Human carbon emissions cause only 25% of the CO_2 increase

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Abstract:

The natural carbon cycle specified by the United Nations Intergovernmental Panel on Climate Change (IPCC) has consequences. It supports a physics carbon cycle model that calculates a "true' human carbon cycle. This "true" human carbon cycle contradicts IPCC's human carbon cycle and contradicts IPCC's assumption that natural CO_2 stayed at its 1750 level while human CO_2 caused all the CO_2 increase. It shows human CO_2 has added only 33 ppm to the atmosphere as of 2020, which means natural CO_2 has added 100 ppm. It shows if human CO_2 emissions stopped at the end of 2020, the human-caused CO_2 increase would fall from 33 ppm to 16 ppm by 2040, and to 10 ppm by 2100, showing there is no climate emergency. It shows how increased surface temperature and deep ocean overturning can independently add 100 ppm of CO_2 to the atmosphere to explain the rise in natural CO_2. It shows carbon from net land use change flows rapidly to the deep ocean, leaving little carbon in the atmosphere. Finally, the D14C balance level has remained near zero even as the $14CO_2$ and $12CO_2$ levels changed, which shows the ocean is the primary source of the natural $12CO_2$ increase.

Keywords: carbon cycle, carbon cycle model, carbon dioxide, climate change, CO_2 increase

1. Introduction

This paper uses the following definitions:

- "Natural carbon" is carbon added to the atmosphere by natural actions.
- "Human carbon" is carbon added to the atmosphere by human actions.

Human carbon has two forms:

- "New human carbon" is human carbon from burning carbon fuels and producing cement.
- "Land human carbon" is human carbon from human-caused land-use changes.

New human carbon and land human carbon are fundamentally different. New human carbon adds carbon from the slow carbon cycle to the fast carbon cycle. Land human carbon moves carbon from the land to the atmosphere within the fast carbon cycle.

The level or concentration of atmospheric CO_2 is typically in units of ppmv (parts per million by volume in dry air). However, it is customary to omit the "v" and write ppm. To convert the level of CO_2 in ppmv into the mass of carbon in PgC (petagrams), multiply the ppm by 2.12. GtC (Gigatons of carbon) is numerically equivalent to PgC.

The Intergovernmental Panel on Climate Change [1] (IPCC, 2013) assumes the level of natural CO_2 in the atmosphere has remained at about 280 ppm before and after 1750. This assumption forces the conclusion that human carbon has caused all the increase in atmospheric CO_2 since 1750 or above 280 ppm.

IPCC [1] (pp. 467-468) uses reconstructed ice core data to justify its assumption,

> "During the last 7000 years prior to 1750, atmospheric CO_2 from ice cores shows only very slow changes (increase) from 260 ppm to 280 ppm, in contrast to the human-caused increase of CO_2 since pre-industrial times."

This paper uses a new carbon cycle model to calculate how carbon moves between the land, atmosphere, surface ocean, and deep ocean. Unrestricted by IPCC's assumption, this model uses the turnover times in IPCC's natural carbon cycle to calculate how human carbon changes the level of atmospheric CO_2.

Carbon cycle models define outflow as a function of level. The new carbon cycle model defines outflow to equal the level divided by turnover time. The IPCC uses this case.

IPCC [2] (p. 948) defines turnover time such that outflow is proportional to the first power of the level,

> "Turnover time (T) is the ratio of the mass M of a reservoir (e.g., a gaseous compound in the atmosphere) and the total rate of removal S from the reservoir: T = M / S. For each removal process,

separate turnover times can be defined."

"Carbon dioxide (CO_2) is an extreme example. Its turnover time is only about four years because of the rapid exchange between the atmosphere and the ocean and terrestrial biota."

The IPCC says the turnover time for atmospheric CO_2 is about four years, but this IPCC [1] (p. 469) claim requires the turnover time to be much larger than four years,

"The removal of human-emitted CO_2 from the atmosphere by natural processes will take a few hundred thousand years (high confidence). Depending on the RCP scenario considered, about 15 to 40% of emitted CO_2 will remain in the atmosphere longer than 1,000 years. This long time required by sinks to remove anthropogenic CO_2 makes climate change caused by elevated CO_2 irreversible on human time scale. {Box 6.1}"

IPCC's Box 6.1 bases all its conclusions on its assumption that the natural CO_2 level has remained at 280 ppm. This assumption requires human CO_2 to have caused all the CO2 increase, which in turn requires human CO_2 to have a long turnover time. However, human CO_2 and natural CO_2 must have the same turnover times because all 12C carbon atoms are identical.

IPCC data show that annual human CO_2 emissions into the atmosphere are about 5% of the annual natural CO_2 emissions. As a first approximation, human carbon in the atmosphere will be about 5% of the total carbon in the atmosphere.

IPCC's [1] (p. 467, Executive Summary) says,

"With a very high level of confidence, the increase in CO_2 emissions from fossil fuel burning and those arising from land use change are the dominant cause of the observed increase in atmospheric CO_2 concentration."

With the level of atmospheric CO_2 at about 415 ppm in 2020, IPCC's statement says the 5% human carbon inflow has added 135 ppm. or 33% of atmospheric CO_2.

2. Carbon data review

2.1 IPCC's carbon cycle data

IPCC [1] (p. 470) introduces IPCC's carbon cycles,

"Atmospheric CO_2 represents the main atmospheric phase of the global carbon cycle. The global carbon cycle can be viewed as a series of reservoirs of carbon in the Earth System, which are connected by exchange fluxes of carbon. Conceptually, one can distinguish two domains in the global carbon cycle."

> "The first is a fast domain with large exchange fluxes and relatively 'rapid' reservoir turnovers, which consists of carbon in the atmosphere, the ocean, surface ocean sediments and on land in vegetation, soils and freshwaters."
>
> "Reservoir turnover times, defined as reservoir mass of carbon divided by the exchange flux, range from a few years for the atmosphere to decades to millennia for the major carbon reservoirs of the land vegetation and soil and the various domains in the ocean."
>
> "A second, slow domain consists of the huge carbon stores in rocks and sediments which exchange carbon with the fast domain through volcanic emissions of CO_2, chemical weathering, erosion and sediment formation on the sea floor."

IPCC's reference to "turnover times" clarifies that the IPCC intends outflows to be directly proportional to the reservoir levels and that IPCC's data include biogeochemical processes for the carbon cycle.

Figure 1 shows IPCC's Figure 6.1 with its four major carbon reservoirs – land, atmosphere, surface ocean, and deep ocean – and its separation of the natural (in black) and human (in red) carbon cycles.

IPCC [1] (p. 470) says its Figure 6.1 applies to the fast domain,

> "A schematic of the global carbon cycle with focus on the fast domain is shown in Figure 6.1. The numbers represent the estimated current pool sizes in PgC and the magnitude of the different exchange fluxes in PgC/year averaged over the time-period 2000-2009."

IPCC [1] (p. 471) Figure 6.1 legend says it is a "simplified schematic of the global carbon cycle. Numbers represent reservoir mass in PgC and annual carbon exchange fluxes (in PgC per year)."

IPCC Figure 6.1 separates the natural carbon cycle (in black) from the human carbon cycle (in red),

> "Black numbers and arrows indicate reservoir mass and exchange fluxes estimated for the time prior to the Industrial Era, about 1750."
>
> "Red arrows and numbers indicate annual 'anthropogenic' fluxes averaged over the 2000-2009 time-period."

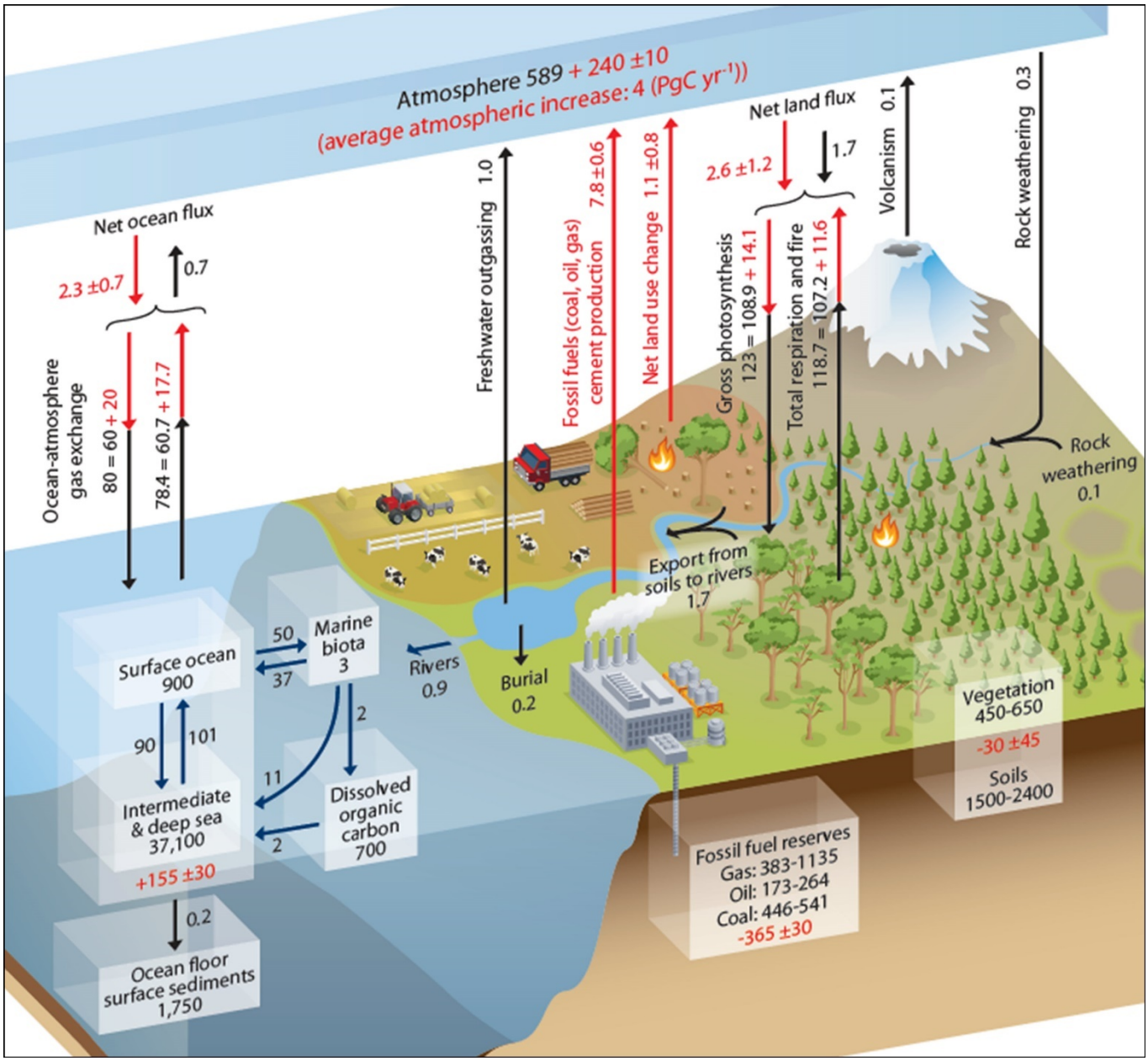

Figure 1. IPCC Figure 6.1 showing IPCC's data for its natural and human carbon cycles.

"Uncertainties are reported as 90% confidence intervals. Individual gross fluxes and their changes since the beginning of the Industrial Era have typical uncertainties of more than 20%, while their differences are determined from independent measurements with a much higher accuracy."

The Gilfillan et al. [3] data show new human carbon emissions is 7.8 PgC per year in about 2005 and the accumulated new human carbon emissions was 365 PgC in 2010, agreeing with Figure 1 data for the 2000-2009 time-period.

2.2 IPCC's natural carbon cycle

Figure 1 shows annual natural carbon emissions to the atmosphere are 107.2 PgC per year from the land and 60.7 PgC from the surface ocean for a total of 168 PgC per year.

IPCC's natural carbon cycle is at equilibrium. IPCC's Figure 1 data show the net natural flows between the reservoirs are near zero, but they must be at net zero to truly be at equilibrium.

Figure 2 shows IPCC's natural net flows set to zero (a 1% adjustment to IPCC's data) to keep the IPCC's reservoir levels constant. The boxes represent reservoirs, and the arrows represent flows between the reservoirs. The origins of the arrows are "nodes."

