Global Warming:

Velocity and Acceleration of

Change in Cumulative CO2 Emissions

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Abstract

This publication introduces two parameters related to cumulative CO2 emissions.
The first parameter is "*Velocity of Change in Cumulative CO2 Emissions*", VCCO2.
This parameter represents average annual change in cumulative CO2 emissions,
and is expressed in ton of CO2 per year.

The second parameter is "*Acceleration of Change in Cumulative CO2 Emissions*,
ACCO2, and is expressed in ton of CO2 per year, per year ($tCCO2/y^2$).

These two parameters are in addition to the parameter "*Global Warming Rate*",
GWR [°C/y], and "*Global Warming Acceleration*", GWA [$°C/y^2$], described in the
previous publication.

The velocity of change in cumulative CO2 emissions, VCCO2, is +0.559 GtCCO2/y
in the last 31 years and the acceleration of change in cumulative CO2 emissions,
ACCO2, is +0.011 $GtCCO2/y^2$ in the last 31 years.

Glossary

a = VCCO2 = velocity of change in cumulative CO_2 emissions, parameter "a" in linear trendline:
$dCO2(y) = (y-n) * a + b$, average change in cumulative CO_2 emissions per year in the trendline period, tCO2/y

ACCO2 Acceleration of change in cumulative CO2 emissions, $tCO2/y^2$ (ton CO_2 per year per year)

Ave average

CCO2 Global cumulative CO2 emissions according to publication [1] [2], CO_2 emissions produced from fossil fuels and cement production only – land use change is not included

CO2 emissions of Carbon Dioxide, CO_2

dCO2 Change in global cumulative CO_2 emissions (CCO2), tCO2/y (ton CO_2 per year)

GtCO2 Giga-ton of CO_2, 10^9 ton, 10^9 ton, 1,000,000,000 ton of CO_2

GWA Global Warming Acceleration, yearly change in the global warming rate, $°C/y^2$ [3]

GWR Global Warming Rate – average change in global surface temperature per year in the trendline period, °C/y [3]

OWID Our World in Data – Internet site [1] [2]

Ref reference

tCO2 ton CO_2

TL trendline

VCCO2 = a = Velocity of change in cumulative CO_2 emissions, tCO2/y

Database of Global Cumulative Amount of CO2

Table 1 -   Database of global cumulative amount of CO2

Source of Data	OWID
Reference	[1] [2]
Baseline year	1749
From year	1750
To year	2020
Period, years	271
CO2 from fossil fuels	Yes
CO2 from cement production	Yes
CO2 from other sources	No
Other GHG	No
Land use change	No
Units	ton CO2
Resolution	1 ton CO2/y

The database is from publication [1] [2], CO2 emissions produced from fossil fuels and cement production only – land use change is not included.

Formulas

Formula 1 - Linear trendline

$$dCO2(y) = (y-n) * a + b$$

dCO2(y)   change in global cumulative CO2 emissions in year y [tCO2/y]

n   the year before the trendline start point, i.e., for trendline in period 1950-1980 n=1949

a, b   parameters related to the linear function displayed on the Excel trendline chart

Formula 2 - Velocity of change in cumulative CO2 emissions, VCCO2 [tCO2/y]

$$VCCO2 = a \ [tCO2/y]$$

Formula 3 - Acceleration of change in cumulative CO2 emissions, ACCO2 [tCO2/y^2]

$$ACCO2 = \Delta a / \Delta y \ [tCO2/y^2]$$

Formula 4 - Δa

$$\Delta a = a(i+1) - a(i)$$

a(i+1)   average change in cumulative CO2 emissions per year in trendline "i+1" period = parameter "a" of trendline "i+1" (from Excel chart formula) [GtCO2/y]

a(i)   average change in cumulative CO2 emissions per year in trendline "i" period = parameter "a" of trendline "i" (from Excel chart formula) [GtCO2/y]

