SCC Publishing
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ISSN: 2703-9072

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ocn.ne.jp

Vol. 5.1 (2025)

prelimin. pp. 1-30

Pitfalls in Global Warming and Climate Change Research: Flaws in Ice Core Reconstructions of Atmospheric CO_2

- The Naked King of 280 ppm at the Industrial Revolution -

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Abstract

Recent global warming and climate change studies frequently assume that the rise in atmospheric CO_2 is entirely due to human emissions. In particular, the assumption is based on a figure of CO_2 concentration of 280 ppm at the end of the pre-industrial period. However, this assumption reveals itself to be contradicted by an examination of the relevant underlying data. At least, this assumption cannot be fully trusted. This paper points out in plain language the flaws in the fundamentals of the relevant climate change research, using as little technical terminology as possible. Furthermore, some clarification is made in the Appendix, to address typical misunderstandings of the author's previous paper, that have been seen discussed in the Internet.

Keywords: CO_2; preindustrial CO_2, 280 ppm; ice core data reconstruction; ice cores; Zbigniew Jaworowski; Ernst-Georg Beck; Climate Change

Submitted 2024-12-09, Accepted 2025-02-08. https://doi.org/10.53234/scc202501/04

1. Introduction

In the recent debate on global warming and climate change, there are two major positions. The first one is that the change is wholly or partially caused by humans (the Intergovernmental Panel on Climate Change, IPCC, [1]). When attributing human causes, the largest contributor is the increase in atmospheric CO_2 due to the use of fossil fuels. This is followed by the impact of methane. Based on this hypothesis, various regulations and taxation are widespread around the world, with emissions trading as a typical example.

The other position is that humanity is irrelevant or has negligible climate impact. This position is represented by the Global Warming Petition Project [2], the International Conference of Climate Change (ICCC, Singer [3]), the Global Climate Intelligence Group (CLINTEL [4]), CO_2 Coalition [5], and the declaration made by more than 90 Italian scientists [6].

Instead of human impacts, the dominant influence is seen in natural variations like solar radiative forcing (Soon [7], Soon et al. [8]) and the effect of cloud formation due to the Svensmark effect (Svensmark et al. [9], Nikolov et al. [10]).

In any case, the climate models primarily employed by IPCC are fatally flawed as they virtually trivialize the effects of solar activity. John Clauser, the 2022 Nobel Prize Laureate in Physics, criticizes the IPCC-adopted model for not adequately assessing the impact of clouds (Clauser, [11]).

Furthermore, most of the representatives of a dominating native climate change believe in the overwhelming benefits of CO_2 for life on Earth [2 - 6].

On the other hand, there are two major views for the rising atmospheric CO_2 concentration. First, it is all man's responsibility [1, 5], and second, there is no human impact or only a minute contribution, which is supported by (Ato [12], Salby et al. [13], Humlum et al. [14], Berry [15], Koutsoyiannis et al. [16]).

Therefore, the contemporary global warming and climate change debate can be broadly categorized into the following three groups:

- All or most of the recent CO_2 rise and climate change has been caused by mankind
- The recent rise in CO_2 is all or mostly due to mankind, but mankind is not responsible for climate change, or just a minor part of the change
- Neither the recent CO_2 rise nor climate change is caused by mankind, or, the anthropogenic effects are small

This study mainly points to flaws that lead to the assumption of a mostly human-caused increase in CO_2, in particular to the problems related to the methods used in the reconstruction from Antarctic ice cores and of the general consensus of 280 ppm CO_2 at the onset of the Industrial Revolution.

The outline is as follows:

- The limitations of the accuracy of CO_2 reconstruction using Antarctic ice core data, and the contradictions of the 280-ppm theory.
- Meaning of the decrease in atmospheric methane concentration at the beginning of the 21st century.
- A review of related papers from the past as well as points raised by Zbigniew Jaworowski.
- Verification based on past periods of dramatic climate change.
- Update and simulation of the author's previous report [12].

In addition, supplementary information is added as Appendix, concerning misinterpretations of the author's previous paper.

In the analysis of this report, all human emissions data will be taken from Our World In Data (OWID, [17]). The consistency with the International Energy Agency (IEA) data has been verified in the author's previous report in this journal and using only OWID data is appropriate (Figure 3 in [12]). And because the IEA charges a fee for long-term data, the author expects that readers around the world will be able to reproduce the contents of the current paper on their own at a low cost.

2. Limitations of accuracy of the latest Antarctic ice core data

These data are available to the public in an Excel file on the National Oceanic and Atmospheric Administration (NOAA) website (NOAA [18], Bereiter et al. [19]). Data obtained from sampling at multiple sites in Antarctica are summarized.

CO_2 reconstructions are obtained from ice cores with the year 1950 as the starting point (Microsoft® Excel® sheet "CO_2 Composite"). However, even for relatively recent data, such as the early 20th century, data for some years are missing. On the other hand, there are years in which two or more data exist within the same year.

To summarize these data as annual values going back to 1850, representative values for each year were calculated using certain rules. In years with multiple data, the average was used as the representative value. For years with no data, average of the data before and after the missing years is used. Table 1 shows examples. The data since 1850, calculated according to this rule, are shown in Table 2.

Table 1. Calculation example of annual average CO_2 data from Antarctic ice cores. BP=A.D. 1950, unit for CO_2 concentration in ppm, the data for 1951, 1955, 1888, 1886, 1881, 1880, 1875 and 1874 are not available in the above examples. If there are multiple data for the same year, the average is calculated. In years where there is no data, the average change of the surrounding years was calculated.

year	Gasage (yr BP)	CO_2 (original)	CO_2 Yearly average	CO_2 representative value
1958	-8.56	316.33	316.22	316.22
1958	-8.10	316.10		
1957	-7.87	314.57	315.15	315.15
1957	-7.26	315.27		
1957	-7.20	316.33		
1957	-7.10	314.44		
1956	-6.16	315.34	315.34	315.34
1955				315.03
1954	-4.80	314.71	314.71	314.71
1953	-3.79	313.17	312.73	312.73
1953	-3.71	312.80		
1953	-3.56	312.22		
1952	-2.38	312.18	312.18	312.18
1951				312.09
1950	-0.25	312.00	312.00	312.00
1949	0.33	313.66	313.66	313.66
1948	1.23	309.69	309.69	309.69
1947	2.29	311.57	311.57	311.57
1946	3.34	310.36	311.61	311.61
1946	3.37	312.87		

year	Gasage (yr BP)	CO_2 (original)	CO_2 Yearly average	CO_2 representative value
1889	60.13	290.92	291.63	291.63
1889	60.99	292.34		
1888				292.99
1887	62.61	294.34	294.34	294.34
1886				291.23
1885	64.40	288.12	288.12	288.12
1884	65.82	289.23	289.23	289.23
1883	66.21	289.76	289.76	289.76
1882	67.08	292.46	292.46	292.46
1881				290.90
1880				289.34
1879	70.05	287.77	287.77	287.77
1878				288.29
1877				288.81
1876	73.09	289.33	289.33	289.33
1875				290.07
1874				290.81
1873	76.26	291.56	291.56	291.56
1872	77.17	286.66	286.66	286.66

Table 2. CO_2 data from Antarctic ice cores. The unit for the CO_2 concentration is ppm, and years with no data in the original Excel file are marked in red.

year	CO_2 representative value	year	CO_2 representative value	year	CO_2 representative value	year	CO_2 representative value	year	CO_2 representative value	year	CO_2 representative value
		1940	309.77	1920	302.81	1900	294.22	1880	289.34	1860	286.99
		1939	310.65	1919	301.88	1899	295.19	1879	287.77	1859	286.81
1958	316.22	1938	310.29	1918	304.61	1898	296.16	1878	288.29	1858	286.63
1957	315.15	1937	311.92	1917	303.85	1897	295.75	1877	288.81	1857	284.90
1956	315.34	1936	307.41	1916	302.88	1896	295.34	1876	289.33	1856	283.16
1955	315.03	1935	307.64	1915	301.92	1895	294.92	1875	290.07	1855	284.36
1954	314.71	1934	308.00	1914	300.70	1894	294.51	1874	290.81	1854	285.57
1953	312.73	1933	308.35	1913	301.00	1893	294.10	1873	291.56	1853	288.05
1952	312.18	1932	307.49	1912	301.30	1892	295.02	1872	286.66	1852	286.76
1951	312.09	1931	306.62	1911	298.49	1891	293.89	1871	286.49	1851	285.47
1950	312.00	1930	305.74	1910	298.11	1890	292.76	1870	286.33	1850	286.40
1949	313.66	1929	305.38	1909	297.87	1889	291.63	1869	287.99		
1948	309.69	1928	305.72	1908	301.50	1888	292.99	1868	289.54		
1947	311.57	1927	308.02	1907	300.56	1887	294.34	1867	287.99		
1946	311.61	1926	306.49	1906	299.61	1886	291.23	1866	285.05		
1945	312.11	1925	304.97	1905	298.66	1885	288.12	1865	285.85		
1944	310.65	1924	304.72	1904	297.33	1884	289.23	1864	286.65		
1943	312.36	1923	304.70	1903	295.99	1883	289.76	1863	286.00		
1942	312.36	1922	304.69	1902	295.80	1882	292.46	1862	285.35		
1941	312.39	1921	303.75	1901	295.61	1881	290.90	1861	287.17		

These data were linked to the modern directly measured data at Mauna Loa, Hawaii (NOAA [20]). Absolute values since 1851 are shown in Figure 1, and annual increases (ΔCO_2) in Figure 2.