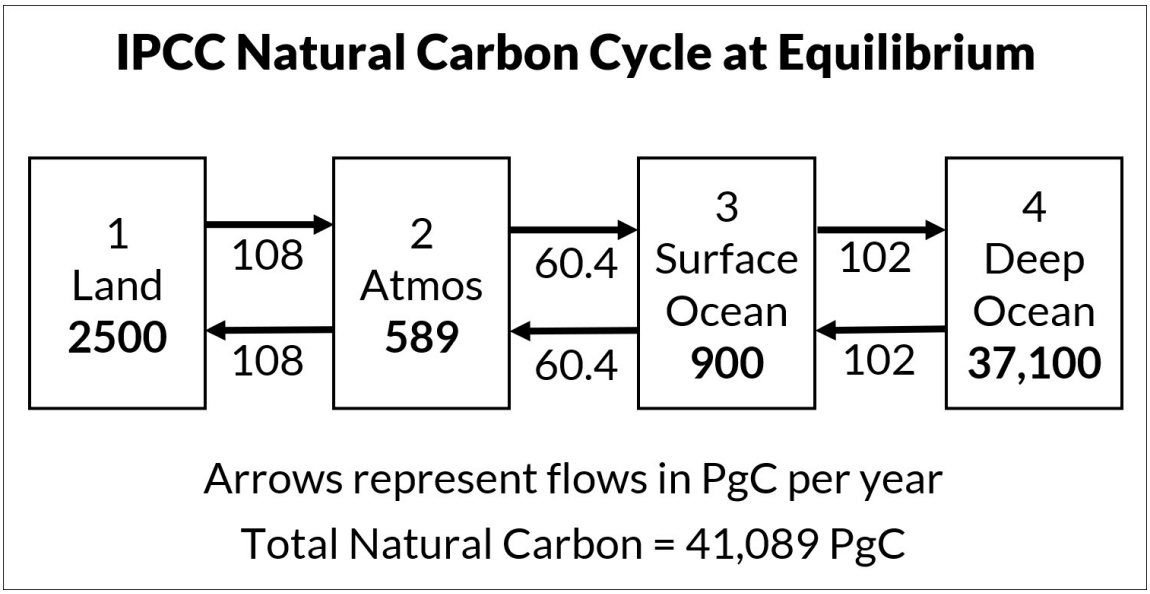

Figure 2. Levels and flows for IPCC's [1] natural carbon cycle shown in Figure 1. The boxes represent the reservoirs and arrows represent the flows between the reservoirs.

Figure 2 uses IPCC's assumption that the natural level remained constant at 589 PgC (278 ppm) after 1750. The Land 2500 PgC in Figure 2 is the total of averages of Vegetation (550 PgC) and Soils (1950 PgC) in Figure 1.

Figure 3 shows the percent of natural carbon in each reservoir from Figure 2. Only 1.43% of natural carbon is in the atmosphere and 90% is in the deep ocean.

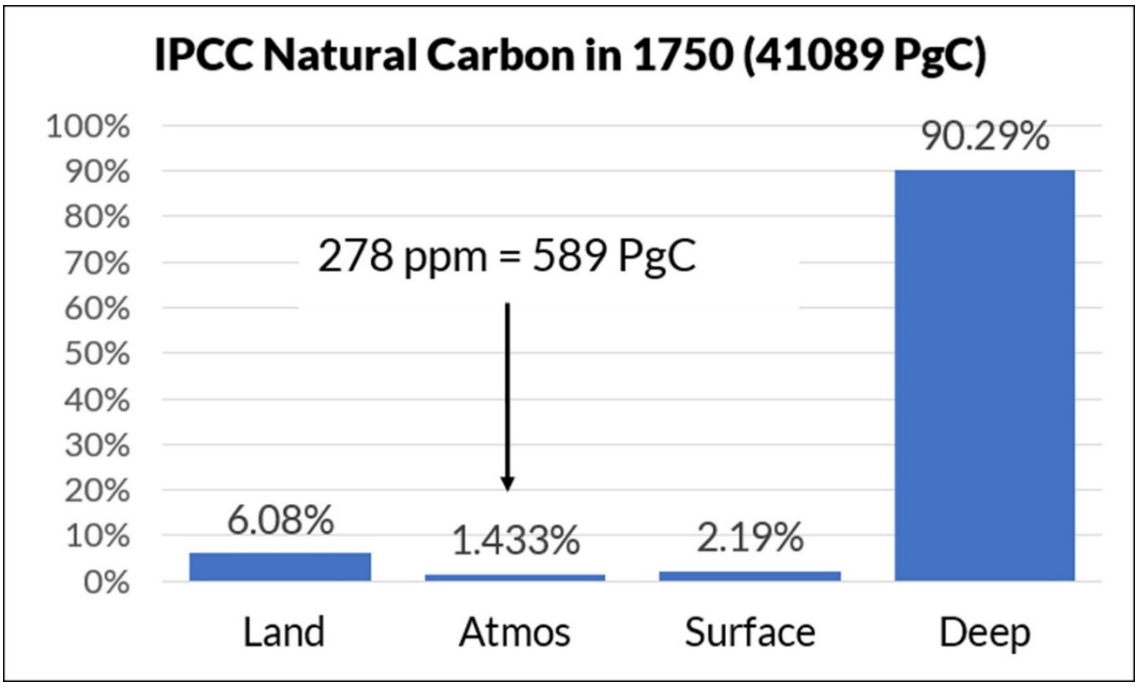

Figure 3. The percent of natural carbon in each reservoir for IPCC's natural carbon cycle in Figure 2.

The Figure 3 reservoir percentages are a fingerprint of the IPCC's natural carbon cycle at equilibrium. Since human carbon has the same turnover times as natural carbon, the human carbon cycle will have this same equilibrium fingerprint. If all human carbon emissions were to stop, the human carbon percentages would move toward the natural carbon percentages shown in Figure 3.

2.3 IPCC's human carbon cycle

Figure 1 shows annual new human carbon emissions in 2005 were 7.8 PgC per year and land human carbon emissions were 1.1 PgC per year for a total of 8.8 PgC per year which is 5% of the annual natural emissions of 168 PgC per year.

Figure 4 shows IPCC's human carbon cycle values in Figure 1 for the 2000-2009 time-period. Human carbon emissions added 365 PgC to the human carbon cycle as of 2010.

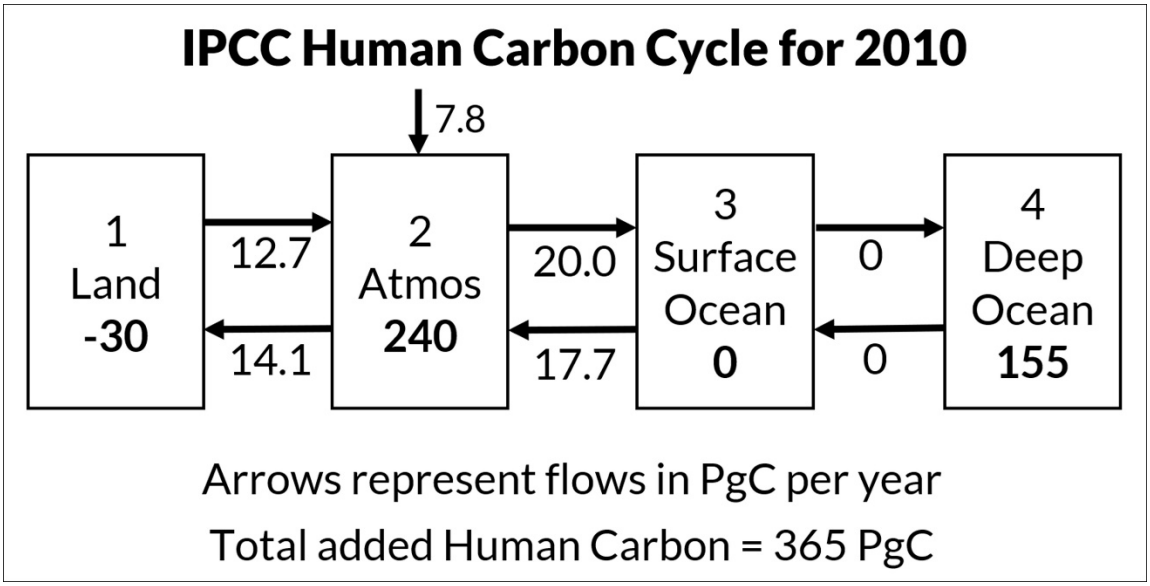

Figure 4. Levels and flows for IPCC's human carbon cycle shown in Figure 1. The boxes represent the reservoirs and arrows represent the flows between the reservoirs.

Figure 5 shows the percent of the 365 PgC of human carbon in each reservoir for IPCC's human carbon cycle shown in Figure 4. These percentages show 8% of 365 has moved from the land to the atmosphere to the deep ocean, 66% is in the atmosphere, and 42% is in the ocean.

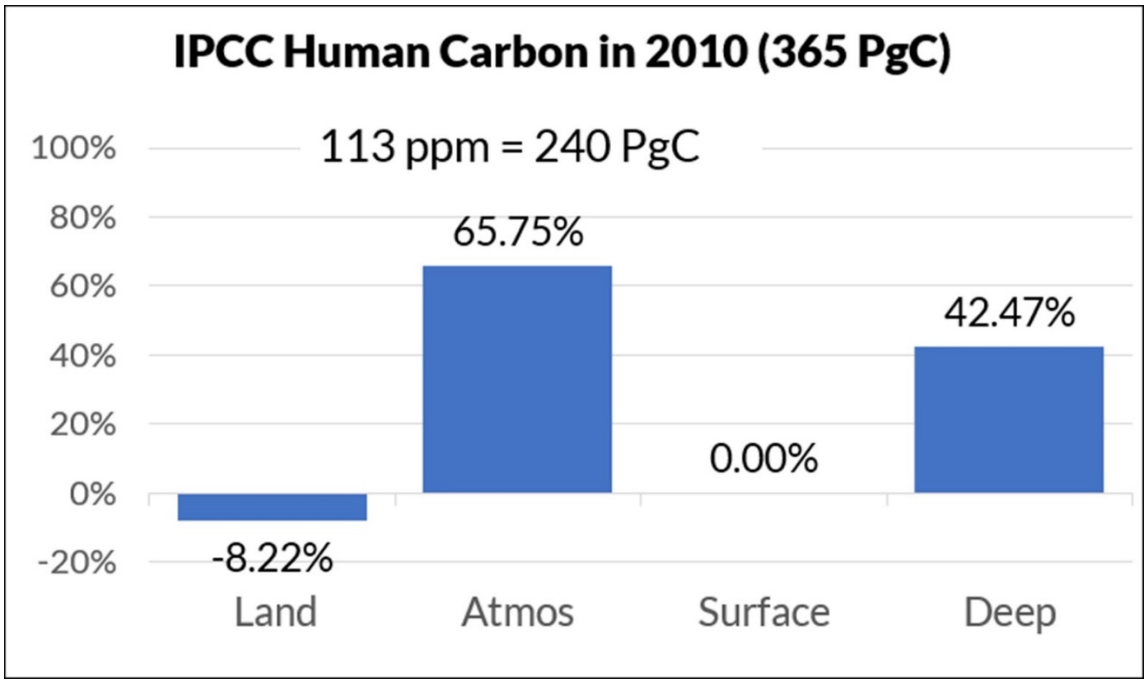

Figure 5. The percent of human carbon in each reservoir for IPCC's human carbon cycle in Figure 4.

Ignoring the 8% percent loss in the land carbon, which has large errors and could even be positive, the percentage in the atmosphere does not resemble IPCC's natural carbon cycle percentages in Figure 3. This difference suggests that IPCC's human carbon cycle uses different physics than IPCC's natural carbon cycle.

Rather than calculate a human carbon cycle, the IPCC simply assigned 240 PgC or 66% of the human carbon 365 PgC to the atmosphere based solely on its assumption that natural CO_2 remained at 280 ppm while human carbon caused all the increase in atmospheric CO_2. Then the IPCC assigned the remaining human carbon to the deep ocean.

IPCC's human carbon data in Figure 1 are from IPCC's Table 6.1 [1] (p. 486) "Global anthropogenic CO_2 budget" for the decade 2000 to 2009.

Table 1 shows IPCC's Table 6.1 with the Row 3 signs reversed to show positive flow from the atmosphere to the ocean. Positive flux numbers are in the direction of the flux title.

Table 1. IPCC's Table 6.1 "Global anthropogenic CO_2 budget, accumulated since the Industrial Revolution (onset in 1750) and averaged over the 1980s, 1990s, 2000s, as well as the last 10 years until 2011." The uncertainty range is for a 90% confidence interval.

IPCC [1] Table 6.1 (p 486). Row-3 signs reversed to show positive flow from atmosphere to surface ocean.	1750-2011 Cumulative PgC	1980-1989 PgC/Year	1990-1999 PgC/Year	2000-2009 PgC/Year	2002-2011 PgC/Year
Atmospheric increase	240 ± 10	3.4 ± 0.2	3.1 ± 0.2	4.0 ± 0.2	4.3 ± 0.2
Fossil fuel and cement production	365 ± 30	5.5 ± 0.4	6.4 ± 0.5	7.8 ± 0.6	8.3 ± 0.7
Atmosphere-to-ocean flux	155 ± 30	2.0 ± 0.7	2.2 ± 0.7	2.3 ± 0.7	2.4 ± 0.7
Land-to-Atmosphere flux	30 ± 45	-0.1 ± 0.8	-1.1 ± 0.9	-1.5 ± 0.9	-1.6 ± 1.0
Net land use change	180 ± 80	1.4 ± 0.8	1.5 ± 0.8	1.1 ± 0.8	0.9 ± 0.8
Residual land sink (inferred)	-150 ± 90	-1.5 ± 1.1	-2.6 ± 1.2	-2.6 ± 1.2	-2.5 ± 1.3

The IPCC calculates the "inferred" values of Residual land sink as follows:

> [Residual Land Sink] = [Fossil fuel and cement production] + [Net land-use change] – [Atmospheric increase] – [Atmosphere-to-Ocean flux]

This formula finds the Cumulative Residual land sink is -150 PgC rather than -160 PgC and Table 1 corrects this IPCC error.