Formula 5 - $\underline{\Delta y}$

$$\Delta y = CenterTL(i+1) - CenterTL(i)$$

CenterTL(i+1)   center of trendline "i+1" [year]
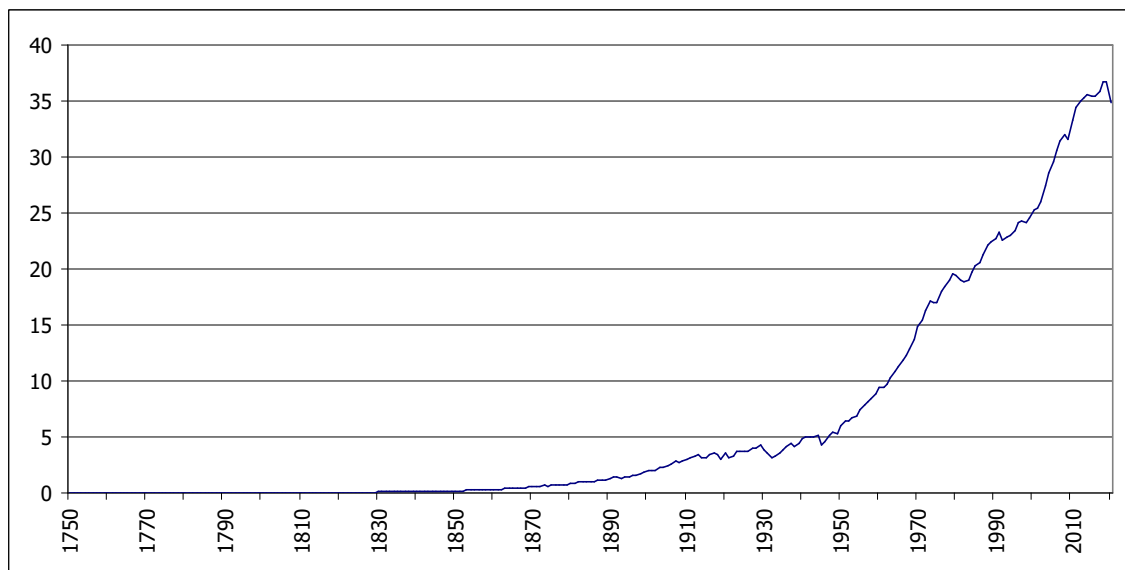CenterTL(i)   center of trendline "i" [year]

Formula 6 - <u>CenterTL</u>

CenterTL(i) = Average(start year of trendline TL(i), end year of trendline TL(i))

Period Applied for Calculations of Trendlines

The period applied in this work for calculations of trendlines is 31 years. The starting points of the trendlines are every 10 years from 1750.

Change in Cumulative Amount of CO2

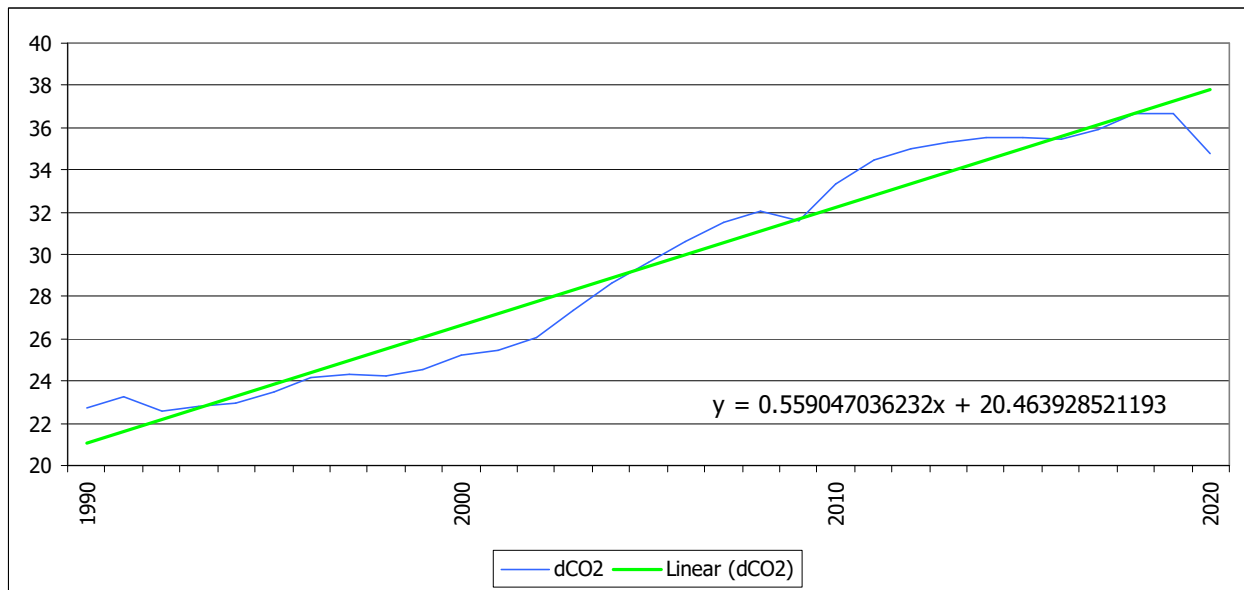Chart 1 -   Annual change in the cumulative amount of CO2 [GtCO2/y]

The change in 2019 was +36.70 GtCO2/y and in 2020 +34.81 GtCO2/y.

Velocity of Change in Cumulative CO2 Emissions

In this work, the velocity of change in the cumulative CO2 emissions is determined as the slope of the 31 years trendline, as indicated on the trendline chart in the specific period.

Following is an example of a trendline in the period 1990-2020, trendline ID=TL25.