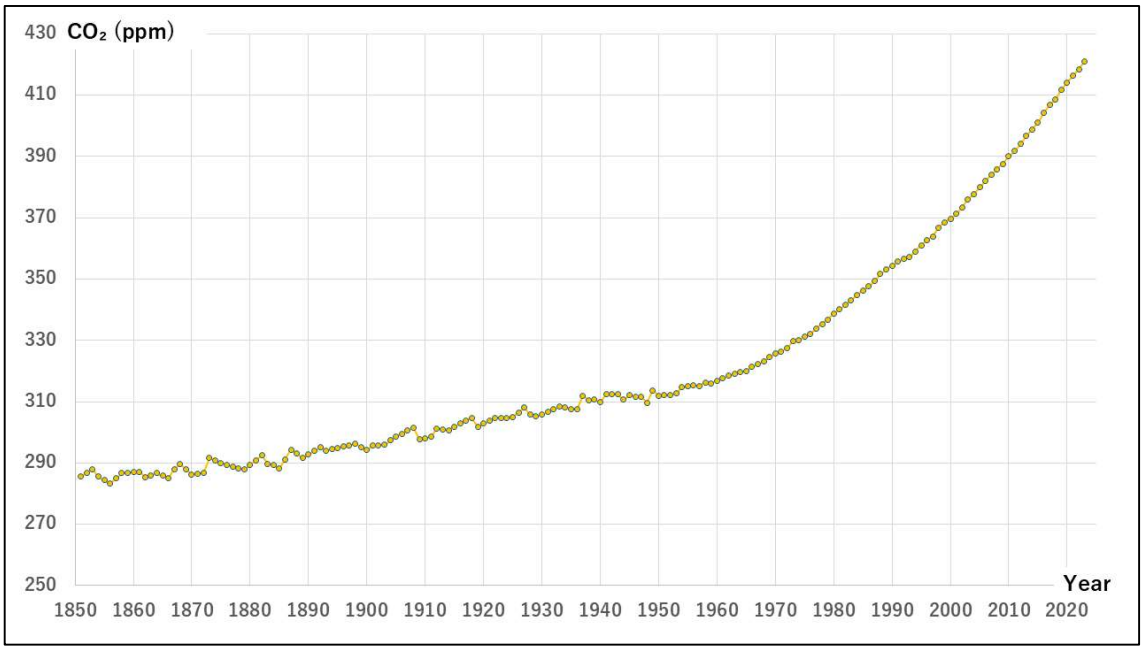

Figure 1. Linking CO_2 data from the Mauna Loa in Hawaii and the Antarctic ice cores

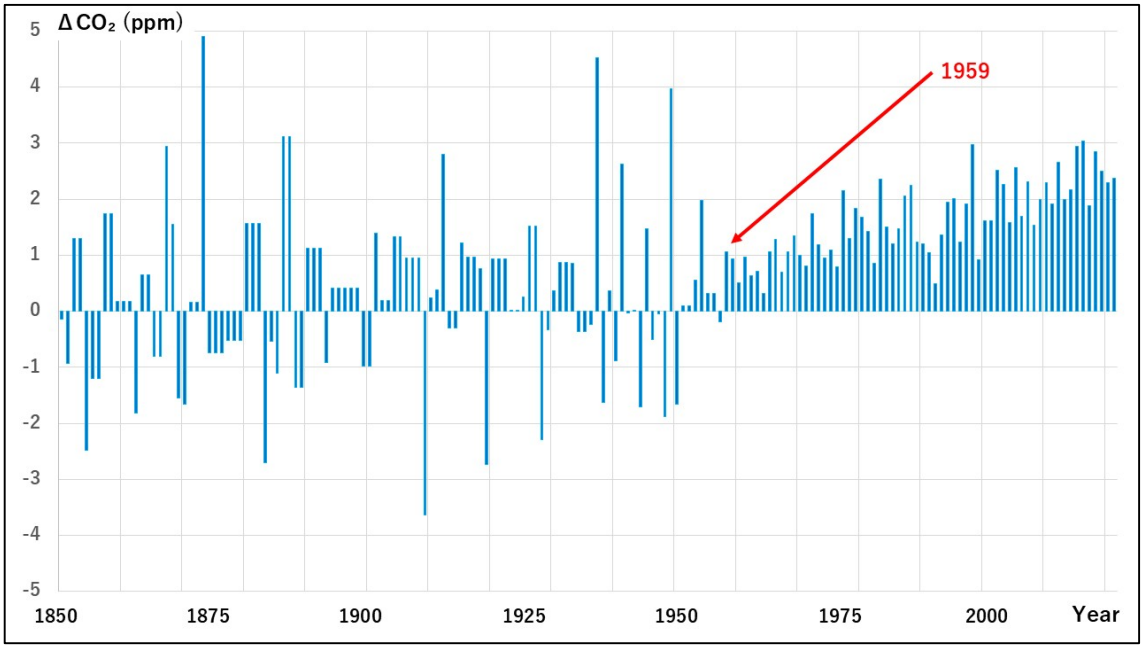

Figure 2. Annual increase in atmospheric CO_2 since 1851, ΔCO_2 = CO_2 concentration over one year.

In Figure 1, the graph may look smooth at first glance. However, Figure 2 shows a number of inexplicable variations of ΔCO_2. Since 1959, ΔCO_2 has fluctuated but has risen consistently and has not decreased. Furthermore, the maximum ΔCO_2 since 1959 is about 3 ppm.

On the other hand, before 1958 there are several years which show an increase of about 5 ppm or a decrease of about 3.5 ppm. These data compel us to question the accuracy of the data. If these reconstructed values are correct, then there have actually been many years since the Industrial Revolution in which atmospheric CO_2 has decreased. In other words, the idea that human emissions have always been accumulating is rejected.

Similarly, in years of an increasing concentration, the underlying problem becomes apparent.

These are data of ΔCO_2 which could not have occurred, even if all human emissions at that time [17] would have remained in the atmosphere.

The most impressive value is the ΔCO_2 of 4.9 ppm in 1873. The data for 1872 and 1873, which correspond to this ΔCO_2, are noted in the original data (Excel® sheet "CO_2 Composite", [18]). They are 286.66 ppm (77.17 yr BP, BP = 1950) and 291.56 ppm (76.26 yr BP), respectively (just to be clear, this is not a calculation made by the author). These values are also shown in Tables 1 and 2.

The year, when human emissions exceeded 7.8 gigatons (Gt, equivalent to 1 ppm) was 1913 [17]. Before this year, an increase of more than 1 ppm per year is impossible, even when the CO_2 increase over the Industrial Era is assumed to be only of anthropogenic origin.

On the other hand, this is also problematic for years in which CO_2 declines. There is no rational explanation as to why nature absorbed so much at this time. According to NOAA [21, 22], the maximum intra-annual variation of atmospheric CO_2 in modern Antarctica is about 3 ppm (Figure 3). Furthermore, in ice core reconstructions, the values for the periods before and after are assumed to be averaged. Hence, in any case, the pre-1958 ΔCO_2 as shown in Figure 2 is not plausible and the stronger fluctuations can only be explained as inaccuracy of the relative year-to-year measurements, independent of additional errors for specifying the absolute CO_2 level.

And this phenomenon of ΔCO_2 reveals a further problem. This is an unexplainable phenomenon occurring even in ice core data of the youngest group. This fact proves the various limitations in the reconstruction of atmospheric component concentrations by ice cores that Jaworowski pointed out. This is especially likely the case for older ice core data. The points made by Jaworowski will be summarized later.

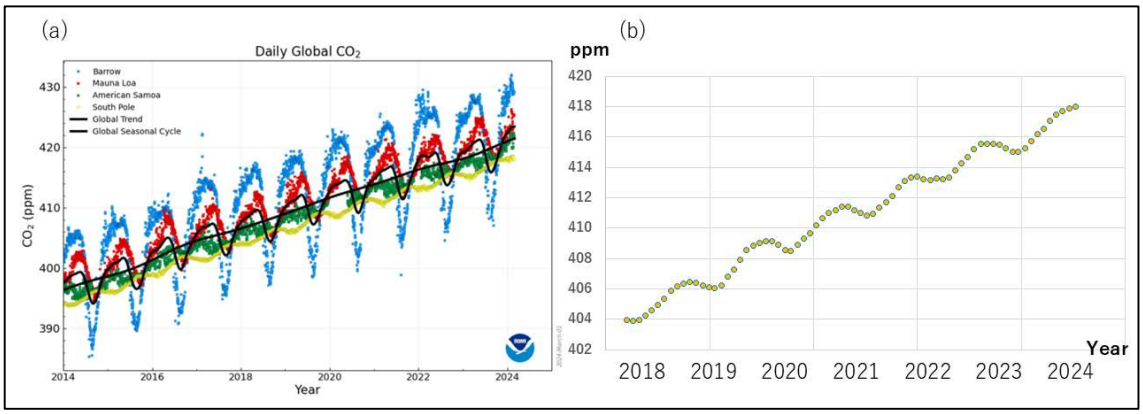

Figure 3. World atmospheric CO_2 (data from NOAA), (a) Global, (b) Antarctica only

This is also the reason why the author (Ato, [12]) did not include pre-1958 data in the previous paper (see also the Appendix). This is because there are many ΔCO_2 values that cannot be explained by human emissions at that time, thus making it impossible to use them in a multivariate analysis. Whenever using these values, it will only produce erroneous statistical analysis results.

3. Discrepancy between cumulative anthropogenic CO_2 emissions and assumed absorption for the 280-ppm hypothesis

The Sixth Assessment Report (AR6) of the IPCC [1] asserts that the entire increase in greenhouse gases since around 1750 is undoubtedly caused by humans. Furthermore, it is stated that over the past 60 years, 56 % of human CO_2 emissions have flowed from the atmosphere to the oceans and land at a nearly constant rate.

However, a simple numerical check of this explanation and the assumed CO_2 concentration at the time (280 ppm) reveals a contradiction. When the first report of WG 1 of AR6 was released in

2021, the analysis in this section considers the data up to this year. The atmospheric CO_2 concentration is based on data from Mauna Loa, Hawaii.