Table 1 values will be uses to calculate the effect of net land use change on the human carbon cycle.

3. Physics model method

(The casual reader may skip this Section that develops the mathematics for the physics model.)

3.1 Physics model for one reservoir

The physics carbon cycle requires a theoretical base. All models are approximations to reality. A system describes a subset of nature. A system includes levels and flows between levels. Levels set flows and flows set new levels. The mathematics used in the physics model are analogous to the mathematics used to describe many engineering and chemical systems.

Figure 6 shows the one-level physics model with one outflow for carbon in the atmosphere. The same model applies to carbon in any reservoir.

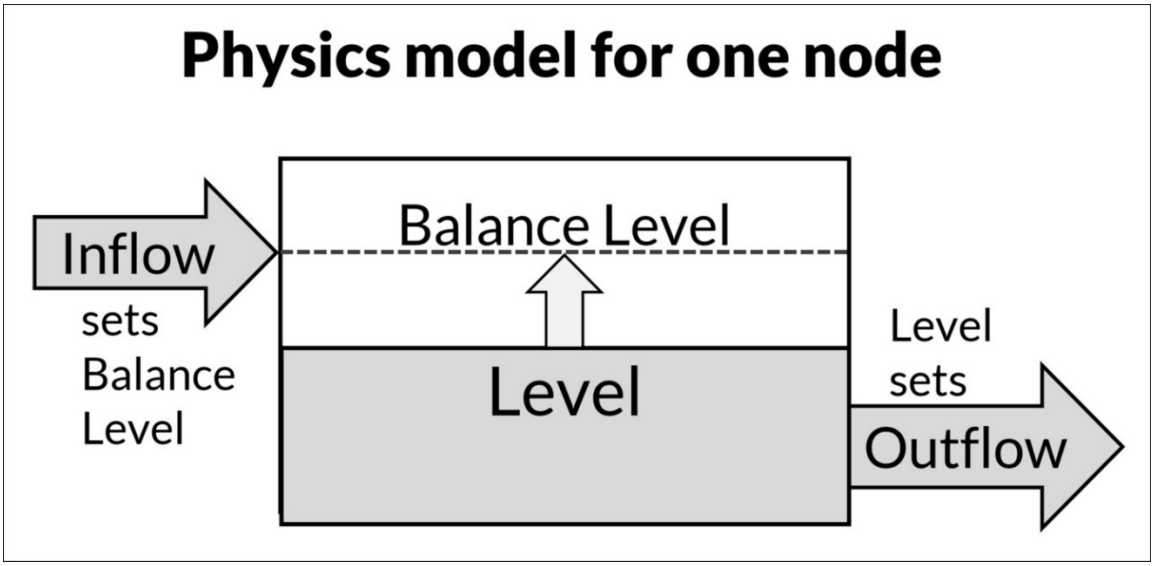

Figure 6. The physics model for one level and one outflow node.

Following Berry [4], the physics model derivation begins with the continuity equation (1) which says the rate of change of level is the difference between inflow and outflow,

$$dL / dt = Inflow - Outflow \quad (1)$$

where,

L = carbon level (PgC)

t = time (years)

dL / dt = rate of change of L (PgC / year)

Inflow = carbon inflow (PgC / year)

Outflow = carbon outflow (PgC / year)

When *Outflow* = *Inflow*, then $dL/dt = 0$. The flows continue while the level is constant.

The physics model has only one hypothesis: outflow is proportional to level,

$$Outflow = L / T_e \tag{2}$$

where: T_e is the "e-time," so defined because it is an exponential time. Equation (2) shows e-time *Te* is the same as IPCC's turnover time, *T*.

E-time is the time for the level to move (1 - 1/e) of the distance from its present level to its balance level. E-time has the same definition as IPCC's turnover time.

Substitute (2) into (1) to get,

$$dL / dt = Inflow - L / T_e \tag{3}$$

When dL/dt is zero, the level will be at its balance level, L_b, defined as,

$$L_b = Inflow\ T_e \tag{4}$$

Substitute (4) for *Inflow* into (3) to get,

$$dL / dt = -(L - L_b) / T_e \tag{5}$$

Equation (4) shows how inflow sets the balance level. Equation (5) shows the level always moves toward the balance level set by the inflow. The variables L, L_b, and T_e are functions of time.

In the special case when L_b and T_e are constant, which means *Inflow* is constant according to (4), there is an analytic solution to (5). Rearrange (5) to get,

$$dL / (L - L_b) = - dt / T_e \tag{6}$$

Then integrate (6) from L_0 to L on the left side, and from 0 to t on the right side to get,

$$\text{Ln}\,[(L - L_b) / (L_0 - L_b)] = - t / T_e \qquad (7)$$

Where,

L_0 = Level at time zero ($t = 0$)

L_b = the balance level for a given inflow and T_e

T_e = time for L to move (1 – 1/e) from L to L_b

e = 2.7183

Define half-life, T_h, as the time for the level to fall to half its original level. Then (7) becomes,

$$\text{Ln}\,(1/2) = - T_h / T_e \qquad (7a)$$

$$T_h = T_e\,\text{Ln}\,(2) = 0.6931\ T_e \qquad (7b)$$

The original integration of (6) contains two absolute values, but they cancel each other because both L and L_0 are always either above or below L_b.

Raise e to the power of each side of (7), to get the level as a function of time,

$$L(t) = L_b + (L_0 - L_b)\,\exp(- t / T_e) \qquad (8)$$

Equation (8) is the analytic solution of (5) when L_b and T_e are constant.

All equations after (2) are deductions from hypothesis (2) and the continuity equation (1).

3.2 Physics model properties

The physics model's only hypothesis (2) is a linear function of level. This allows the physics model to apply independently and in total to human and natural carbon.

The physics model also applies independently and in total to all definitions of carbon or CO_2. For example, it applies independently to human CO_2, natural CO_2, and their sums, and to $12CO_2$, $13CO_2$, and $14CO_2$, and their sums.

However, if outflow (2) were a strictly increasing function of level other than level to the power of one, then the physics model would *not* apply independently and in total to human CO_2 and natural CO_2.

Hypothesis (2) shows it is possible, and preferable, to calculate the natural and human carbon cycles separately. Just add another instance of the physics model for each carbon definition. Then add the separate calculations to produce the total carbon cycle.

Hypothesis (2) is compatible with all applicable physical and chemical laws. It is used in scientific, climate physics, chemical, pharmacology, and engineering models. It is the simplest hypothesis for carbon cycle models, and it replicates IPCC's natural carbon cycle.

The physics model allows external processes to change reservoir levels only by changing the inflows, outflows, or e-times. The physics model *includes all effects of external processes* (chemical, biological, etc.) on the level of carbon in a reservoir because IPCC's natural carbon cycle data that it will use include these effects.

Equation (5) shows how the level moves toward its balance level with a speed set by the e-time. When the level equals its balance level, outflow will equal inflow. At the balance level, constant inflow sets a constant level. Carbon will not accumulate in the reservoir.

The balance level (4) shows that neither human nor natural emissions accumulate in the atmosphere. Constant inflows create constant outflows when the levels are at their balance levels.

3.3 Physics carbon-cycle model

The IPCC defines four key carbon reservoirs: land, atmosphere, surface ocean, and deep ocean. We apply the physics model to each reservoir and each outflow node. The "level" of each reservoir is the mass of carbon in each reservoir.

The physics model is not a static mass balance. Nor is it a statistical curve fit to data. The physics model is a dynamic flow model that accurately computes the evolution of levels and flows as functions of time. It may be the first fully functional mathematical model of IPCC's carbon cycle. It follows the same model dynamics used by Berry [5,6] and Berry and Reinhardt [7-10] to model the evolution of cloud droplets into raindrops by stochastic collection.

Figure 7 shows the physics carbon cycle model with IPCC's 4 reservoirs and 6 outflows where the arrows are all positive numbers. The origin of each arrow is a "node."

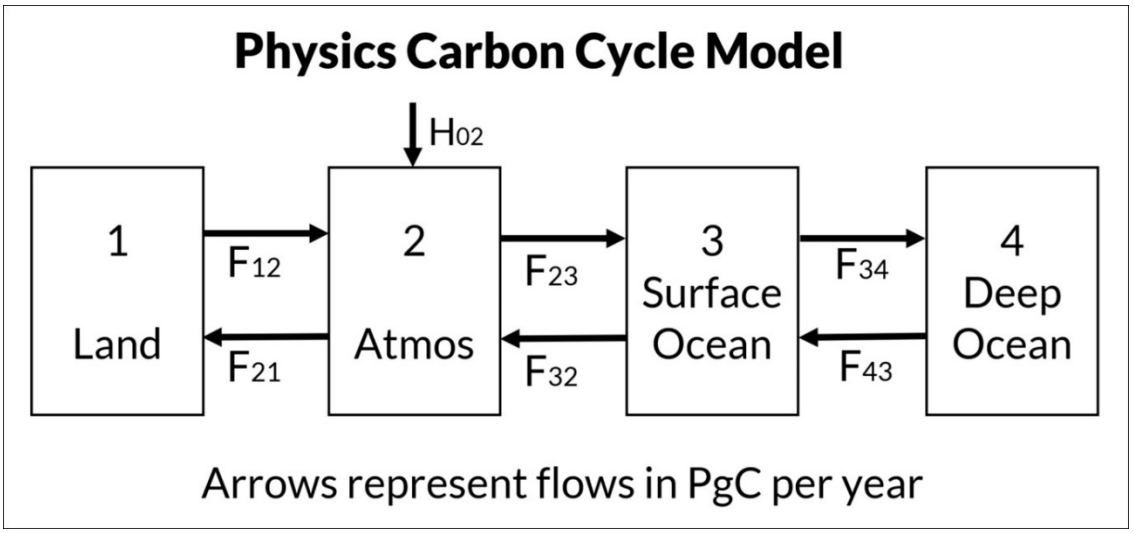

Figure 7. The physics carbon cycle model for IPCC's carbon cycles.

Define the Levels,

L_1 = level of carbon in the land

L_2 = level of carbon in the atmosphere

L_3 = level of carbon in the surface ocean

L_4 = level of carbon in the deep ocean

Define the individual flows out of the six nodes,

F_{12} = flow from land to atmosphere

F_{21} = flow from atmosphere to land

F_{23} = flow from atmosphere to surface ocean

F_{32} = flow from surface ocean to atmosphere

F_{34} = flow from surface ocean to deep ocean

F_{43} = flow from deep ocean to surface ocean

Define other variables,

t = time in years

H_{02} = new human carbon flow to atmosphere

H_{12} = land human carbon flow to atmosphere

Using (2), the flows out of the six nodes are,

$$F_{12} = L_1 / T_{12}$$

$$F_{21} = L_2 / T_{21}$$

$$F_{23} = L_2 / T_{23}$$

$$F_{32} = L_3 / T_{32}$$

$$F_{34} = L_3 / T_{34}$$

$$F_{43} = L_4 / T_{43} \qquad (9a)$$

The same equations in terms of e-times are,

$$T_{12} = L_1 / F_{12}$$

$$T_{21} = L_2 / F_{21}$$

$$T_{23} = L_2 / F_{23}$$

$$T_{32} = L_3 / F_{32}$$

$$T_{34} = L_3 / F_{34}$$

$$T_{43} = L_4 / F_{43} \qquad (9b)$$

Using (9) and (1), the rate equations for each reservoir are,

$$dL_1 / dt = F_{21} - F_{12} - H_{12}$$

$$dL_2 / dt = F_{12} - F_{21} + F_{32} - F_{23} + H_{02} + H_{12}$$

$$dL_3 / dt = F_{23} - F_{32} + F_{43} - F_{34}$$

$$dL_4 / dt = F_{34} - F_{43} \qquad (10)$$

The physics model uses (9) and (10) to calculate the natural and the human carbon cycles.

3.4 Capacitor analogy

Figure 8 shows the capacitor analogy to Figure 8 suggested by Happer and van Wijngaarden [11].

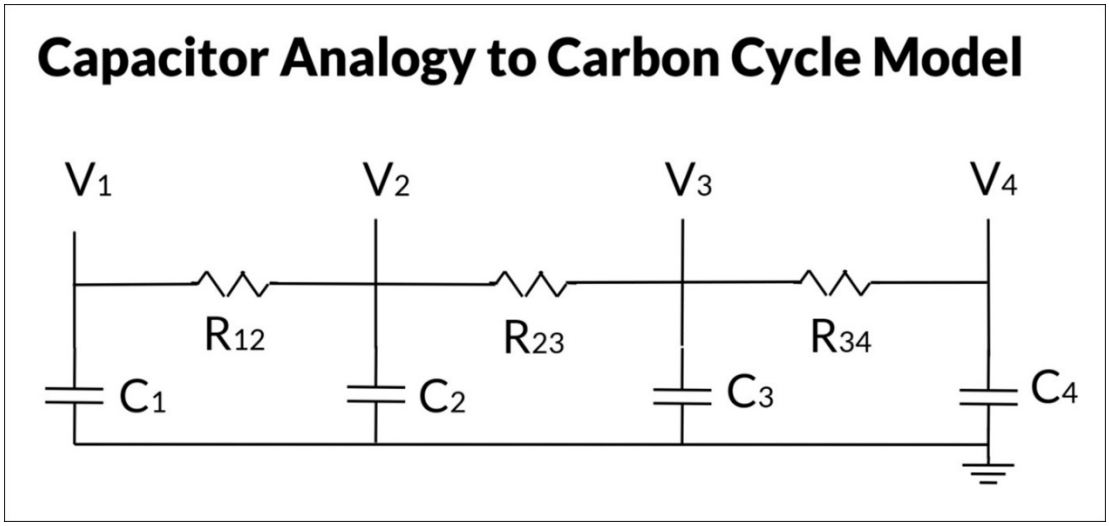

Figure 8. Capacitor analogy to IPCC's carbon cycle.