Chart 2 - <u>Annual change in cumulative CO2 emissions in period 1990-2020, TL25 [GtCO2/y]</u>

The trendline formula for this period (TL25) is:

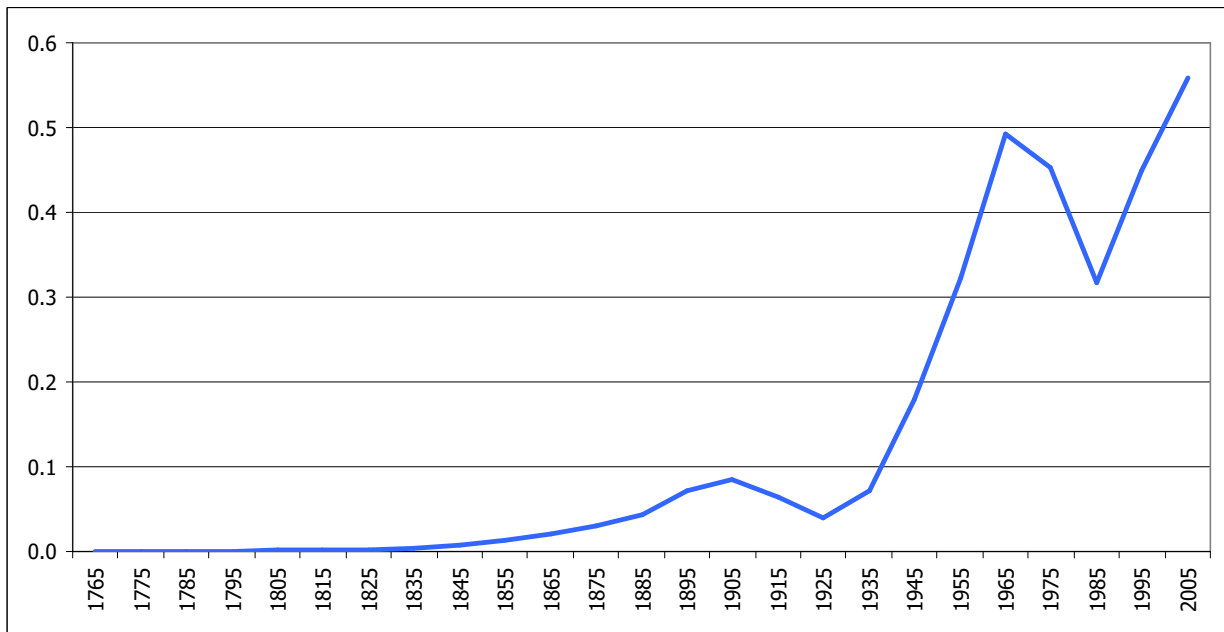$$y = 0.559047036232x + 20.463928521193$$

$$a = 0.559047036232$$

$$b = 20.463928521193$$

The average change in cumulative CO2 emissions in the period 1990-2020 is 0.559 GtCO2/y (=a), which is the slope of the linear trendline in this period (1990-2020).

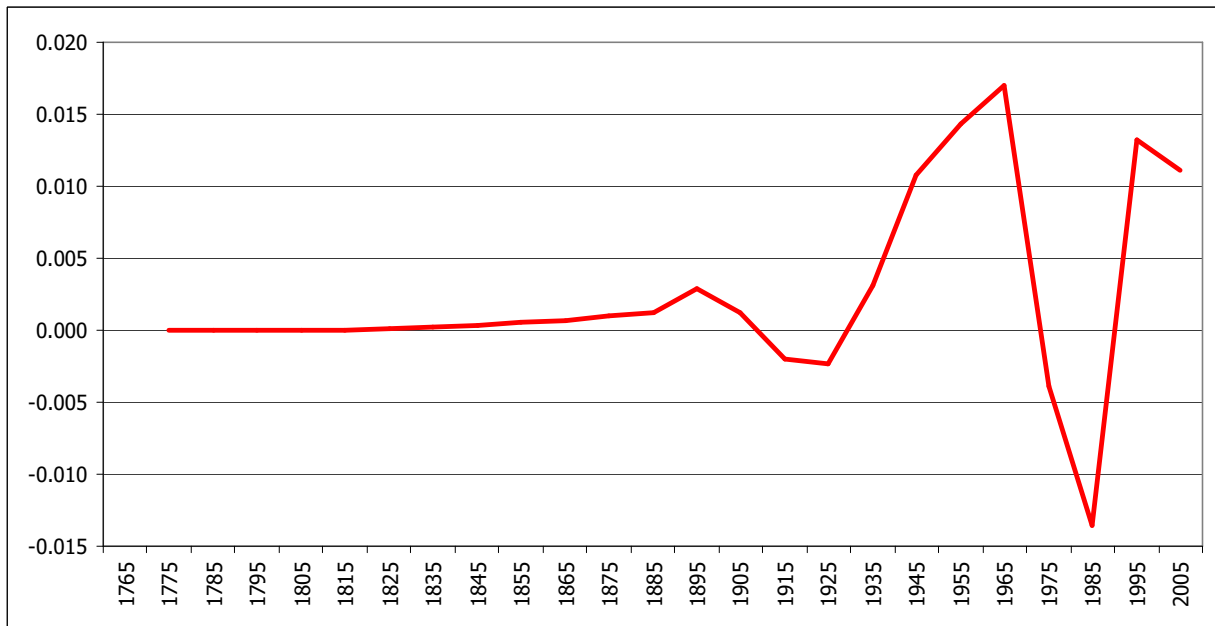## Table 2 - Velocity of change in cumulative CO2 Emissions