Between 1959 and 2021, atmospheric CO_2 increased by 100.43 ppm. The amount of CO_2 emitted by humans during this time is equivalent to 225.69 ppm (including land use change (LUC), 1760.39 Gt ÷ 7.8 = 225.69 ppm, 1960-2021). Therefore, the residual rate for this period is 44.5 % (the absorption rate is 55.5%) (100.43 ÷ 225.69). Therefore, this part is correct.

Next, the data before 1959 will be verified. As only the data including LUC are available from 1850 onwards, the data between 1850 and 1959 will be used for the further inspection.

The total emissions from 1850 to 1959, including LUC, were 768.45 Gt (equivalent to 98.52 ppm) (Figure 4). If the assumed natural absorption rate during this period was also 55.5 %, then the atmospheric CO_2 concentration in 1850 can be assumed to have been 272.14 ppm (315.98 - 98.52 x 0.445).

At this time, it is below 280 ppm. Therefore, to reach 280 ppm in 1850, the residual rate - also called Airborne Fraction (AF) - has to be assumed to be 36.5% ((316 - 280) ÷ 98.52 ≅ 0.365). However, even though the residual rate has been almost constant at 44.5 % since 1960, there is no rational explanation, why it was 36.5 % on average over the previous 110 years.

Furthermore, although the figures are unknown before 1849, it is certain that there were emissions from humans, including LUC. Therefore, the residual rate from 1750 to 1959 should have been even lower than 36.5 %.

The discrepancy is also clear in terms of quantity. Between 1960 and 2021, the natural environment of the Earth assumedly absorbs an average of 15.76 Gt (1760.39 x 0.555 ÷ 62) of CO_2 per year.

On the other hand, even if atmospheric CO_2 were assumed to be 280 ppm in 1850 and remained stable at 280 ppm from 1750 to 1849, only 4.44 Gt (768.45 x 0.635 ÷ 110) was absorbed annually on average from 1850 to 1959. And in this case, the residuals from 1750 to 1849 would be 0 %.

There is no reasonable explanation for these dramatic differences between the pre-1959 and post-1960 periods. In other words, it shows the limitation of interpreting the absorption rate by nature as a relatively constant ratio to human emissions. Moreover, as shown in Figure 2, if the CO_2 reconstructed data from ice cores are correct, the idea of a constant ratio of natural absorption (or flows to the sea and land) of human emissions is not valid for the period before 1959.

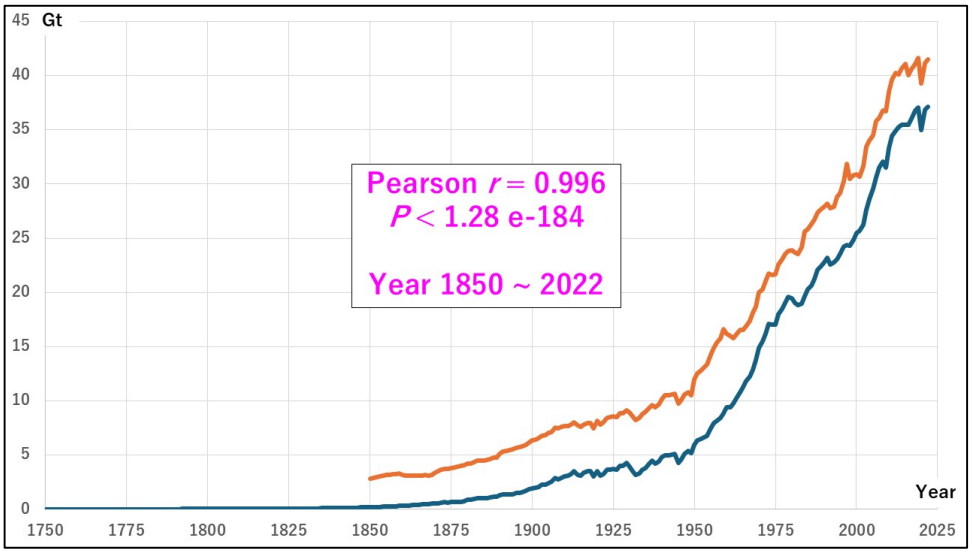

Figure 4. Human CO_2 emissions (1750 - 2022), blue: fossil fuels only, orange: including land use change, human emissions derived from OWID (reference [17])

In reality, the concentration of CO_2 in the atmosphere is determined by the balance between both the natural and anthropogenic inflows and outflows, and the natural flows dominate. This is as Salby and Harde [13], as well as Berry [15] have pointed out.

Therefore, even from this perspective, it has been shown that a value of 280 ppm at the time of the Industrial Revolution cannot be relied upon. This contradiction also provides one basis for supporting the validity of the reports by Beck [23] and Harde [24]. Beck compiled the CO_2 concentration in the atmosphere from quite accurate chemical methods, which are tens of ppm higher than that in ice cores [23]. Harde also confirms the validity of Beck's chemical method for CO_2 reconstruction (Harde, Figure 2 in [24]).

Furthermore, the ΔCO_2 that can be predicted using sea surface temperature (SST) is compared with the assumed natural absorption rate (Figure 5).

Details of the ΔCO_2 prediction using SST are explained in the author's previous paper (Ato [12]). The CO_2 absorption rate estimated using the SST (as a surrogate indictor) from the University of Alabama in Huntsville (UAH) is about 10 % higher than that assumed from the actual ΔCO_2 measurements taken in Hawaii. However, the overall trend of fluctuations is similar. On the other hand, the absorption rates estimated using SST data from the UK's Hadley Centre (HAD) and NASA's Goddard Institute for Space Studies (GISS) are similar.

And while the fluctuations are smaller than the absorption rate assumed from the actual measurements in Hawaii, the trends are similar. However, the possibility of divergence can be suggested, especially from 1963 to 1964 and before. This divergence substantiates the limitations of the accuracy of measurements and integration of global SST before the 1960s.

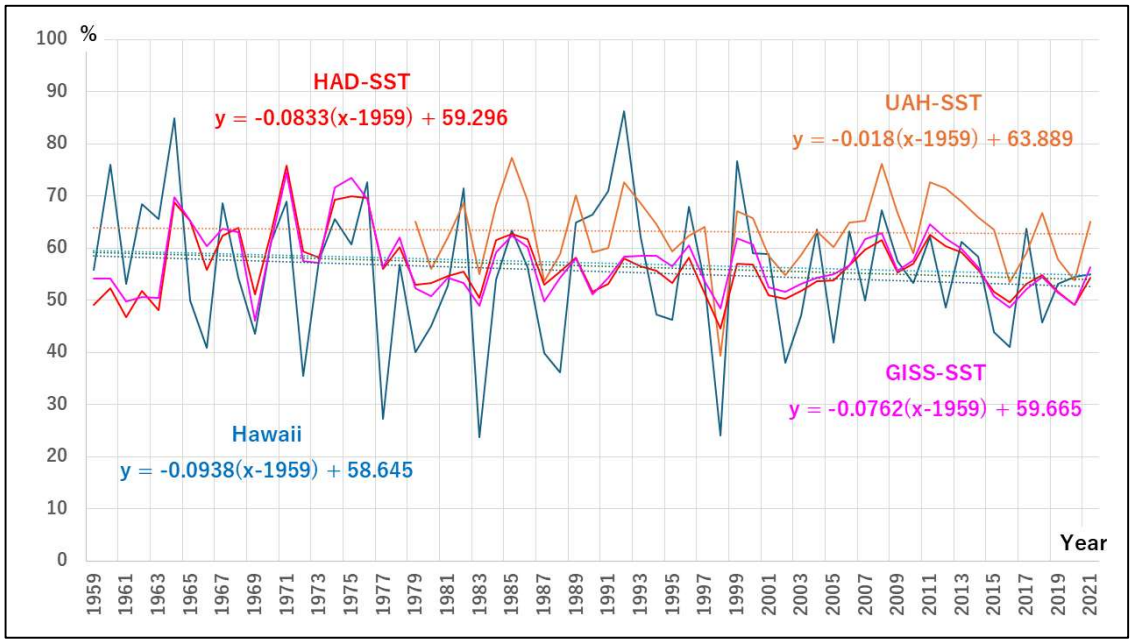

Figure 5. Comparison of absorption rate estimated by sea surface temperature and that assumed to have been absorbed by nature, since 1959, "x" in the equation means year (AD), hypothetical absorption rate (%) = (human emissions (ppm) - predicted ΔCO_2) ÷ human emissions (ppm) x 100. The actual measured value (blue) is (human emissions (ppm) - ΔCO_2 for the relevant year) ÷ human emissions (ppm) x 100. Human emissions converted to ppm (1 ppm = 7.8 Gt), refer to the previously published report for information on the ΔCO_2 predicted using SST. The analyzed period is set to 2021 to match with the first edition of the sixth IPCC report.

4. Meaning of the atmospheric methane decline in the Early 21st Century

It is frequently argued that humans are also responsible for the recent rise in atmospheric methane.

However, as the author (Ato [12]) showed in the previous paper, this figure has declined twice since the beginning of the 21st century (Figure 6, NOAA, [25]). This is what has actually happened in the modern era of mass human emissions. If all human emissions remain in the atmosphere, they should rise by at least 100 ppb per year in the 21st century and beyond (Ato, [12]). However, there are actually years of decline. Moreover, the annual fluctuation values are not consistent.