The four capacitors simulate the four reservoirs. The capacitor charge simulates the carbon levels. The three resistors simulate the "resistance to flow" between the reservoirs. Current simulates flow.

The following derivations show how electrical circuit theory uses the physics model hypothesis (2).

The physics model defines the ends of each resistor as "nodes." Equation (11) shows how the outflow hypothesis (2) is the same as electrical circuit theory:

$$Outflow = L / T_e \quad = I \quad = V / R \quad = Q / RC \tag{11}$$

where:

I = current outflow

V = voltage on the capacitor

R = resistance to outflow

Q = charge on the capacitor

C = capacitance

In electrical terms, Ohm's law requires the net flow between nodes to be,

$$Net\_F_{jk} = (V_j - V_k) / R_{jk} \quad (12a)$$

$$Net\_F_{jk} = F_{jk} - F_{kj} \quad (12b)$$

Therefore, the outflow from each node is,

$$F_{jk} = V_j / R_{jk} \quad (13)$$

where the resistance between nodes j and k is bidirectional

$$R_{jk} = R_{kj} \quad (14)$$

The charge on a capacitor is the analog of the carbon level, L, so

$$V_j = L_j / C_j \quad (15)$$

Substituting (15) into (13), the flow out of each node is,

$$F_{jk} = L_j / R_{jk}\, C_j \quad (16)$$

Comparing (16) to (9) shows the capacitor analogy of T_e is,

$$T_{jk} = R_{jk}\, C_j \quad (17)$$

Therefore, the nodal flows for the capacitor analogy are the same as the nodal flows for the physics model (9) when (17) replaces the T_{jk} in (9).

At equilibrium, all V_j are equal. Therefore, (15) means,

$$L_j / C_j = L_k / C_k \quad (18)$$

In an electrical RC circuit, the time constant "*Tau*" is,

$$Tau \text{ (seconds)} = C \text{ (Farads)} * R \text{ (Ohms)} \quad (19)$$

The capacitor analogy uses the same equations and data as the physics carbon cycle model. Therefore, their results will be identical. Students can build a capacitor model.

3.5 Method of calculation

Set the flows in (9a) to equal IPCC's equilibrium flows shown in Figure 2 (in PgC/Year),

$$F_{12} = L_1 / T_{12} = 108.0$$

$$F_{21} = L_2 / T_{21} = 108.0$$

$$F_{23} = L_2 / T_{23} = 60.4$$

$$F_{32} = L_3 / T_{32} = 60.4$$

$$F_{34} = L_3 / T_{34} = 102.0$$

$$F_{43} = L_4 / T_{43} = 102.0 \qquad (20)$$

Set the levels to equal IPCC's equilibrium levels shown in Figure 2 (in PgC),

$$L_1 = 2500$$

$$L_2 = 589$$

$$L_3 = 900$$

$$L_4 = 37{,}100 \qquad (21)$$

Use (9b) to calculate the nodal e-times and use (17) to equate to RC e-times (in Years),

$$T_{12} = 2500 / 108 \quad = 23.1481 \quad = R_{12}\, C_1$$

$$T_{21} = 589 / 108 \quad = 5.4537 \quad = R_{12}\, C_2$$

$$T_{23} = 589 / 60.4 \quad = 9.752 \quad = R_{23}\, C_2$$

$$T_{32} = 900 / 60.4 \quad = 14.9007 \quad = R_{23}\, C_3$$

$$T_{34} = 900 / 102 \quad = 8.8235 \quad = R_{34}\, C_3$$

$$T_{43} = 37100 / 102 \quad = 363.7255 \quad = R_{34}\, C_4 \qquad (22)$$

The extended decimal places in (22) are not physically relevant. These decimal places are relevant only to those who wish to check the carbon cycle calculations.

Equation (22) shows the atmosphere has two outflows and two e-times: T_{21} = 5.4 years for flow to land and T_{23} = 9.8 years for flow to the surface ocean. The outflows (2) add up,

$$Outflow = L\,(1 / T_{21} + 1 / T_{23}) = L / 3.5 \qquad (23)$$

Therefore, the overall e-time for atmospheric CO_2 for the IPCC [1] natural carbon cycle is 3.5 years which corresponds to IPCC's estimate of about 4 years.

Happer and van Wijngaarden [11] used a relaxation method to perform independent calculations using the equations in this paper and same input data. Their results matched the numerical calculations of this paper to 2 decimal places, which, of course, exceeds the accuracy of the data.

The numerical calculations use annual time steps as follows:

1. Set initial levels.
2. Calculate nodal flows using (9a).
3. Calculate level rates of change using (10).
4. Multiply level rates of change by time step to get changes of levels.
5. Add changes of levels to the levels to get new levels.
6. Repeat for next time step.

Supplementary Materials has two links to download the Excel file that includes all the data, numerical calculations, and plots used in this paper.

4. Physics model results

4.1 IPCC's true human carbon cycle

The physics carbon cycle model correctly simulates IPCC's data for the natural carbon cycle. Since human carbon must obey the same rules as natural carbon, the physics carbon cycle model computes the human carbon cycle using the e-times found in IPCC's natural carbon cycle (22).

These calculations also use [3] data for human carbon emissions from 1750 to 2017, and this paper's estimates of human emissions for 2018 and 2019.

The physics carbon cycle model hypothesis (2) allows independent calculations of natural and human carbon cycles. The sum of the human and natural carbon-cycles equals the total carbon cycle.

The calculation begins with the human carbon levels at zero in 1750. Each numerical time step inserts human carbon and allows carbon to flow between reservoirs.

Figure 9 shows how the reservoir levels change with time for new human carbon. The purple dashed line shows the cumulative new human carbon inserted into the fast carbon cycle since 1750. The purple dashed line is also the total human carbon emissions since 1750 [3].

The solid bold line shows the measured atmospheric carbon level above 594 PgC (280 ppm) using Antarctic ice and firn [12] before 1960 and measured [13] thereafter.

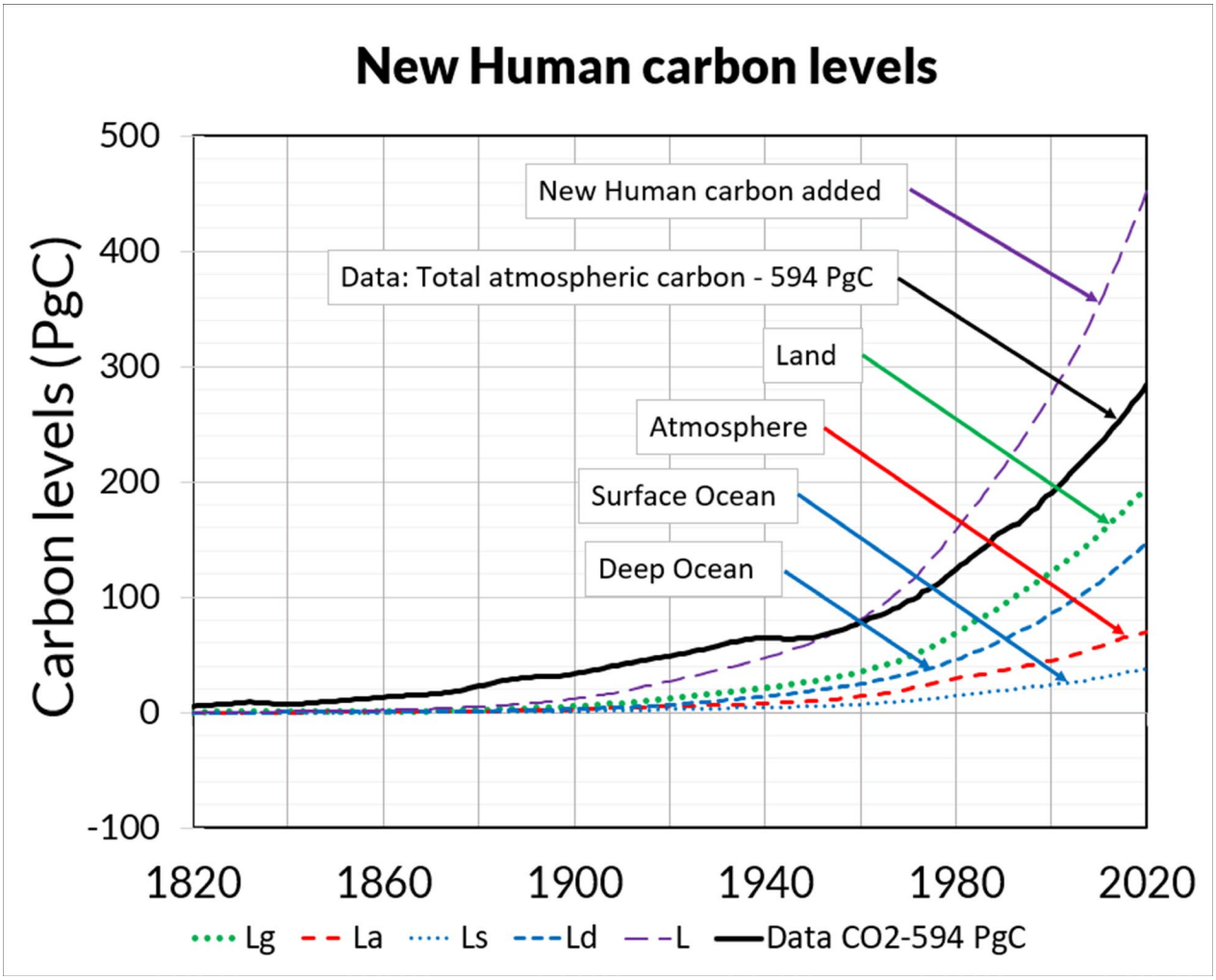

Figure 9. The dashed lines show the calculated new human carbon levels for each reservoir. Measured atmospheric carbon level (solid bold line) above 594 PgC (280 ppm) is from Antarctic ice and firn [12] before 1960 and measured [13] thereafter.

Figure 10 shows the levels for Land human carbon. Table 1 shows accumulated "Net Land Use Change" is 180 PgC over 260 years, for an average of 0.6923 PgC per year. These calculations use a more generous land to atmosphere flow of 1.0 PgC per year beginning in 1750.

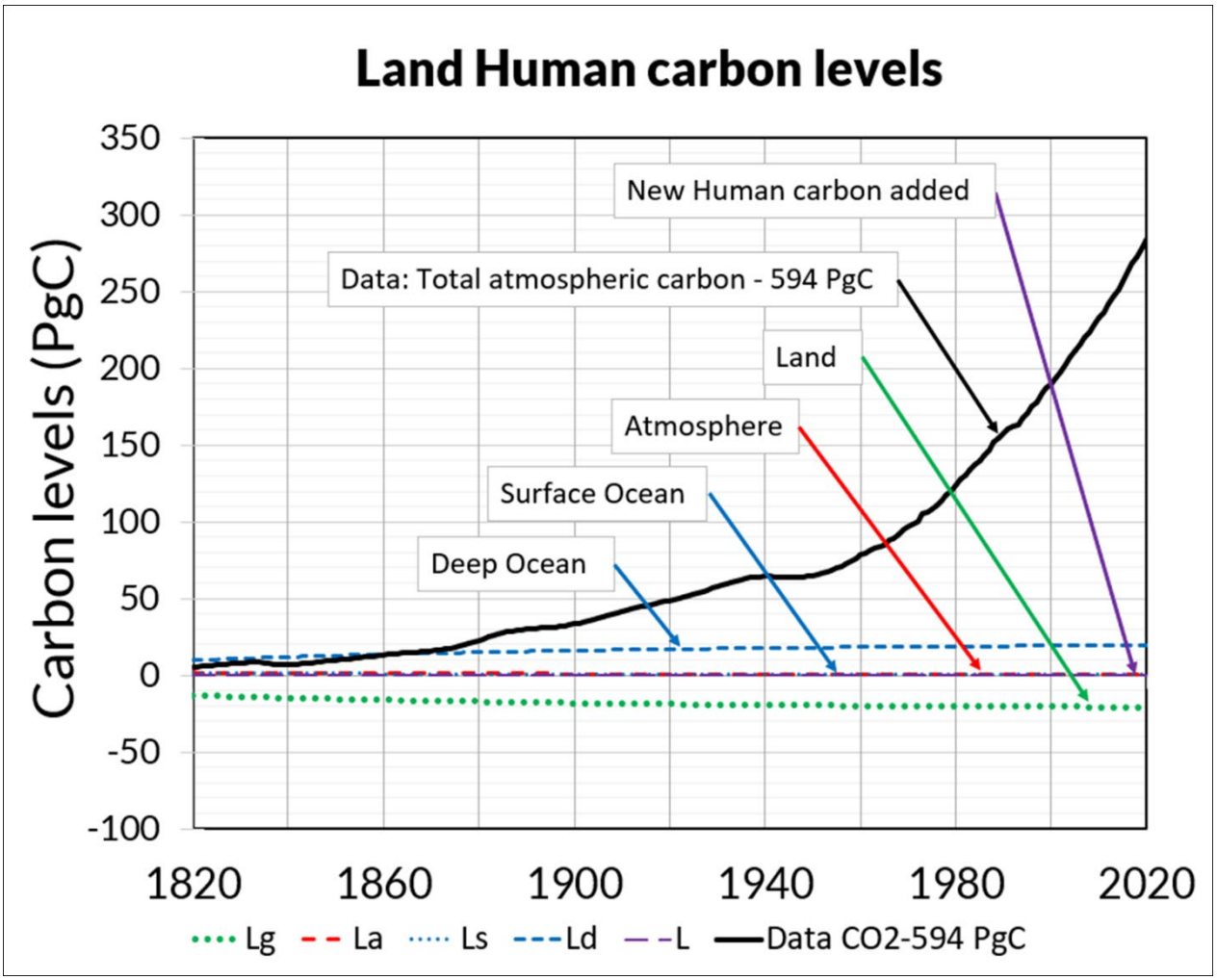

Figure 10. Same as Figure 9 but for Land human carbon. Calculations set the land use change carbon flow from land to atmosphere at 1.0 PgC per year.