i	Trendline ID	Trendline period			Trendline Center		Velocity of change VCCO2		Acceleration of change
		from	to	years		Δy	a	Δa	ACCO2
Symbol	TL(i)				CenterTL	Δy	a	Δa	ACCO2
Formula					Formula 6	Formula 5	Formula 1	Formula 4	Formula 3
Units		year	year	years	year	years	GtCO2/y	GtCO2/y	GtCO2/y^2
1	TL1	1750	1780	31	1765		0.000220		
2	TL2	1760	1790	31	1775	10	0.000311	+0.000091	+0.000009
3	TL3	1770	1800	31	1785	10	0.000453	+0.000142	+0.000014
4	TL4	1780	1810	31	1795	10	0.000776	+0.000323	+0.000032
5	TL5	1790	1820	31	1805	10	0.001066	+0.000290	+0.000029
6	TL6	1800	1830	31	1815	10	0.001443	+0.000377	+0.000038
7	TL7	1810	1840	31	1825	10	0.002604	+0.001162	+0.000116
8	TL8	1820	1850	31	1835	10	0.004615	+0.002010	+0.000201
9	TL9	1830	1860	31	1845	10	0.007932	+0.003317	+0.000332
10	TL10	1840	1870	31	1855	10	0.013843	+0.005911	+0.000591
11	TL11	1850	1880	31	1865	10	0.020686	+0.006843	+0.000684
12	TL12	1860	1890	31	1875	10	0.030357	+0.009671	+0.000967
13	TL13	1870	1900	31	1885	10	0.043131	+0.012773	+0.001277
14	TL14	1880	1910	31	1895	10	0.071491	+0.028360	+0.002836
15	TL15	1890	1920	31	1905	10	0.084017	+0.012526	+0.001253
16	TL16	1900	1930	31	1915	10	0.063628	-0.020389	-0.002039
17	TL17	1910	1940	31	1925	10	0.039970	-0.023658	-0.002366
18	TL18	1920	1950	31	1935	10	0.071128	+0.031158	+0.003116
19	TL19	1930	1960	31	1945	10	0.179048	+0.107920	+0.010792
20	TL20	1940	1970	31	1955	10	0.322026	+0.142978	+0.014298
21	TL21	1950	1980	31	1965	10	0.491742	+0.169716	+0.016972
22	TL22	1960	1990	31	1975	10	0.452316	-0.039426	-0.003943
23	TL23	1970	2000	31	1985	10	0.316548	-0.135768	-0.013577
24	TL24	1980	2010	31	1995	10	0.448283	+0.131735	+0.013174
25	TL25	1990	2020	31	2005	10	0.559047	+0.110764	+0.011076

Chart 3 - <u>Velocity of change in cumulative CO2 emissions a=VCCO2 [GtCO2/y]</u>

Axis x is the center of the trendline period (2005 is the center of the 1990-2020 trendline period)

Chart 4 - <u>Acceleration of change in cumulative CO2 emissions, ACCO2 [GtCO2/y^2], [Giga-ton CO$_2$ per year per year]</u>

Axis x is the center of the trendline period (2005 is the center of the 1990-2020 trendline period)

Negative acceleration in the years 1915-1925 and the year 1985 means a decrease in velocity of change in the cumulative amount of CO2. In the period of trendline 1985, from 1970 to 2000, the velocity changed from 0.45 GtCO2/y to 0.32 GtCO2/y, -0.13 GtCO2/y.

References

1. Hannah Ritchie, Max Roser, Edouard Mathieu, Bobbie Macdonald and Pablo Rosado - Data on CO_2 and Greenhouse Gas Emissions by Our World in Data
   https://github.com/owid/co2-data#data-on-co2-and-greenhouse-gas-emissions-by-our-world-in-data

2. Our World in Data, Cumulative CO_2 emissions, 2020
   https://ourworldindata.org/grapher/cumulative-co-emissions

3. Global Warming Acceleration - Joseph Nowarski, DOI: 10.5281/zenodo.6393436

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