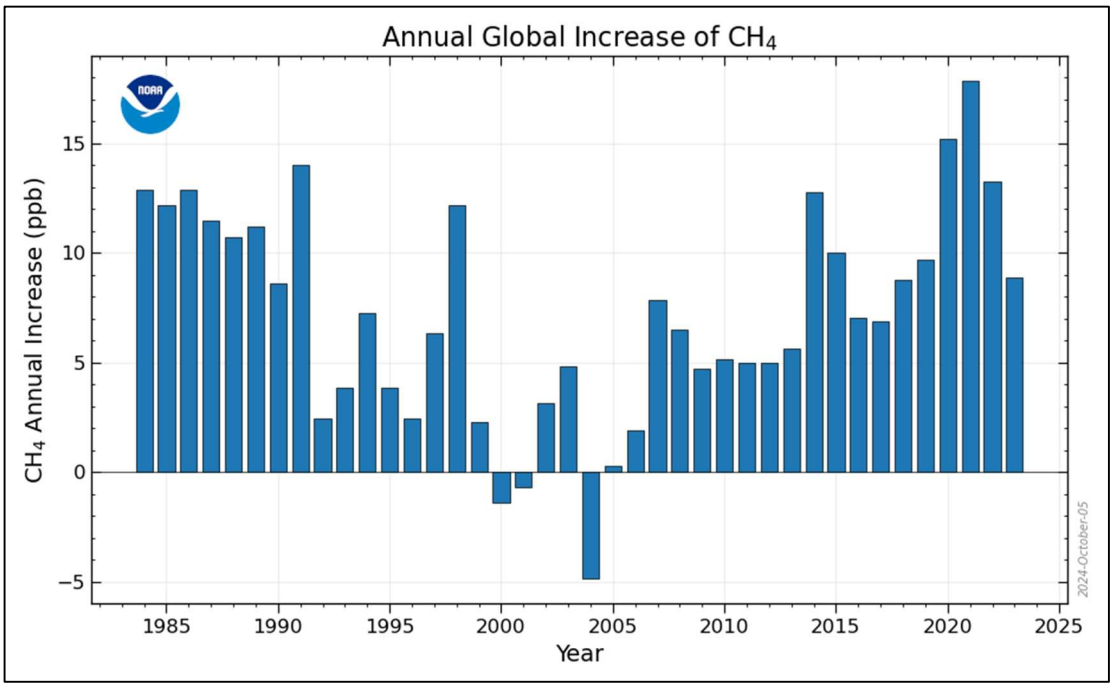

Figure 6. Recent atmospheric concentration of methane, the image is adopted from NOAA [25]

This phenomenon means at least three things.

Firstly, in the methane cycle of the Earth, the influence of nature far exceeds that of modern humans.

Secondly, even the values that have risen by about 10 ppb in recent years can no longer be attributed to human influence. This happens, as long as there are actual years of decline, and as long as there are actual years in which nature transcends human emissions.

Thirdly, this phenomenon is common to the reconstructed CO_2, and that meaning will be explained later.

If the rise in methane in all years would have been due to the methane produced by humans, it would be inconsistent, when it did not rise at least consistently and to a similar degree during all years. Thus, the representative data by IPCC showing that methane has risen about 1000 ppb since the Industrial Revolution, also is in contradiction (Ato, [12]).

Since atmospheric methane has actually dropped even in present days, when humans are emitting large amounts of the gas, it cannot be assumed that about 1000 ppb would have accumulated and risen in previous periods of low emissions.

Moreover (third aspect), this behaviour of methane compels us to question the reconstructed value of atmospheric CO_2 because the abrupt increase that coincides with the Industrial Revolution is the same phenomenon (Figure 7, IPCC, [26]).

This is because the data reconstructed by ice cores were shifted forwards and linked onto modern measurements. However, now where the inconsistency of methane reproduction by ice cores has been clarified, we must consider similar phenomena for CO_2. Therefore, the appropriateness of this method must be verified.

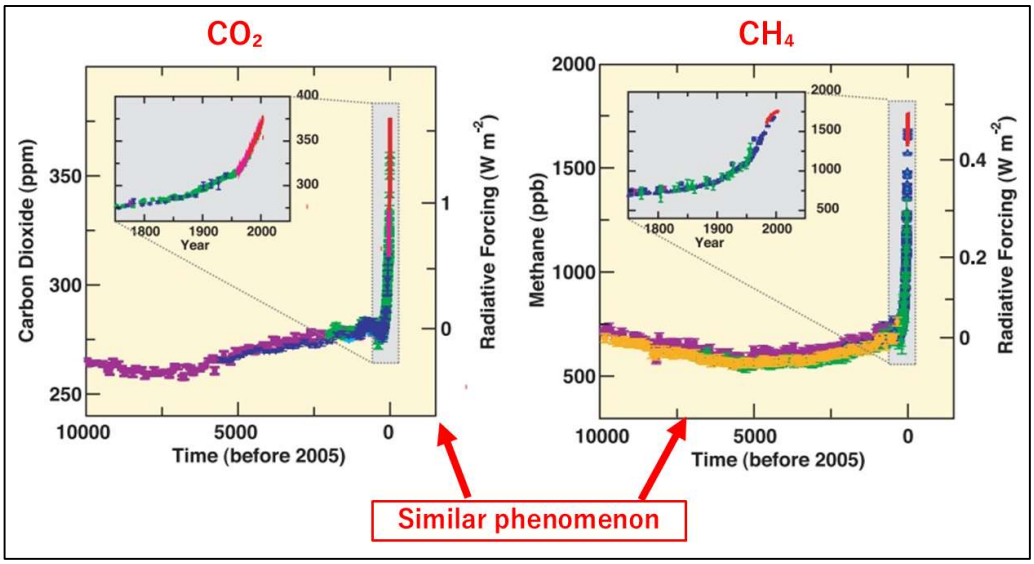

Figure 7. Phenomena common to the reconstructed values of methane and CO_2, the image is taken from the IPCC Fourth Assessment Report [26].

5. Conflicting reports from the 1980s about reconstructed CO_2 and methane from ice cores

In this section, the first published papers from the 1980s on CO_2 and methane data linkage will be reviewed.

The first important report on this issue was from methane. Table 3 shows the overview.

Table 3. Highlights of key reports from the 1980s on the reconstruction of CO_2 and methane from ice cores and data linkage

Reconstructed gas	year	Authors, Journal	Key points
CO_2	1985	A. Neftel, E. Moor, H. Oeschger & B. Stauffer Nature volume 315, pages45–47 (1985)	CO_2 concentration from the Antarctic ice is reconstructed (Siple Station). Data is presented for depths below 68.2m from the surface. The age of the ice at this location is set at 1891, and it is concluded that the gases within it are 95 years younger.
	1986	H. Friedli, H. Lötscher, H. Oeschger, U. Siegenthaler & B. Stauffer Nature volume 324, pages237–238 (1986)	In the first paragraph of the main text, the authors explain that, "One of the prerequisites for reproducing the gases in an ice core is that there is no melting layer, and the sample from Siple station satisfies this." The age of the gas was then moved forward by 83 years and linked to the data from Hawaii. Furthermore, the method was deemed consistent based on the verification of carbon isotopes.
CH_4	1982	H. Craig, C. C. Chou Geophysical Research Letters Volume 9, No. 11, Pages 1221-1224, November 1982,	The methane values reconstructed from the Greenland ice core were linked to modern data (Cape Meares, Oregon). For this purpose, the data from the ice core was moved forward 90 years to the present day. In this report, no rigorous verification was carried out using carbon isotopes.
	1988	H. Craig, C. C. Chou, J. A. Welhan, C. M. Stevens, and A. Engelkemeir Science, 16 Dec 1988, Vol 242, Issue 4885, pp. 1535-1539	Verification of the above-mentioned age shifting was performed. Based on the divergence in carbon isotope concentrations, the age of the gas is virtually equivalent to the age of the ice itself, and the authors pointed out that the procedure of age shifting is not reasonable.

First, a group of methane reconstructions reported in 1982 (Craig et al. [27]), and the data from Greenland were linked to the current measurements. This report did not include a rigorous verification of the gas age using a carbon isotope.

Next, there were two reports on the reconstruction of CO_2. In the 1985 report (Neftel et al. [28]),

they reported the reconstructed data based on Antarctic ice cores.

Then, in the 1986 paper (Friedli et al. [29]), these data were shifted forward by 83 years and linked to current high-precision data from Hawaii (Figure 8, originally Figure 1 in [29]).

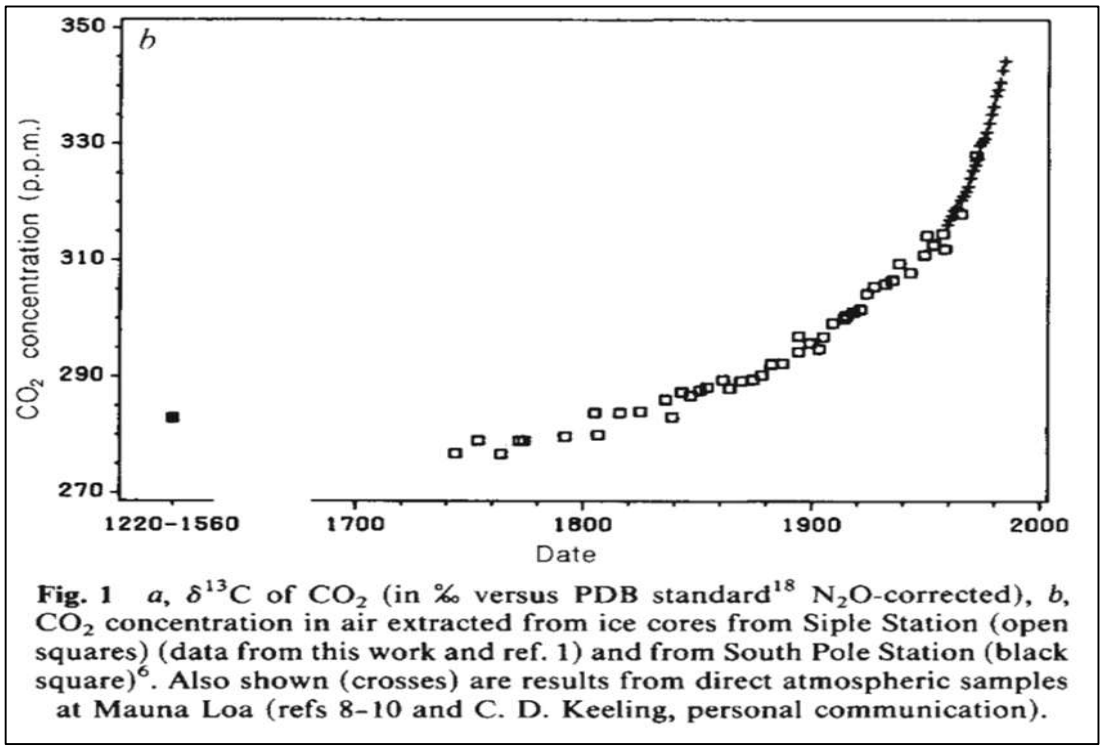

Fig. 1 *a*, $\delta^{13}C$ of CO_2 (in ‰ versus PDB standard[18] N_2O-corrected), *b*, CO_2 concentration in air extracted from ice cores from Siple Station (open squares) (data from this work and ref. 1) and from South Pole Station (black square)[6]. Also shown (crosses) are results from direct atmospheric samples at Mauna Loa (refs 8–10 and C. D. Keeling, personal communication).