Net land use change of 1.0 PgC per year has almost no effect on atmospheric CO_2. The flow of carbon from land to atmosphere adds no new carbon to the carbon cycle and the carbon it adds to the atmosphere flows rapidly to the deep ocean.

Figure 11 shows the combined effects of new human carbon and land human carbon. Although calculated separately, this combination equals the sum of its two components.

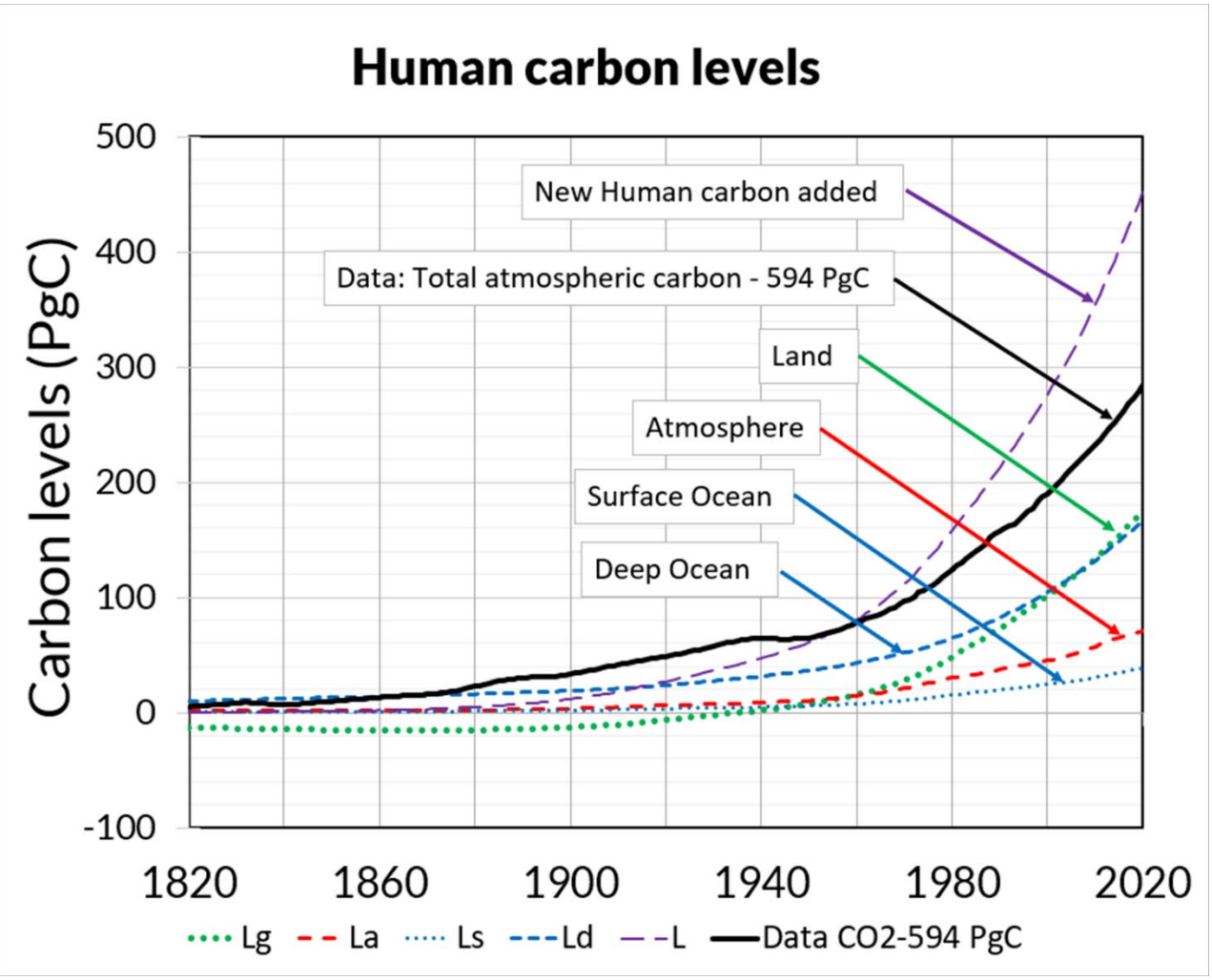

Figure 11. Same as Figure 9 but for all human carbon.

Figures 9 and 11 show the total new human carbon added to the carbon cycle is well below the measured atmospheric carbon before 1950, proving that nature has played a major part in the increase of atmospheric CO_2 after 1750.

Tables 2, 3, and 4 show the calculated levels of new, land, and total human carbon for selected years. All three calculations are independent, yet the independent values for new human carbon in Table 2 and land human carbon in Table 3, when summed, equal the values for human carbon in Table 4. The levels for 2100 assume emissions of new human carbon stop at the end of 2020.

Table 2. Calculated values of new human carbon for selected years.

Year	Lg	La	Ls	Ld	Total	La ppm
1820	0.19	0.08	0.04	0.11	0.21	0.02
1900	5.27	2.49	1.18	2.84	11.78	1.17
2000	121.86	44.66	24.03	85.50	276.05	21.07
2010	154.35	57.05	29.98	112.77	354.14	26.91
2020	196.10	70.18	37.95	147.32	451.55	33.11
2100	110.77	21.31	17.14	302.33	451.55	10.05

Table 3. Calculated values of land human carbon for selected years.

Year	Lg	La	Ls	Ld	Total	La ppm
1820	-13.02	1.89	1.27	9.87	0.00	1.06
1900	-18.00	1.00	0.83	16.17	0.00	0.47
2000	-20.45	0.56	0.62	19.26	0.00	0.27
2010	-20.58	0.54	0.61	19.43	0.00	0.25
2020	-20.69	0.52	0.60	19.58	0.00	0.24
2100	-21.29	0.41	0.55	20.33	0.00	0.19

Table 4. Calculated values of human carbon for selected years.

Year	Lg	La	Ls	Ld	Total	La ppm
1820	-12.82	1.97	1.31	9.98	0.21	1.08
1900	-12.73	3.49	2.01	19.01	11.78	1.64
2000	101.41	45.22	24.65	104.76	276.05	21.33
2010	133.77	57.59	30.58	132.20	354.14	27.16
2020	175.41	70.70	38.55	166.90	451.55	33.35
2100	89.48	21.72	17.69	322.67	451.55	10.25

Table 3 shows the flow of 1.0 PgC of land carbon to the atmosphere flows rapidly to the deep ocean, leaving little in the atmosphere, and it adds no new carbon to the fast carbon cycle.

Figures 12, 13, and 14 show the calculated level percentages for human carbon in Table 4 for the years 2010, 2020, and 2100, respectively.

Figure 12 shows in 2010, 16% of human carbon is in the atmosphere, 44% is in the land, and 32% is in the deep ocean. The percentages are significantly different from those in IPCC's [1] human carbon cycle shown in Figure 5.

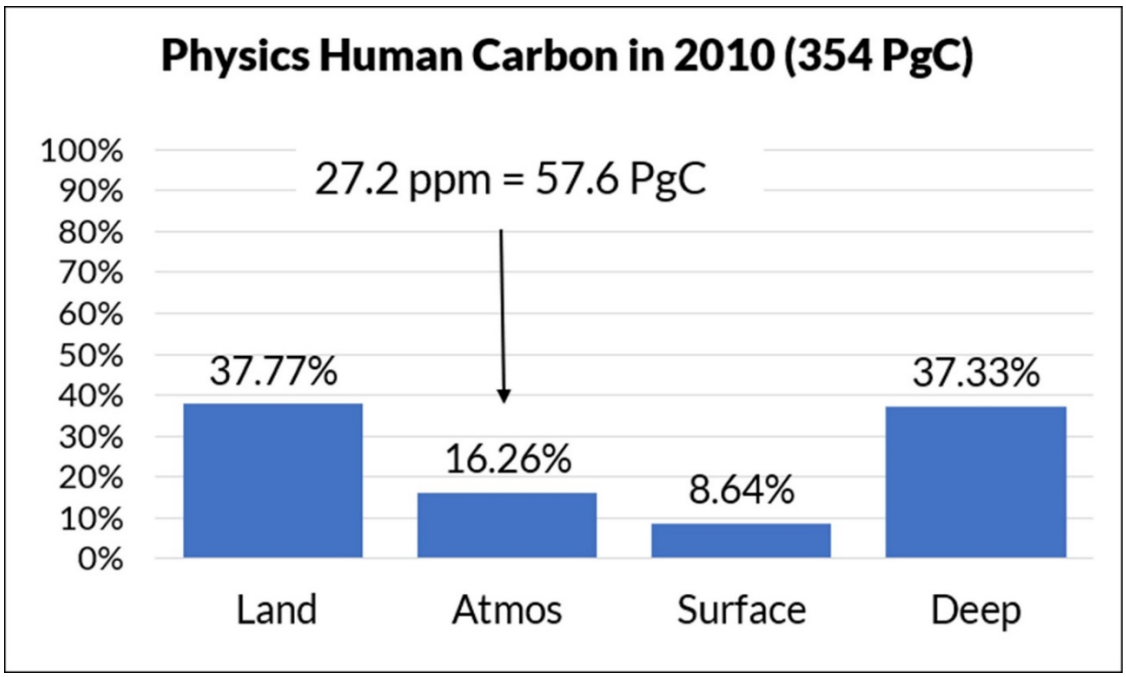

Figure 12. Physics carbon cycle calculations for the new human carbon percentages in 2010.

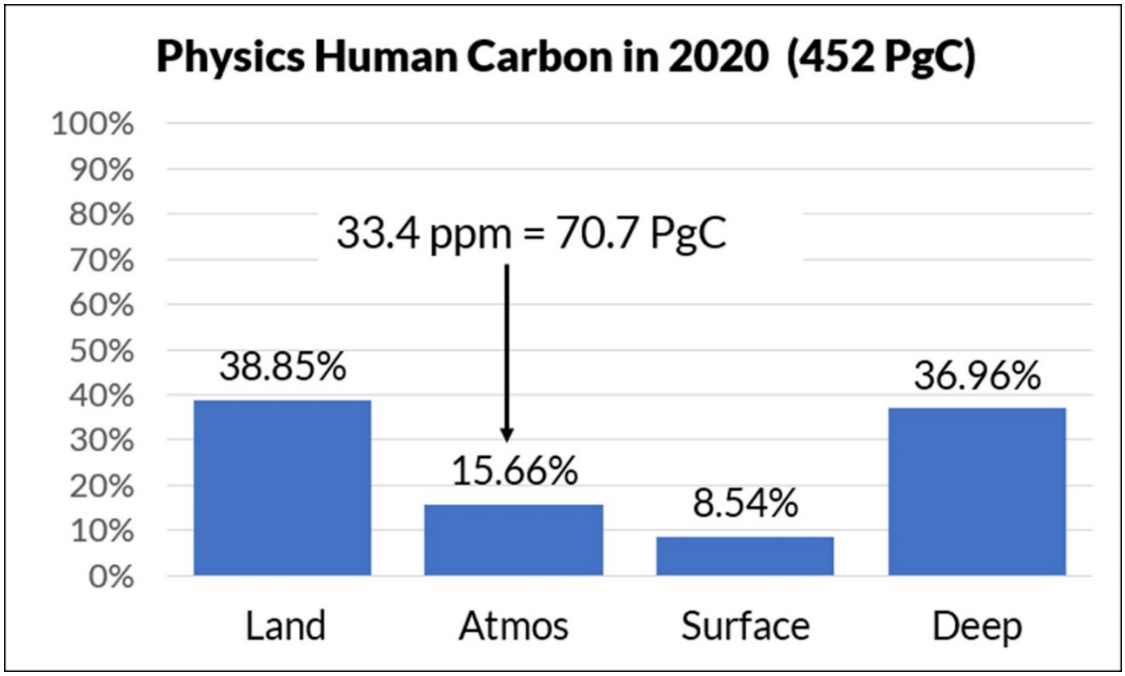

Figure 13. Physics carbon cycle calculations for the human carbon percentages in 2020.

