226,6	10,32
4		918	41067	216,3	224,1	7,75
5		910	41075	216,4	222,2	5,82
6		905	41080	216,4	220,8	4,37
7		900	41085	216,4	219,7	3,28
8		897	41088	216,4	218,9	2,46
9		895	41090	216,4	218,3	1,85
10		893	41092	216,4	217,8	1,39
11		891	41094	216,5	217,5	1,04
12		890	41095	216,5	217,2	0,78
13		889	41096	216,5	217,0	0,59
14		889	41096	216,5	216,9	0,44
15		888	41097	216,5	216,8	0,33



Ultimately 98% of the added CO_2 ends up in the sink, only 2% in the atmosphere

Human CO_2 does not accumulate in the atmosphere

The time to re-equilibrate from a perturbation is shorter than the residence time

- Stallinga (2023) shows that the adjustment time is **always shorter** than the residence times.
- The extra CO_2 is distributed to atmosphere and sink in the **ratio based on the size** of the reservoirs. In this case: land/ocean absorbs around **50 times more** than the atmosphere.

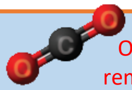
Only a small percentage of human CO_2 remains in the atmosphere

- Since 1750 humans have emitted around 700 PgC (incl. land use change). From up to 10 years ago, only 2% of all that is still in the atmosphere. From the last 10 years a larger part is in the atmosphere.
    - If we stabilize human emission at current level, around **7%** of the CO_2 in the atmosphere is **human caused**.
    - If we would stop emitting today (net-zero), the human contribution will quickly go down to **less than 2%**.

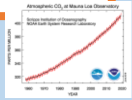
Source: Stallinga 2023 + excel calculations

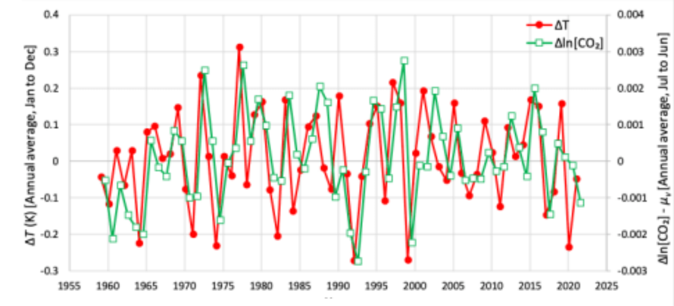
Temperature is a far more likely cause for the rising CO_2

Use of fossil fuels → More CO_2 emission ✗→ Higher CO_2 level in atmosphere ✓← More global warming



Only a small percentage remains in the atmosphere (2% after 10 years)





Changes in T are always *followed by* changes in CO_2.

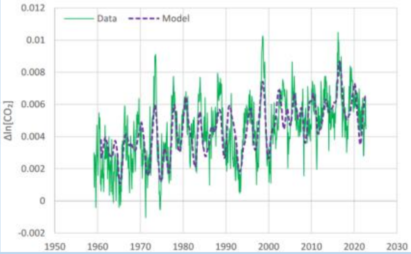
Source: Koutsoyiannis 2023

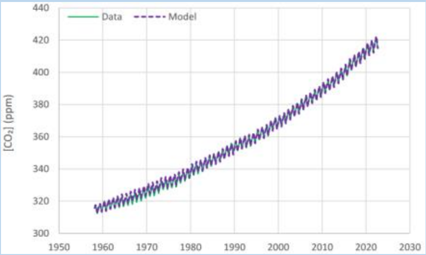
Temperature change is a likely cause for CO_2 change

- There is a significant **correlation** between changes in T and CO_2, where CO_2 lags T.
- Koutsoyiannis (2023) investigated the **causal relationship** based on accurately measured data: *"Changes in CO_2 concentration cannot be a cause of temperature changes. On the contrary, temperature change is a potential cause of CO_2 change on all time scales."*.
- Temperature is important factor in **Henry's Law**. So, for the oceans and other waters:
  Higher temperature ➜ less solubility in water ➜ more emission / less absorption.
- Soil respiration is **exponentially related to temperature** (Lee 2011). The temperature induced increase is >25% in the past 50 years (Zhang 2016).

Based on linear regression, CO_2 rise can be fully explained by temperature variations

Change in CO_2 modelled with temperature data (R^2 = 55%)



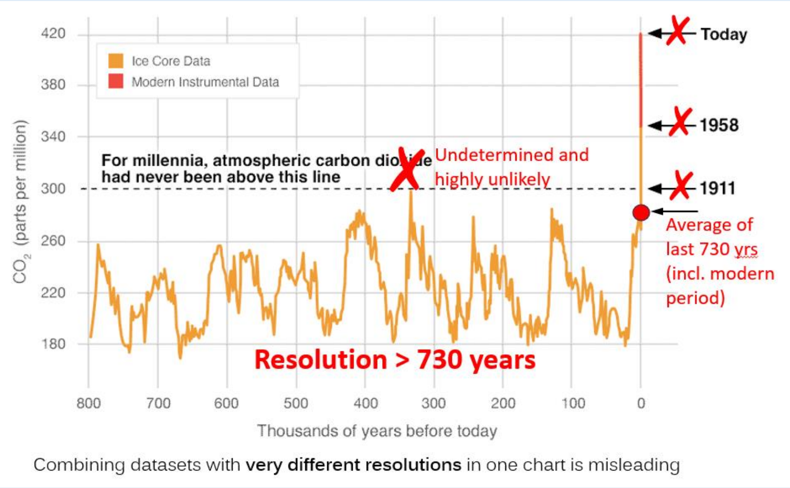


CO_2 concentration modelled with temperature data (R^2 = 99.9%)

Source: Koutsoyiannis 2023

❸ Ice core data do not refute a natural cause for the CO_2 rise

- Most of the **CO_2 dissolves in the water and ice** in the many years before the air bubbles in the ice are fully closed. So, the absolute value of the measured concentration is a fraction of the original value.(Jaworowski 1992).
- Ice core reconstructions over the past 800,000 years give a very **flattened representation**. A single observation in an ice layer represents a period of on average 730 years, with peaks up to more than 5000 years. Short fluctuations (<5000 years), even with much higher concentrations, are therefore not visible.
- Other observations that show (much) **higher historical CO_2 values** and/or **more variation**, have largely been disregarded: direct scientific measurements in the period before 1959, CO_2 ice core reconstructions in Greenland, ice core measurements from before 1985, and CO_2 proxies from plant stomata.



Source original chart: Nasa 2023

Conclusions

Human CO_2 does not accumulate in the atmosphere

- We cannot conclude that the natural flows are in balance:
- As the ocean surface is not saturated with CO_2 and the removal of carbon from the surface layer into the deeper layers is not restricted, a long adjustment time for a relatively small surplus of CO_2 is nonsensical.
- The vast majority of human emitted CO_2 ends up in the oceans in a relatively short period of time (~10 years).

Temperature is a far more likely cause for the rising CO_2

- Higher temperature causes more emission from oceans and soil.
- CO_2 rise can be fully explained by the measured temperature variations .

Ice core data do not refute a natural cause for the CO_2 rise

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