Figure 8. Diagram showing the connection between ice cores and high-precision modern CO_2, the image is derived from Friedli et al. [29].

This paper stated at the beginning that "Prerequisites for obtaining a good ice core record of the recent past are a high accumulation rate which yields good time resolution, and the absence of summer melting (meltwater interferes with CO_2)." [29]. In this study [29], the authors explained that the conditions were fulfilled and concluded that there was no contradiction in the age-shifting based on the analysis of carbon isotopes.

However, in the 1985 paper [28], it was stated at the beginning that only one clearly identifiable melt layer of irregular thickness (2 ~ 10 mm) was observed in the entire core at 7 m below the surface (page 45, left column). They also claimed that the annual precipitation was 500 kg/square meter in the sampling site (Siple). This means that the annual precipitation (snowfall) is about 0.5 meters.

Thus, the melting layer had formed about 14 years before the ice was excavated. Therefore, based on the year of ice drilling from which the data in this paper is based (work in the summer of 1983 ~ 1984 [28, 29]), the gas in the ice sheet just below this layer (below 7 m) was confined before 1970, no matter how young.

On the other hand, the 1985 paper [28] assigns 1891 as the year of formation of the ice itself in samples 68.2 to 68.6 m below the surface, while the gases it contains are from 1962 to 1983 (Table 1 in [28]).

However, a distinct melt layer occurred throughout the sample around or before 1970. Therefore, it is impossible for gases from that year onward to enter the lower layer (more than 7 meters below the surface).

Furthermore, the authors argued for the validity of the method by correlating seasonal variations and CO_2 reconstructions at each age (Figure 2 in [28]). However, there are data showing a difference of about 15 ppm at around 82.4 m below the surface, even though the difference is only a

few months (actually most likely 1 or 2 months based on a difference of a few cm in ice core thickness; this paper states in Table 1 in [28] that the 82-83 m sample was formed in 1867) (Figure 9, derived from [28]). Even when changes are smoothed, a difference of 10 cm in the ice cores still equivalates more than 5 ppm in this data (Figure 9).

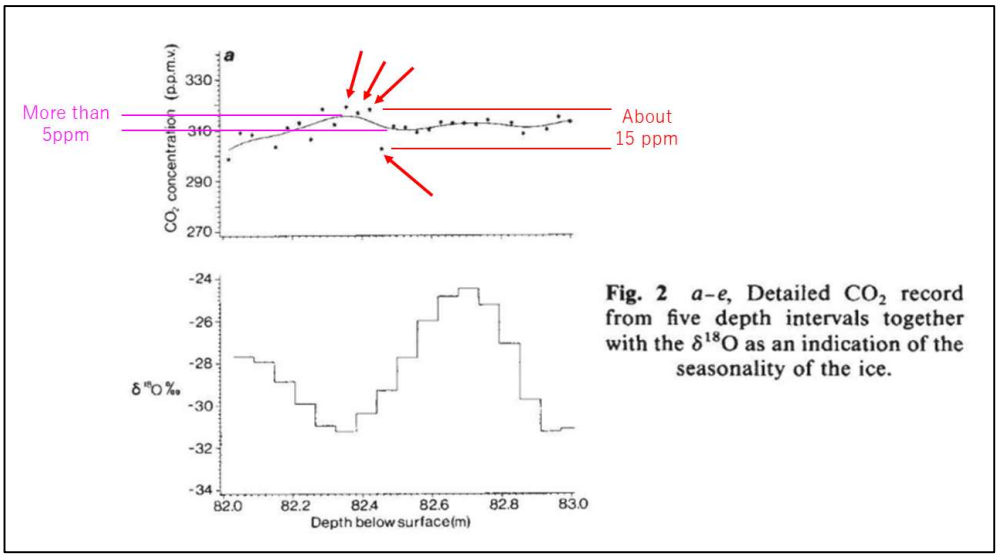

Fig. 2 *a–e*, Detailed CO_2 record from five depth intervals together with the $\delta^{18}O$ as an indication of the seasonality of the ice.

Figure 9. Seasonal cycle of CO_2 in ice cores, the images are derived from Neftel et al.[28], the red and pink supplementary lines were added by the author (Ato). The ice from which the data in this figure was derived is stated to have formed in 1867 in Table 1 of the original paper [28].

In addition, this difference (10-15 ppm) is not only seen in the (a) diagram for the cited year, but also in other years (b ~ e of Figure 2 in [28]).

In reality, however, even in modern Antarctica, the maximum annual difference is about 3 ppm (Figure 3). If the assumption is that the concentration of each component of gas in the ice cores is averaged out until it is closed, then such dramatic differences cannot occur. An unexplainable phenomenon is believed to occur. This is the same kind of inexplicable ΔCO_2 phenomena derived from ice cores as described in Section 2.

Furthermore, in the 1986 paper [29], the authors claimed that CO_2 emissions from the oceans have little effect on changes in atmospheric $\delta^{13}C$. They explain that this is because carbon isotope ratios are very similar between atmospheric and oceanic emissions.

In reality, however, $\delta^{13}C$ (the C13/C12 isotope ratio or normalized permille difference) in the oceans and biosphere are also lower than in the atmosphere (Spencer, [30], Koutsoyiannis, [31], Ollila, [32]). These processes and phenomena again suggest problems related to ice core reconstructions and age shifting.

Next, there was a follow-up report on methane in 1988. In this article, the author (Craig et al. [33]) stated that the age shifting of methane in an ice core is problematic from a carbon isotope perspective. This was due to the large discrepancy between the $\delta^{13}C$ value in the youngest ice core and that in the modern (1980) methane (actually measured).

Figure 10 shows the actual description and the caption of the figure provided by the authors. And the methane reconstruction group also noted a conflict in this regard with the CO_2 reconstruction group. They have, in fact, determined that the age shifting of gases in the ice cores is irrational (Table 3, Figure 10).

Furthermore, there are issues to consider in these series of studies. The group of CO_2 reconstruction performed the gas age shifting despite the fact that there was clearly a melting layer near the surface in their 1986 report [28, 29]. However, the CO_2 reconstruction group

described the method and the values as reasonable. Jaworowski has been meticulous in pointing out the problems with these research processes.

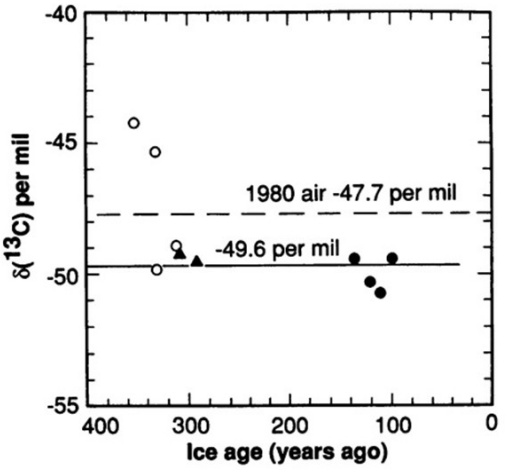

Fig. 2. δ(^{13}C) values of methane in Greenland ice versus age of the enclosing ice. Each sample represents ~0.002 cm^3 (STP) of CH_4 extracted from ~25 kg of ice. Triangles, samples from "Crete," Site A; circles, Dye 3 core samples; solid circles, solid ice; open circles, wafered ice. The means of the two groups of samples differ by only 0.6 per mil: −49.3 ± 0.2 per mil at 310 years, and −49.9 ± 0.3 per mil at 120 years. This difference is insignificant with respect to the mean value of −49.6 ± 0.2 per mil for the set of eight good samples and the ±0.7 per mil errors on the individual data points. [Errors for the two groups of samples and the total set refer to the means; uncertainty in δ(^{13}C) of 1980 air is ±0.2 per mil.]

<related explanation, P1537>
Thus we assumed that trapped air at Dye 3 is as much as 90 years younger than the ice in which it is sealed. Schwander and Stauffer reached the same conclusion. However, the isotopic data seem to preclude such a large difference in age between air and ice. As shown in Fig. 2, this large an age difference at Dye 3 would require an extremely steep rate of change: 2 per mil in isotopic composition in the last 10 years (that is, if the 100-year-old ice contains 10-year-old air). Such a large change seems unreasonable.

Figure 10. Discrepancy of $\delta^{13}C$ in methane between ice cores and modern atmosphere, the figure and the legend are derived from Craig et al. [33].

6. Limitations of the reconstruction method of gas concentrations within ice cores as pointed out by Zbigniew Jaworowski

The following assumptions are made when reconstructing past gas concentrations using polar ice cores (Jaworowski et al. [34, 35], Jaworowski, [36]).