Figure 13 for 2020 shows even though the amount of new carbon has increased from 354 PgC in 2010 to 452 PgC in 2020, the percentage of human carbon in the atmosphere has decreased while the percentage in the deep ocean has increased. The 33 ppm of human carbon in the atmosphere means nature added

about 100 ppm to the 280 ppm in 1750 to get 413 ppm.

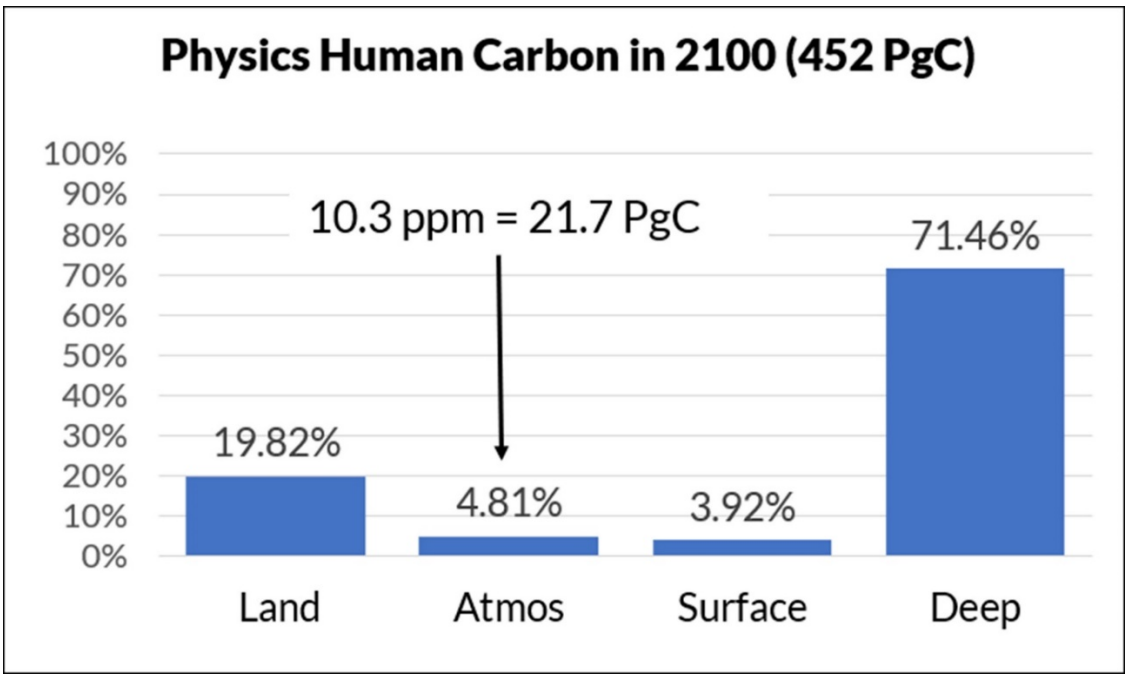

Figure 14. Physics carbon cycle calculations for the human carbon percentages in 2100 assuming all human carbon emissions were to stop in 2020.

Figure 14 for 2100 shows how fast human carbon in the atmosphere would flow to the deep ocean if all human emissions were to stop in 2020. The level percentages move toward IPCC's natural carbon cycle percentages shown in Figure 3.

Figure 15 show the time plot of human carbon in the atmosphere. It peaks at 33 ppm in 2020 and this level falls rapidly if new human carbon emissions were to stop at the end of 2020, showing human carbon flows rapidly from the atmosphere.

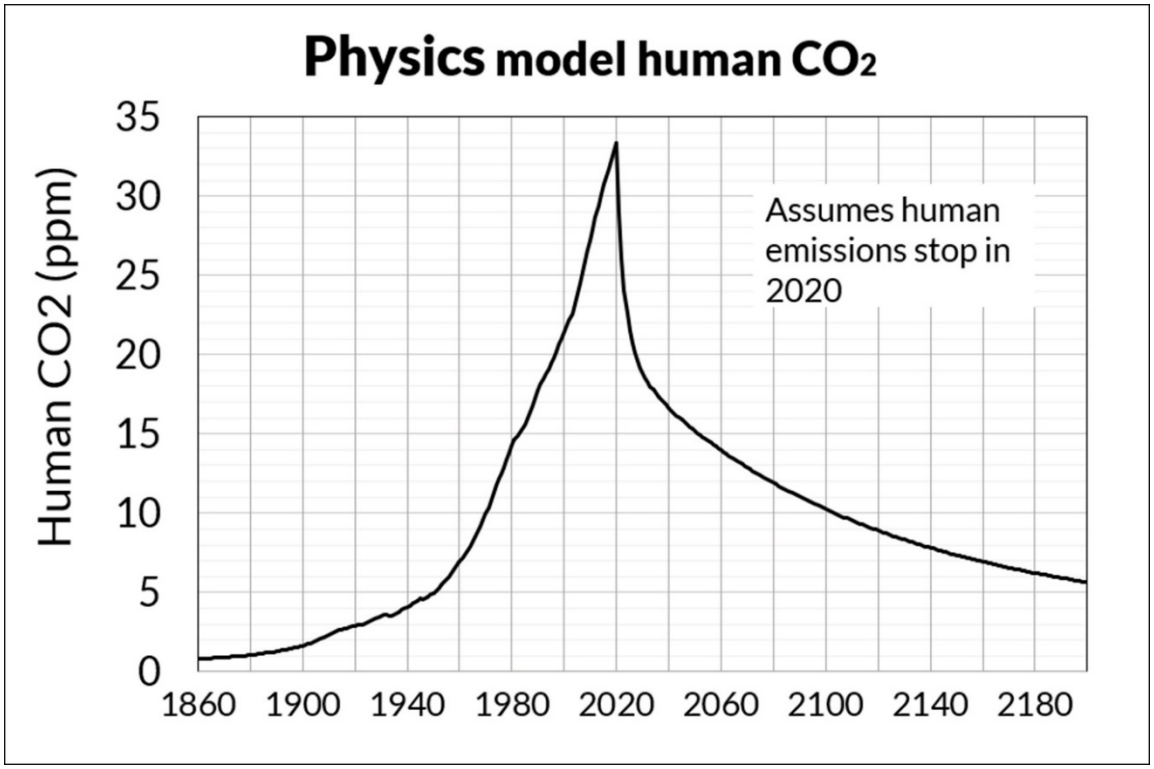

Figure 15. Physics carbon cycle calculations show human atmospheric CO_2 from 1900 to 2100, assuming all human CO_2 emissions stop in 2020.

4.2 Values at IPCC's extreme error bounds

To find the extreme values for IPCC's true human carbon cycle, adjust the e-times in (22) to their 20% borders. This is more extreme than IPCC's stated error bounds permit. The deep ocean e-times do not change the level of atmospheric CO_2.

The following e-times (years) maximize atmospheric CO_2 from 33 ppm to 48 ppm:

$$T_{12} = (2500 / 108 = 23.1481) * 0.67 \quad = 15.43$$

$$T_{21} = (589 / 108 = 5.4537) * 1.20 \quad = 6.544$$

$$T_{23} = (589 / 60.4 = 9.752) * 1.20 \quad = 11.70$$

$$T_{32} = (900 / 60.4 = 14.9007) * 0.67 \quad = 9.98 \qquad (24)$$

The following e-times (years) minimize atmospheric CO_2 from 33 ppm to 24 ppm,

$$T_{12} = (2500 / 108 = 23.1481) * 1.49 \quad = 34.49$$

T_{21} = (589 / 108 = 5.4537) * 0.80 = 4.36

T_{23} = (589 / 60.4 = 9.752) * 0.80 = 7.80

T_{32} = (900 / 60.4 = 14.9007) * 1.49 = 22.20 (25)

In summary, IPCC's natural carbon cycle data with 20% error bounds show human CO_2 has increased atmospheric CO_2 by 33 ppm with a range of 24 ppm to 48 ppm, as of 2020. The probability of occurrence of the extremes of 24 ppm and 48 ppm is small because all e-times were set to their limits.

4.3 Physics carbon cycle pulse decay

Figure 16 shows how a single pulse of carbon in the atmosphere will flow to the other reservoirs in 100 years using IPCC's e-times for natural carbon.

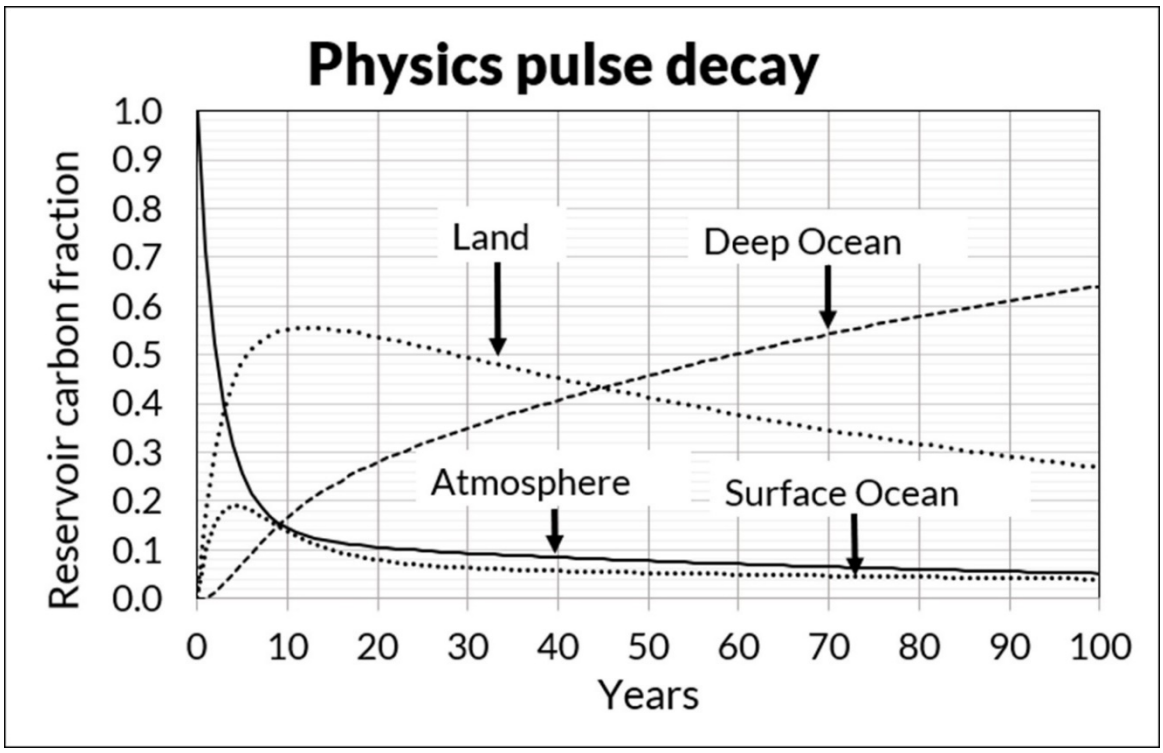

Figure 16. How a pulse of carbon in the atmosphere moves through the reservoirs.

After 10 years, only 15% of the carbon pulse is in the atmosphere. After 100 years, 5% of the carbon pulse is in the atmosphere, 28% is in the land, and 64% is in the deep ocean. This approximates the distribution of human carbon in Figure 13 for 2020.

The land reservoir is the fastest to accept carbon from the atmosphere. But after 10 years, the atmosphere

level decreased so much that the land reservoir sends its carbon back to the atmosphere and thereby to the ocean. The land reservoir begins the rapid decay of atmospheric carbon, but the deep ocean controls the final decay.

Therefore, the atmosphere curve itself does not have a constant e-time even though all six flows have constant e-times. The presence of multiple flow paths can make constant individual e-times appear to be variable e-times.

4.4 The physics model vs the Bern model

Siegenthaler and Joos [14] created the original Bern model. They used 14C data to trace the flow of $12CO_2$ from the atmosphere to the upper ocean and to the deep and interior oceans. However, they used IPCC's assumption to analyze their data.

Joos [15] calculated a Green's function for the Bern model. Then he assumed human carbon enters the atmosphere in sequential annual pulses and the carbon in each pulse flows out of the atmosphere independently according to his Green's function. The Bern model is based on IPCC's assumption which causes the human CO_2 e-time to be large and keeps human CO_2 in the atmosphere for a long time.

To resolve the conflict with data that show e-time is less than 10 years, Joos assumed human CO_2 (but not natural CO_2) decreases buffer capacity, which is incorrect because human and natural CO_2 act the same.