1. In polar regions where the average temperature is -24 degrees or lower, there is no liquid.
2. Fixation of gases within the ice core is a mechanical process that does not involve fractionation (change) of the trapped gas components.
3. The composition of the gas at the time of capture will remain the same indefinitely.
4. The age of the air bubbles is younger than the age of the ice in that location, and there is a difference of tens to thousands of years.

These assumptions can be summarized as follows.

Until a certain part of the ice core is completely sealed off from the outside air, the air bubbles will continue to exchange with the outside air. But once it is sealed off, it will be completely sealed off. Therefore, a time difference will occur. After that, the air bubbles will not undergo any permanent chemical and physical changes.

However, Jaworowski pointed out the flaws in this assumption in detail in two papers he wrote in 1992 [34, 35]. He also wrote a simplified review in 1994 [36]. The overall picture of the points raised by Jaworowski is summarized in Table 4. In reality, there are about 20 chemical and physical processes that can affect the reconstruction of gas concentrations. He also points out the following:

Table 4. Problems with the reconstruction method using ice cores, as pointed out by Jaworowski

	Key Elements and Phenomena	Fractionation
During snow falls and accumulation	The surface of the falling snow is covered in extremely cooled water or salt water (2-3% by volume). After snowfall, a process called snow stratification occurs (due to sunlight and chemical reactions), and a temperature gradient also occurs. In some reports, a gradient of 500° C/m occurs near the surface even in Antarctica. In the upper layers, sunlight is absorbed, the temperature rises, ice crystals melt and evaporate, and then recrystallization occurs repeatedly. In reality, there are an average of 15 melting layers per meter. During this process, separation occurs at each layer (a break occurs), making it difficult or impossible for the gas to be mixed. Even in this process, moisture is present in the microscopic gaps and thin film layers between each ice crystal. At 80-160m, due to pressure, CO_2 (and N_2 and methane) undergo clathrate formation (change from a gas state to a crystalline state). At 900 to 1200 meters, all gases, including N_2 and O_2, become clathrate.	CO_2 is 73 times more soluble in water than N_2 or O_2 (N_2O and methane are also several times more soluble). In addition, these gases are more easily dissolved in very cold water or salt water. The ice contains rare gases and various reactive substances (such as HNO_3, HCL, H_2O_2, SO_2, O_3, etc.), as well as copper, iron, manganese, other molecules, and carbonates, and when these react, they change the CO_2 concentration during reconstruction. The solubility of CO_2 and other gases in water also increases significantly with pressure (from 0.31 to 37.5% from 1 to 200 bar at 0 °C. The amount of salt water as a liquid itself is 100 times more at the 2000m point. At -20°C, the pressure at which the slow release of the clathrate begins is, 5 bar (approx. 70m) for CO_2, 120 bar (approx. 900m) for N_2, and 160 bar (approx. 1200m) for O_2 (CO_2 disappears from the bubbles faster than N_2 and O_2).
During excavation	In these types of ice sheets, secondary gases are generated when the pressure is released during drilling due to differences in the slow release of clathrates. This becomes an artifact and is not the same as the original gas. Due to pressure release, heat, and mechanical shock, large and small tears occur, and the drilling liquids contaminate them. During drilling, mechanical and thermal stress, as well as rapid decompression, can cause large and small fissures to form, resulting in condensation, recrystallization and other structural changes. The fissure will become contaminated regardless of whether or not drilling liquids are used (when the ice core is pulled up to the surface, not only the liquids but also modern gases will be mixed in). The fact that it seeps in from the outside means that the internal gases that may have remained in the fissure area are released outside. For these reasons, it is almost certainly impossible to reconstruct the atmosphere of that time. Due to decompression, it expands particularly in the long axis direction, and after a few minutes, the volume generally expands by 0.2%, and in the case of further relaxation, it expands by 0.6%.	Conversely, during drilling, partial pressure release causes O_2 and N_2 to be released from clathrate far before greenhouse gases such as CO_2, generating secondary gases (which become artifacts). As a result, the impact of the accumulation and the pressure release during excavation of ice core, both reduce the amount of greenhouse gases such as CO_2 (even the ratio of N_2 and O_2 changes).
All of these processes will result in a reduction in the amount of relative CO_2 and greenhouse gases.		

> "There is no experimental evidence to prove the basic assumption of this method, that 'the gases in the upper layers will mix together for several years to thousands of years, and once they are sealed off, they will remain constant and no changes will occur'".

Therefore, he concluded that the reconstructed CO_2 concentration values from polar ice cores were underestimated by 30-50 % as a whole.

Furthermore, he also pointed out that the values change dramatically, depending on the method and time of melting the ice and releasing the gas, when actually reproducing the values. And as shown in Section 4, the fact that the concentration of methane has decreased in modern times has made the flaws evident in the reconstructed values based on ice cores.

Furthermore, the phenomenon is the same for both methane and CO_2, with concentrations increasing abruptly from around the onset of the Industrial Revolution. In other words, CO_2 is inherently prone to the same problems.

Furthermore, Jaworowski also pointed out that there has been very little statistical confirmation in this research field [36]. In fact, the inconsistencies in the assumptions of the reconstructed CO_2 values and the preindustrial value of 280 ppm have become clear, as shown in Section 2 and 3. In particular, it is evident that the unexplainable phenomenon symbolized by Figure 2 does not fulfil the preconditions for the reconstruction of gas concentration by ice cores. Furthermore, the content of the previous paper by the author (Ato, [12]) showed exactly the statistical methods of confirmation. This is also shown in Sections 8 and 9 of the current paper. This is another piece of evidence that proves the correctness of Jaworowski's concerns. For these reasons, the points made by Jaworowski are supported.

7. Issues of the CO_2 data from Antarctic ice cores during past abrupt warming events

Climate reconstructions in Greenland show that climate change has occurred on a much larger scale than in modern times, as evidenced by the oxygen isotope $\delta^{18}O_2$ data (Badgeley et al. [37]). Fluctuations equivalent to 2 ~ 3 °C within 100 years are consistently observed (Figure 11).

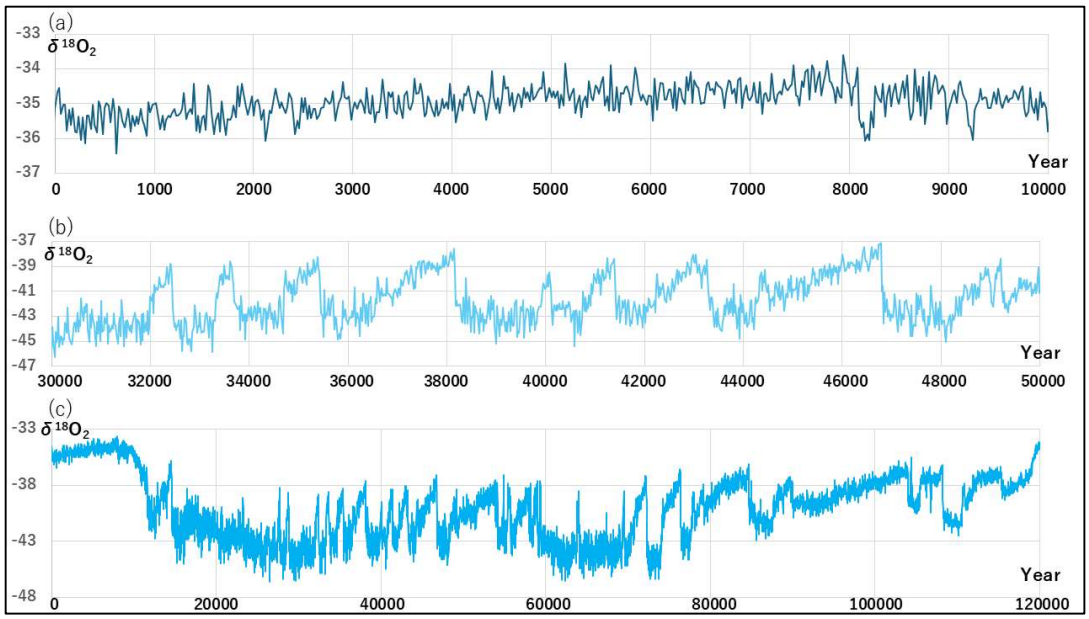

Figure 11. Climate reconstruction in Greenland, (a) up to 10,000 years ago, (b) 30,000 to 50,000 years ago, (c) up to 120,000 years ago, data: North Greenland Ice Core Project (NGRIP), 0 = starting year is 2000 A.D., note that the vertical axis is scaled differently, data derived from Badgeley et al. [37], data used: Oxygen_Isotope_Records_Raw.csv, downloaded on 5th, Sept, 2024.

This is true even during the Holocene Optimum, which was much warmer than in present days. Furthermore, during the Ice Ages, there were numerous fluctuations of around 10 ℃ or more.

Here, modern meteorological satellite data will be used to compare Arctic and global lower tropospheric temperatures. The global fluctuation is just a little more than half that of the Arctic (Figure 12, Spencer, [38]). The 10-year trend since December 1978 was 0.16 ℃ for the globe and 0.26 ℃ for the Arctic.