To deconstruct Joos' integral equation, let inflow occur only in the year when *t*' equals zero. Then the integral disappears, and the Bern model becomes a level equation that depends on its starting level, L_o,

$$L(t) = L_0 \left[A_0 + A_1 \exp(-t / T_1) + A_2 \exp(-t / T_2) + A_3 \exp(-t / T_3) \right] \quad (26)$$

where:

t = time in years

L_0 = level of atmospheric CO_2 in year t = 0

$L(t)$ = level of atmospheric CO_2 in year t

Joos derived these TAR (Third Assessment Report) standard values for the Bern coefficients:

$A_0 = 0.152$

$A_1 = 0.253$

$A_2 = 0.279$

$A_3 = 0.316$

$T_1 = 171$ years

$T_2 = 18.0$ years

$T_3 = 2.57$ years (27)

Where,

$$A_0 + A_1 + A_2 + A_3 = 1.000 \quad (28)$$

In (26), set t equal to infinity to get,

$$L = A_0 L_0 = 0.152 L_0 \quad (29)$$

Equation (29), or the first term in (26) with values (27), predicts 15.2% of each one-year inflow will remain in the atmosphere forever.

For comparison, the (26) Green's function values for the physics carbon cycle (10) with the values of (20), (21), and (22) are,

$A_0 = 0.014$

$A_1 = 0.758$

$A_2 = 0.122$

$A_3 = 0.106$

$T_1 = 94.9$ years

$T_2 = 6.67$ years

$T_3 = 2.84$ years (30)

The physics model A_0 in (30) is one-tenth of the Bern model A_0 in (27), showing the physics model predicts only 1.4% of human carbon emissions will remain in the atmosphere forever. The A_0 in the physics model is the equilibrium percentage for atmospheric CO_2 as shown in Figure 5.

Joos et al. [16] compared the response of atmosphere-ocean models to a pulse emission of human CO_2 and found all the models predicted a "substantial fraction" of pulse would remain in the atmosphere and ocean for millennia. However, all models they compared assumed human carbon caused all the CO_2 increase.

Figure 17 compares the physics model with the Bern model (27). The solid lines in Figures 16 and 17 are the same line for the physics pulse decay.

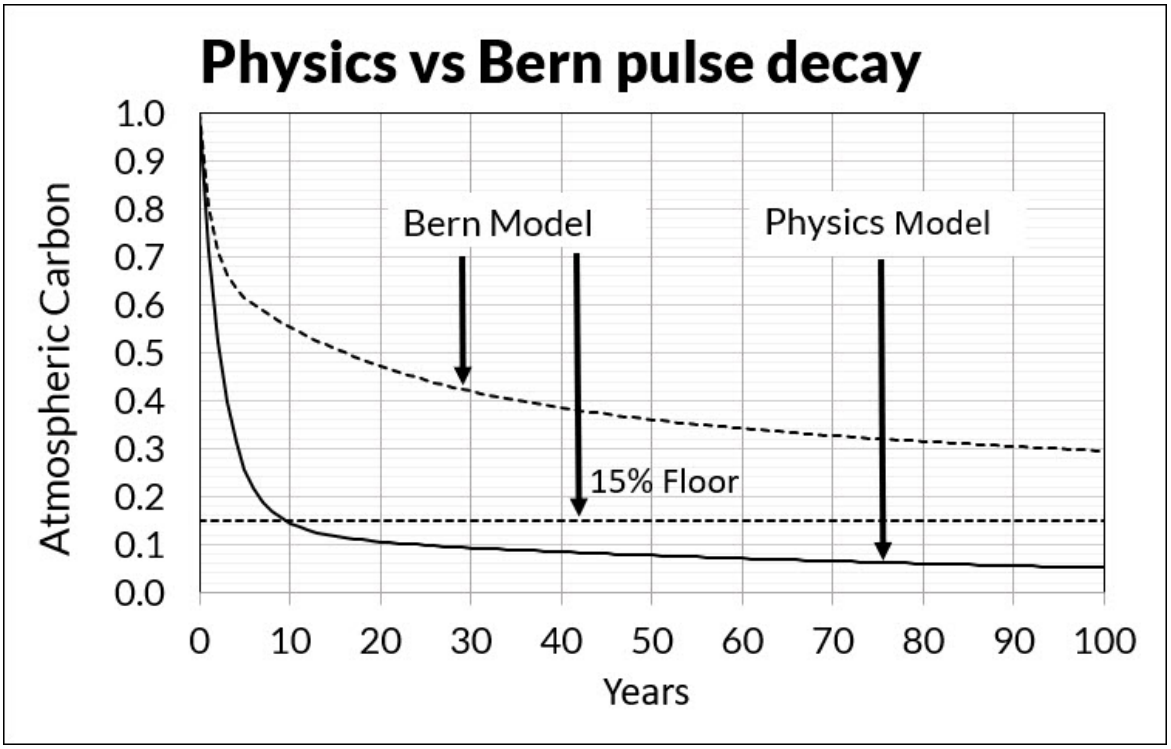

Figure 17. Pulse decay for the Physics model and Bern model compared. The physics model numerical calculations used (9) and (10). The Bern model calculations used (26).

In the Bern model, human CO_2 decays to 55% in 10 years and to 30% in 100 years and will never get below 15%.

In the physics model, human CO_2 decays to 15% in 10 years and to 5% in 100 years and will never get below 1.4%.

5. Discussion

5.1 Short e-time contradicts the assumption.

IPCC [2] (p. 948) says turnover time for atmospheric CO_2 is about 4 years. Equation (23) shows the e-time for atmospheric CO_2 for the IPCC [1] natural carbon cycle is 3.5 years.

Revelle and Suess [17] used 14C data to calculate that the turnover time "of a CO_2 molecule in the atmosphere … is of the order of 10 years." They concluded,

> "This means most of the CO_2 released by artificial fuel combustion since the beginning of the industrial revolution must have been absorbed by the oceans."

Starr [18] found several papers that used IPCC's assumption. By removing the assumption, he found the data shows e-time is 4 to 5 years. He wrote,

> "The short residence time suggests that anthropogenic emissions contribute only a fraction of the observed atmospheric rise, and that other sources need be sought."

Segalstad [19] lists 36 studies performed from 1957 to 1992 using 6 different methods that estimate the e-time for CO_2 is less than 10 years and dominantly between 5 and 10 years.

Rorsch et al. [20] show that allowing human carbon to follow different rules than natural carbon will produce incorrect e-times.

Essenhigh [21] calculated the $12CO_2$ e-time is about 4 years.

Harde [22,23] shows data that supports a $12CO_2$ e-time of about 4 years. Harde [23] and Berry [4] use one-reservoir models (that do not allow human carbon to flow of from land and oceans back into the atmosphere) to conclude that human emissions have added about 17 ppm to 18 ppm to the atmosphere.

Kohler et al. [24] critiqued Harde [22], claiming human (but not natural) CO_2 reduced the "buffer capacity" of the carbonate system:

> "… the rise in atmospheric and oceanic carbon content goes along with an increase in the Revelle factor, a phenomenon which is already measurable. This implies that the oceanic uptake of anthropogenic carbon will become slower if we continue to increase anthropogenic CO_2 emissions. This is already seen in all CHIMP5 model simulations."

However, Kohler et al. assume, like the IPCC, that the natural carbon level remained constant after 1750, and CHIMP5 models cannot be evidence for the Revelle effect because the models also use IPCC's assumption.

Gruber et al. [25] claim to prove human carbon caused the increase in ocean carbon. However, they use IPCC's assumption to analyze their data.

Munshi [26] shows the "detrended correlation of annual emissions with annual changes in atmospheric CO_2" is zero, which means anthropogenic emissions are not the primary cause of the increase in CO_2 concentration. Arguments that natural CO_2 emissions change enough to cover the human signal but always average to net zero, are circular because they follow IPCC's assumption.

Ballantyne et al. [27] found “there is no empirical evidence” that the ability of the land and oceans to absorb atmospheric CO_2 “has started to diminish on the global scale.” This result is expected because, as of 2010, new human carbon added only 0.88% (or 365 / 41,484) to the carbon cycle, which is not enough to change the ability of the land and oceans to absorb atmospheric CO_2.

5.2 D14C data show the CO_2 increase is natural.

The above-ground atomic bomb tests in the 1950s and 1960s almost doubled the D14C in the atmosphere. The bomb tests ended in 1963 but it took about seven years for the $14CO_2$ to mix between the hemispheres and to move from the stratosphere to the troposphere. The 14C data in both hemispheres were virtually identical after 1970.

Hua [28] processed D14C data for both hemispheres from 1954 to 2010. Turnbull [29] processed D14C data for Wellington, New Zealand, from 1954 to 2014. Their 14C data are in units of D14C per mil where the D14C lower bound of -1000 equals the zero 14C level. The “natural” D14C balance level, defined by the average measured level before 1950, is zero.

Figure 18 shows physics model curve fits to D14C and 14C data as a “14C ratio.”

To convert the D14C data after 1970 to a 14C ratio, add 1000 to the D14C data, then multiply by the ratio of the $12CO_2$ level after 1970 divided by the $12CO_2$ level in 1970, then subtract 1000. This 14C ratio allows plotting the 14C change on the D14C plot in Figure 17.

The physics model for a constant e-time (8) fits the D14C data from 1970 to 2014 with a constant e-time of 16.5 years and a balance level of zero [4].

The physics model for a constant e-time (8) fits the 14C ratio from 1970 to 1995 with e-time of 10.0 years and balance level of 203.

The $14CO_2$ e-time of 10 years is an upper limit for the $12CO_2$ e-time because the $14CO_2$ isotope is heavier and slower [30].

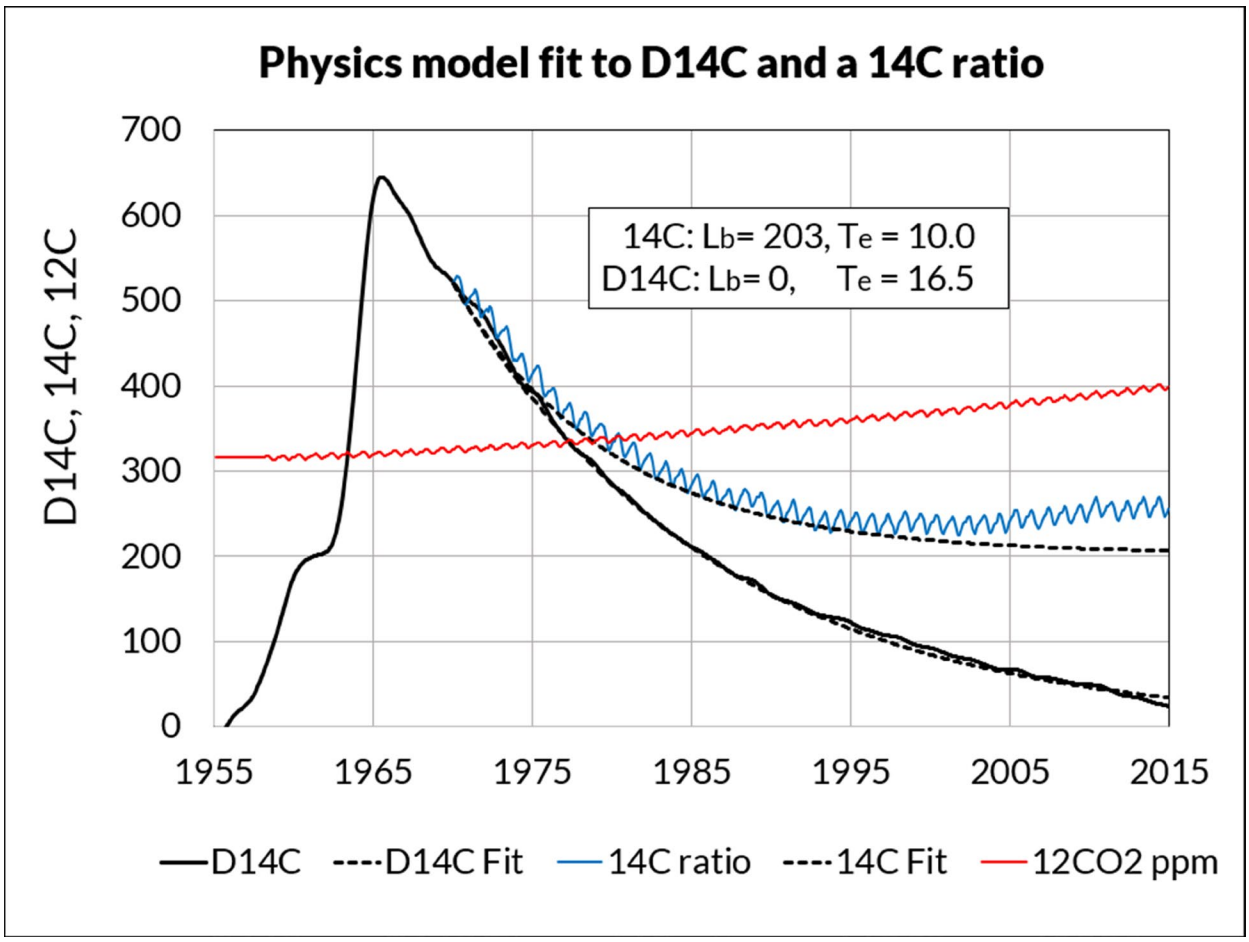

Figure 18. D14C data [29] fit to D14C, 14C ratio (blue sawtooth), and curve fits to each (dashed lines). 12_{CO_2} is in units of ppm. There are two curve fits.

The curve fit to the 14C ratio that finds the e-time is ten years is valid even though the curve fit is good to only 1995. By 1995, the 14C ratio is close to its balance level of 203, so the 14C ratio no longer follows its e-time curve.