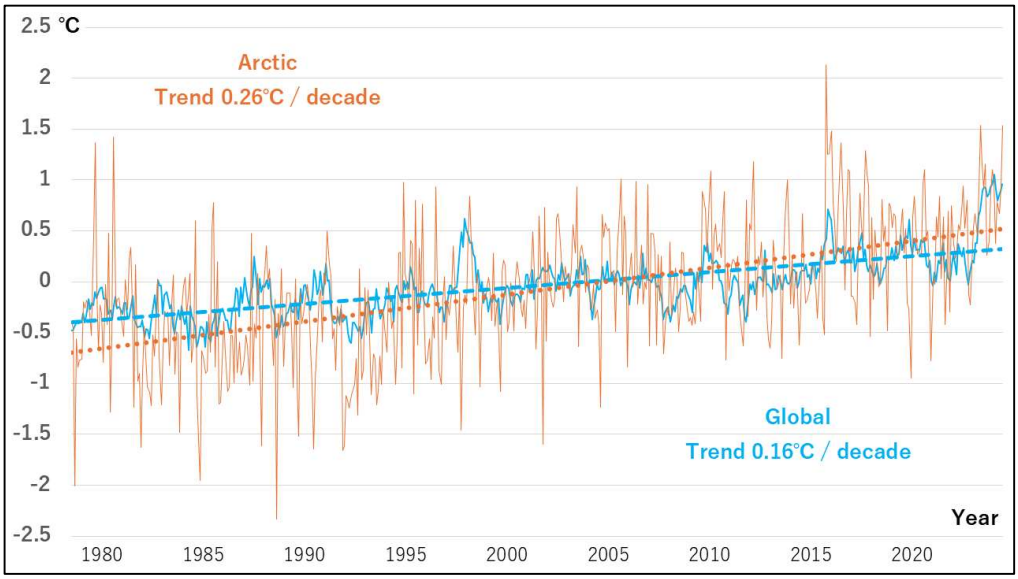

Figure 12. Arctic area and global temperatures from meteorological satellites (lower troposphere), temperature = 0 means the average between 1991 and 2020, from December 1978 to September 2024, data derived from University of Alabama in Huntsville (Version 6.0), [38].

Therefore, the present-day global temperature rise of about 0.8 degrees per century, as proposed by the IPCC, is not anomalous at all. Rather, it is the range of natural variation.

It is also clear that around the Younger Dryas period, a rapid warming of about 10 ℃ occurred within 3 years and 50 years, respectively (Steffensen et al. [39]). Furthermore, drastic changes during the same period are evident from climate reconstruction data from Lake Suigetsu in Fukui Prefecture, Japan (Nakagawa et al. [40]). Moreover, at least the late dramatic period (about 11700 years before A.D. 2000) was almost synchronous [40].

This means that, at least in these years, abrupt warming occurred globally at the same time. Of course, this period did not involve human use of large quantities of fossil fuels as is the case today. Hence, it becomes obvious that the climate can change dramatically with or without CO_2 variability, and far beyond the magnitude of modern fluctuations (so again, about 0.8 degrees in 100 years is not abnormal at all).

Furthermore, the data from that time raises the issue of CO_2 reconstructions from ice cores. CO_2 values from Antarctic ice cores and temperature changes in Greenland during this period are shown in Figure 13.

Significant changes in CO_2 are visually occurring after a little less than 100 years of rising temperatures. However, this time difference itself suggests a problem in terms of modern measurement data.

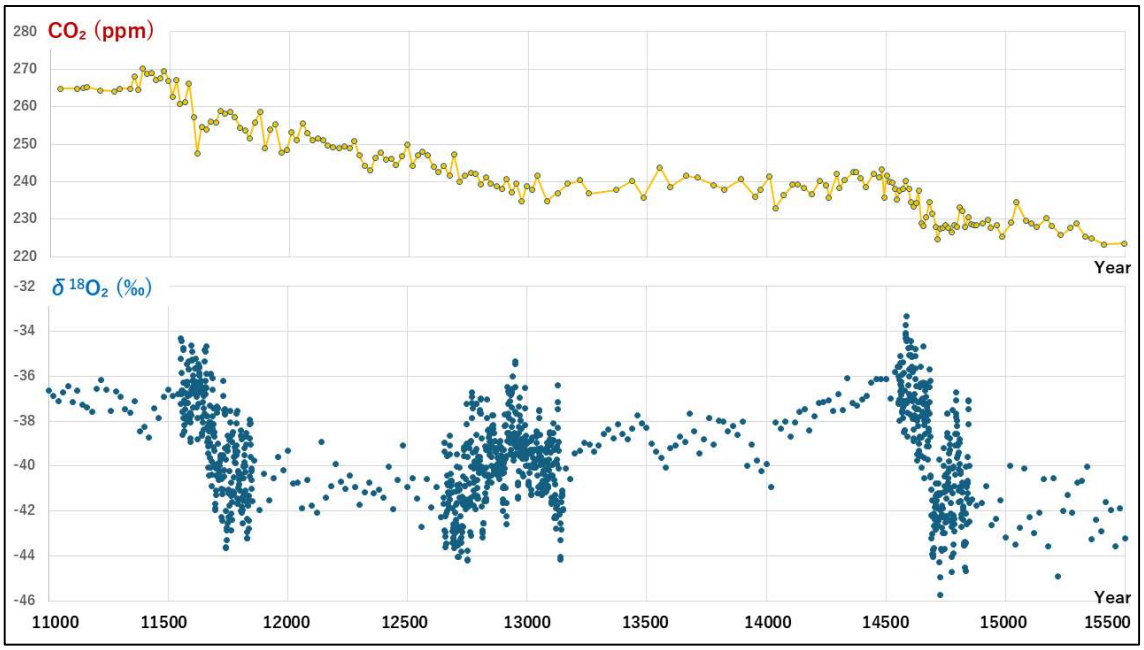

Figure 13. Reconstructed temperature in Greenland and CO_2 in Antarctic, the year 0 means 2000 A.D., thus the year 11500 means 9500 B.C., temperature in Greenland: NGRIP (data same as Figure 12), high resolution data derived from the supplement file (pdf) attached to the paper [39], available year 11511~11850, 12651~13150, and 14551~14850, the other data derived from Badgeley et al. [37] (same as Figure 11). The dataset of CO_2 is the same as of Table1-2 and Figure 1-2 [19]. Note that, in the original data of CO_2, the year = 0 is set at 1950 A.D., thus this year is synchronized (50 year added) to the $\delta^{18}O_2$ data, CO_2 is presented in decimal format for the month as well, however the data is assumed to be for the year.

Figure 14 shows the diurnal variation at Mauna Loa, Hawaii from September to October 2024 (NOAA, [41]). Most of this variability is thought to be caused by changes of SST in the surrounding ocean. This is because the Hawaiian Islands region does not have photosynthetic plants in the same abundance as the continents. Hence, changes in atmospheric CO_2 due to changes in SST are expected to occur in real time in limited areas. And as Figure 3(a) shows, atmospheric CO_2 concentrations are similar over time in the Northern and Southern Hemispheres, although there are seasonal reversals.

Thus, if dramatic warming were to occur globally, on an annual basis, a similar phenomenon would occur with no time lag. This is because CO_2 emissions from the oceans should be occurring (because the warming of the oceans precedes in such events due to the relative heat capacity of the oceans and the atmosphere).

Even in recent data, on a global scale, Humlum et al. [14, 42] have demonstrated that the order of change is SST, global surface temperature, tropospheric temperature, and atmospheric CO_2. The time difference in each factor is 1 ~ 3 months for each temperature, and about a year between the SST and CO_2. Therefore, the time difference of about 100 years in Figure 13 is considered unnatural.

Further discrepancies are considered. There is a rise of about 10 ppm of CO_2 in an era of 10 degrees of warming all at once in 3 or 50 years (even if considered 5 degrees globally on average). Moreover, temperatures were stable for hundreds of years after the last dramatic period. This 10-ppm increase would also need to be considered as underestimation as pointed out by Jaworowski.

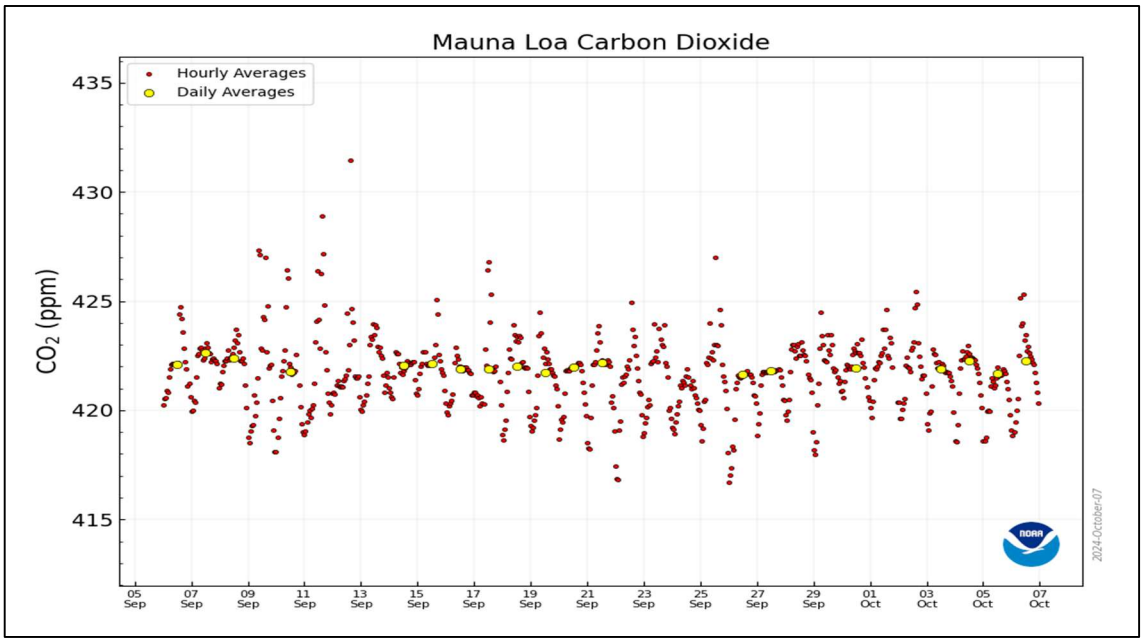

Figure 14. Diurnal cycle of atmospheric CO_2 at Mauna Loa Station, Hawaii, provided by NOAA [41], the image was downloaded on 8, Oct 2024.