As explained below Figure 16, this carbon cycle model has 6 different e-times. When a level is far from its balance level its own e-time dominates its return to its balance level and therefore is measurable. An e-time loses its domination when its level approaches the balance level, allowing other e-times to control its path.

IPCC [2] (p. 948, Lifetime) explains why the "adjustment time" will equal the turnover time when the level is far from its balance level because it is unaffected by other reservoirs. However, "when several reservoirs are involved" (when it is near its balance level) then the adjustment time no longer equals the turnover time.

The D14C curve is significant because its balance level remained near zero after the 14C bomb pulse of

the 1960s and after the 12C increase. The D14C return to its original balance level of zero even as 12C has increased, means the dominant carbon flow into the atmosphere has its D14C equal to zero, which indicates the ocean is the source of the CO_2 increase after 1750.

5.3 Isotope data show the CO_2 increase is natural.

IPCC [2] (p. 512) says,

> "The increase in atmospheric CO_2 concentration is known to be caused by human activities because the character of CO_2 in the atmosphere, in particular the ratio of its heavy to light carbon atoms, has changed in a way that can be attributed to addition of fossil fuel carbon."

However, this IPCC argument has no numbers. Using data, the isotopes data reject the core theory and support the smaller human addition shown by the physics carbon cycle model. See [19,31,22,23,4].

Quirk [31] examined 13C data and seasonal and hemispherical variations of CO_2, to find,

> "The constancy of seasonal variations in *CO_2* and the lack of time delays between the hemispheres suggest that fossil fuel derived *CO_2* is almost totally absorbed locally in the year it is emitted. This implies that natural variability of the climate is the prime cause of increasing *CO_2*, not the emissions of *CO_2* from the use of fossil fuels."

5.4 COVID-19 CO_2 show the increase is natural.

The Global Monitoring Laboratory [32,33] asks if the 2020 emissions reductions due to COVID-19 lowered the CO_2 level. The following approximate numbers illustrate how to answer this question.

The physics carbon cycle model calculates that reducing human CO_2 emissions by 20% in 2020 would reduce the CO_2 level from 33.5 in 2020 to 33.1 in 2021, which is unmeasurable, especially when added to an increasing natural CO_2 level.

However, if human carbon caused all the CO_2 increase, as the IPCC assumes, then reducing human CO_2 emissions by 20% would reduce the CO_2 level from 414.0 in 2020 to 412.4 in 2021 which would be a measurable contrast to the normal annual increase.

The [33] data show the COVID-19 decrease in human CO_2 did not affect the annual increase in CO_2, which suggests IPCC's assumption is false.

5.5 How nature may have increased its CO_2 level

The physics model shows how nature may have increased its natural level of CO_2.

For reference, Table 5 shows IPCC's natural carbon levels and Table 6 shows the e-times that keep

IPCC's natural carbon equilibrium levels constant.

Table 5. IPCC's natural carbon cycle levels in PgC.

Lg	La	Ls	Ld
2500	589	900	37100

Table 6. Physics model e-times in PgC per year that keep IPCC's natural carbon levels constant.

T_{12}	T_{21}	T_{23}	T_{32}	T_{34}	T_{43}
23.15	5.45	9.75	14.90	8.82	363.73

Table 7 shows changes in T_{32} and T_{43} that would increase the natural CO_2 level by 100 ppm.

Table 7. How changes in T_{32} and T_{43} would increase the natural CO_2 level by 100 ppm.

T_{32}	T_{43}	Natural CO_2 level (ppm)	Human CO_2 level	Simulation
14.90	363.73	277.8	33.11	Equilibrium values
10.45	363.73	**377.9**	35.03	Desorption in surface ocean
14.90	**254.00**	**377.4**	33.54	Overturning of deep ocean

If T_{32} for the 12C flow from the surface ocean to the atmosphere decreases from 14.90 to 10.45 PgC per year, the *natural* level of atmospheric CO_2 will increase by 100 ppm, from 277.8 ppm to 377.9 ppm, simulating desorption of carbon in the surface ocean.

If T_{43} for the 12C flow from the deep ocean to the surface ocean decreases from 363.73 to 254.00 PgC per year, the *natural* level of atmospheric CO_2 will increase by 100 ppm, from 277.8 ppm to 377.4 ppm, simulating overturning of the deep ocean.

These e-time changes have insignificant effect on the calculated level of *human* CO_2 because the percent of human carbon in the ocean is still below its equilibrium levels.

Salby [34] (p. 253) uses data to derive an equation that shows how the rate of change of CO_2 level is a function of surface temperature Ts. If all other things are constant, the rate of increase (dLa / dt) in the CO_2 level equals the rate of increase in the flow F_{32}. Then Salby's equation becomes

$$dF_{32} = 3.5 \text{ (ppmv/year /K) } dTs \quad (31)$$

The above reduction of T_{32} from 14.90 to 10.45 increases the flow F_{32} by 25.7 PgC per year, from 60.4 to 86.1 PgC per year.

Using (31), an increased flow F_{32} of 25.7 PgC per year, or 12.1 ppm per year, would require a surface temperature increase of (12.1 / 3.5) = 3.5 C.

Salby shows how the increase in *Ts* since the Little Ice Age in 1650 explains the increase in the level of atmospheric CO_2 from 1750 to 2020.

Harde [22] concluded that natural CO_2 is responsible for most of the CO_2 increase above 280 ppm,

> "These results indicate that almost all of the observed change of CO_2 during the Industrial Era followed, not from anthropogenic emission, but from changes of natural emission. The results are consistent with the observed lag of CO_2 changes behind temperature changes [35,36], a signature of cause and effect."

Harde [22] (Figure 3) shows how the CO_2 level has changed with surface temperature. His equation (17) is his curve fit to these data.

Figure 19, calculated using Harde's equation (17) and his dates in his Figure 3, shows how the natural CO_2 level has increased with surface temperature.

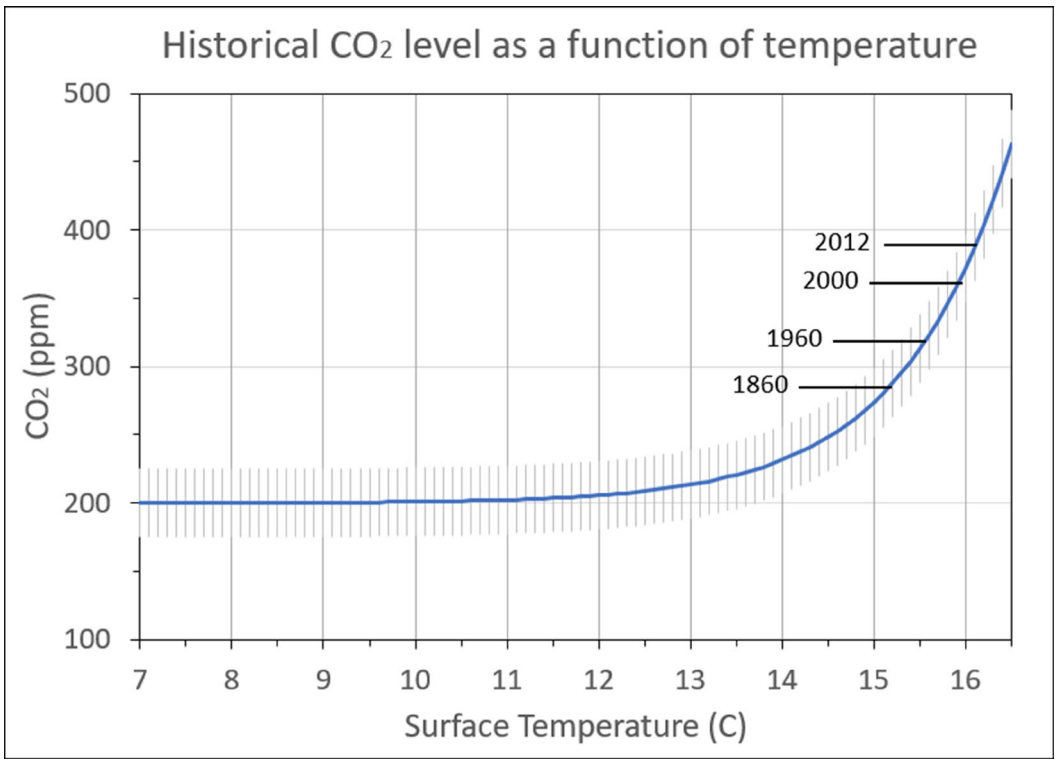

Figure 19. Harde [22] (Figure 3) curve fit by to CO_2 and surface temperature data.

Kuo et al. [37] uses time-series analysis to confirm that temperature and atmospheric carbon dioxide are significantly correlated and found that changes in atmospheric CO_2 lag temperature changes by five months.

Kouwenberg [38] shows evidence that temperature controls the CO_2 level,

> "… temperature-driven changes in CO_2 flux between ocean surface waters and atmosphere may be invoked as a plausible mechanism to explain at least a substantial part of the reconstructed CO_2 variations over the last Millennium."

Rorsch et al. [20] conclude the main cause of the CO_2 increase since 1750 is ocean outgassing.

MacRae [39] found the rate of change of the CO2 level (dL_a/dt) correlates with the surface temperature and thus atmospheric CO2 changes lag atmospheric temperature changes after approximately nine months delay.

Humlum et al. [35] show CO_2 increases do not correlate with human CO_2 emissions but consistently follow temperature increases by about 9 to 12 months.

Salby [36] shows how CO_2 follows the integral of surface temperature.

Munshi [40] found there is no statistically significant correlation between the rate of human carbon emissions and the rate of change of global surface temperature even using time lags up to 20 years.

Quirk and Asten [41] used CO_2 and 13C data from 1978 to 2017 to conclude that 50% of the CO_2 increase comes from the oceans and 50% comes from plants and fossil fuel emissions. If fossil fuel and natural plant sources are about equal, then Quirk's results support the Physics model predictions that about 25% of the increase comes from fossil fuel emissions.

Skrable et al. [42] conclude from d13C and D14C data that the CO_2 increase after 1750 is due primarily to increasing net inputs of non-fossil CO_2 from the oceans due to temperature increases, not anthropogenic CO_2.

Courtney [43] concludes that temperature can change carbon desorption from the oceans,

> "Qualitative consideration of the carbon cycle suggests the carbon cycle cannot be very sensitive to relatively small disturbances such as the present anthropogenic emissions of CO_2. However, the system could be quite sensitive to temperature. Indeed, the considerations suggest that the relatively large increase of CO_2 concentration in the atmosphere in the twentieth century is likely to have been caused by the increased mean temperature that preceded it. The main cause may be desorption from the oceans. The observed time lag of half a century is not surprising.
>
> "Assessment of this conclusion requires a quantitative model of the carbon cycle, but such a model cannot be constructed because the rate constants are not known for mechanisms operating in the carbon cycle."

Upon reviewing this paper's Preprint, Courtney [44] wrote:

> "Your "physics model" quantifies the anthropogenic and natural contributions to changes in atmospheric CO_2 concentration without need for knowledge of rate constants for individual mechanisms. This is a breakthrough in understanding which Segalstad, Harde, Salby and myself all failed to make."

5.6 How to improve the physics model.

The physics model is a basis for future carbon cycle research. It can include more levels for land, atmosphere, and oceans to better simulate carbon cycle data. It can be adapted into a professional software platform to use monthly time steps and other numerical methods to improve its calculations.

Conclusions

The natural carbon cycle specified by the United Nations Intergovernmental Panel on Climate Change (IPCC) may be the best data available, but it has consequences.

It supports a physics carbon cycle model that replicates IPCC's natural carbon cycle by using IPCC's hypothesis that outflow equals reservoir level divided by an e-time. Because IPCC's natural carbon cycle is at equilibrium, the model derives the natural e-times for each of its six outflow nodes.

Because human and natural carbon 12C atoms are identical, this model uses IPCC's natural carbon cycle e-times to compute a "true" human carbon cycle that is compatible with IPCC's natural carbon cycle.

This "true' human carbon cycle contradicts IPCC's assumption that natural CO_2 stayed at its 1750 level while human CO_2 caused all the CO_2 increase. It shows that human carbon adds only 33 ppm to the atmosphere as of 2020, which means natural CO_2 has added 100 ppm. It shows if human CO_2 emissions stopped at the end of 2020, the human CO_2 level would fall from 33 ppm in 2020 to 16 ppm in 2040, to 10 ppm in 2100, and to 5 ppm by 2180, proving there is no climate emergency.

It shows that net land use change adds little to CO_2 because this carbon flows rapidly to the deep ocean. This means the total human carbon added to the atmosphere before 1950 is less than the measured increase in atmospheric carbon, further proving that natural carbon plays a major part in the CO_2 increase.

The model also shows how increased surface temperature and deep ocean overturning each can add 100 ppm to atmospheric CO_2, explaining how the natural CO_2 level may have increased above 280 ppm.

Finally, the D14C balance level has remained near zero even as the $14CO_2$ and $12CO_2$ levels changed, which shows the ocean is the primary source of the natural $12CO_2$ increase.

Supplementary Materials

Berry, E.X: BerryCarbonCycle_2021. Excel file that includes all the data and numerical calculations described in this paper. https://edberry.com/wp-content/uploads/Climate/BerryCarbonCycle-Atmosphere-2021.xlsx

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Conflicts of Interest:

The Author declares he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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