In addition, a general theory has been explained by ice core analysis, as CO_2 follows temperature fluctuations hundreds to thousands of years. It would be necessary to reconsider the perception of this "huge time gap" itself. Furthermore, the gas concentration reconstructions from ice cores are markedly different between the two poles (Figure 15, Anklin et al. [43]).

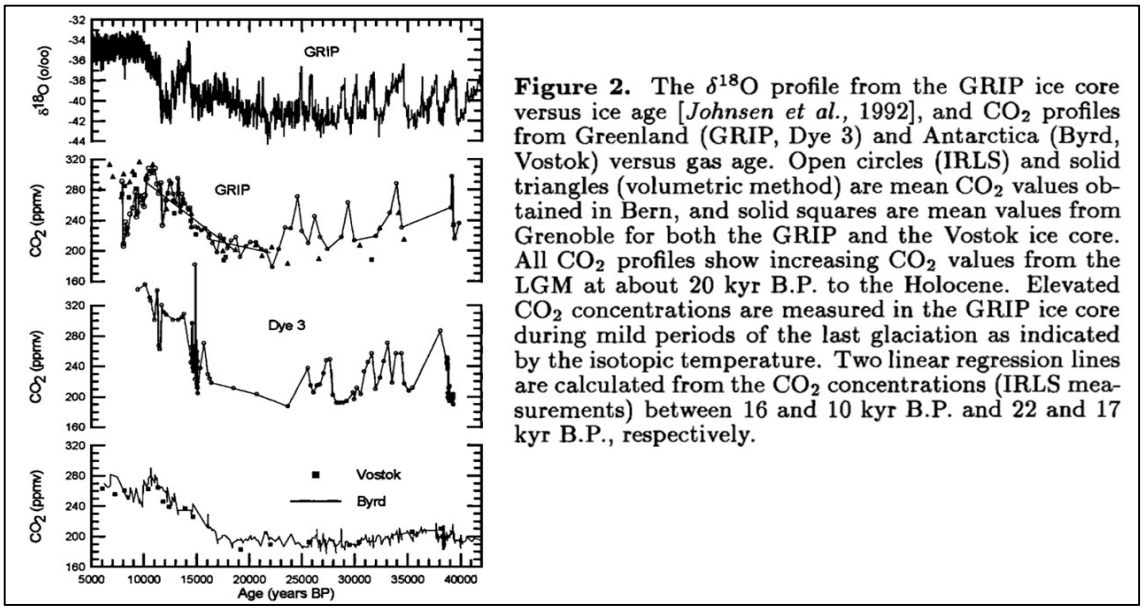

Figure 2. The $\delta^{18}O$ profile from the GRIP ice core versus ice age [*Johnsen et al.*, 1992], and CO_2 profiles from Greenland (GRIP, Dye 3) and Antarctica (Byrd, Vostok) versus gas age. Open circles (IRLS) and solid triangles (volumetric method) are mean CO_2 values obtained in Bern, and solid squares are mean values from Grenoble for both the GRIP and the Vostok ice core. All CO_2 profiles show increasing CO_2 values from the LGM at about 20 kyr B.P. to the Holocene. Elevated CO_2 concentrations are measured in the GRIP ice core during mild periods of the last glaciation as indicated by the isotopic temperature. Two linear regression lines are calculated from the CO_2 concentrations (IRLS measurements) between 16 and 10 kyr B.P. and 22 and 17 kyr B.P., respectively.

Figure 15. CO_2 reconstruction at both poles, the image is derived from Anklin et al. [43].

The Antarctic data has been used as the standard because of its slightly smaller absolute value and smaller fluctuations. However, numerical stability itself does not necessarily guarantee accuracy. The problems with the Antarctic data are not only the discrepancies described in Sections 2 and 3, as was revealed at the same time as the data of the post-1850 reconstructions, which are close to the present day, and are rather unnaturally unstable. And in the paleoclimate category, the issues of time resolution and low sensitivity must also be considered.

As shown in Figure 3, even today, the annual average value of atmospheric CO_2 is not markedly

different between the two poles, even when humans are believed to emit a larger amount of CO_2 than in the past. Barrow (blue dot in Figure 3a) is on the Arctic Ocean side of Alaska, and its intra-year variability is much greater than Antarctica's, but not much different from Antarctica's on average. This difference is about 5 ppm by comparison of regression lines (Figure 16, NOAA [22,44]).

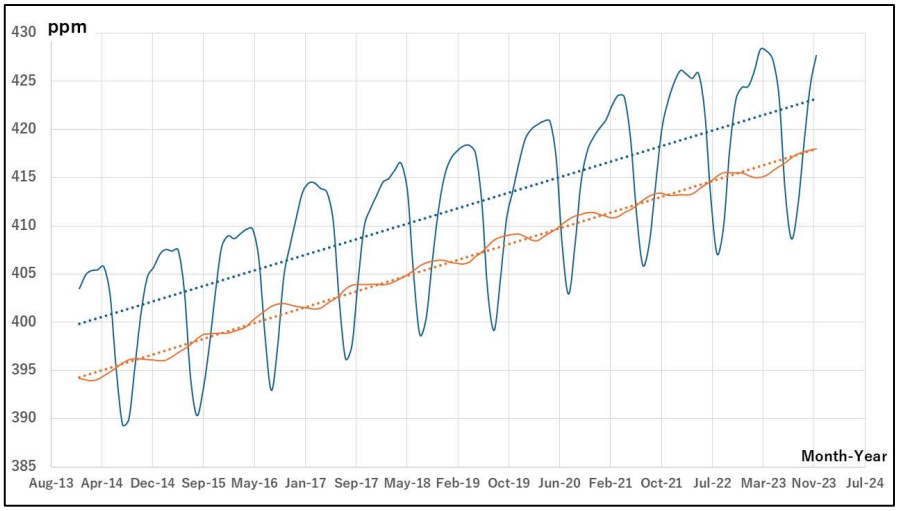

Figure 16. Modern atmospheric CO_2 at Barrow (Arctic region, blue) and Antarctica (orange), vertical axis: CO_2 (ppm), horizontal axis: year and month (from January 2014 to December 2023), dotted line: regression line (the least square method)

Therefore, even in the paleoclimate category, there should not be a marked difference between the two poles, at least in terms of annual averages. Moreover, in the case of ice cores, the averaged figures over multiple years are reproduced according to the reconstruction theory. However, there is a clear difference in CO_2 reconstructions between Greenland and Antarctica (Figure 15).

CO_2 in Antarctica is clearly lower than in Greenland. This difference is clearly more than the 5-ppm noted above. Furthermore, the data for Greenland are markedly fluctuating. Hence, rather, Greenland data is considered more representative of the dramatic climate changes of the time, even considering the issue of accuracy. It is far from ideal, but at least it is better than Antarctica.

Nevertheless, the Greenland data should be considered an underestimation as well. In addition, Clintel presents an article that aggregates past studies on atmospheric CO_2 concentrations (Hannon [45]). Figure 17 shows a symbolic diagram of its contents and the concluding section. The last paragraph reads,

> „Ice core and plant stomata CO_2 records are imperfect data and therefore, the global CO_2 composite should be inclusive of both centennial and millennial scale deterministic measurements. Perhaps it's the Antarctic global CO_2 composite that is the outlier, suppressed smoothed, and muted by extreme Antarctic temperatures and burial conditions. And the centennial modern CO_2 increase is not that unique."

And based on Jaworowski's main point, the possibility of underestimation in other evaluation methods should be also considered. This includes estimates based on stomatal and chemical methods, especially for the pre-modern period (including the Medieval Warm Period and earlier).

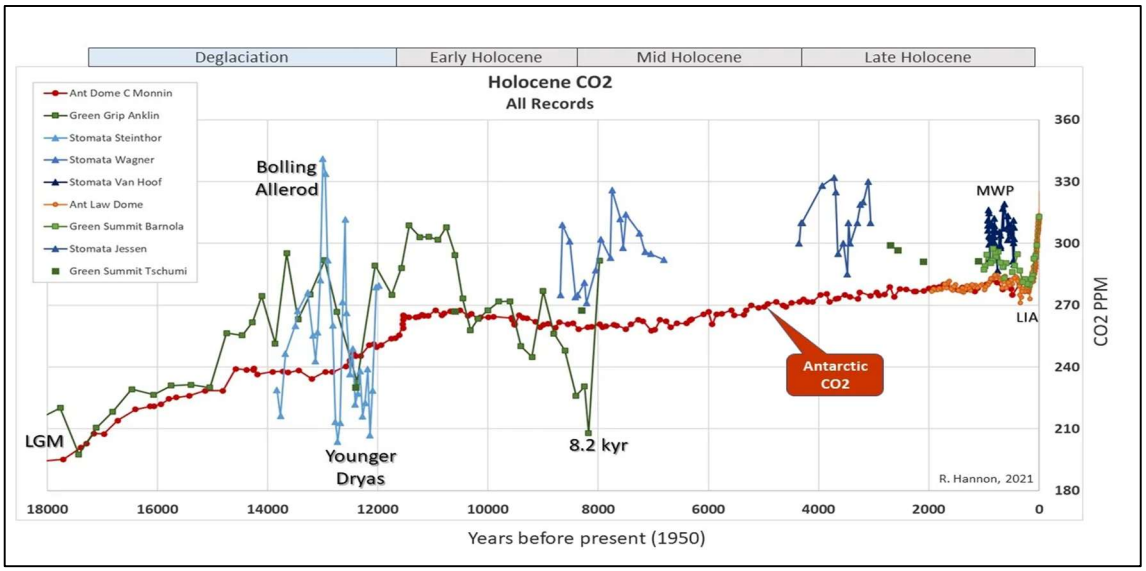

Figure 17. CO_2 reconstruction data of various methods assembled by Hannon, Clintel [45].

8. Update of the author's previous report

Ato [12] reported the following in a previous report published in this journal.

> "Multivariate analysis revealed that SST was the only factor independently determining the annual change in atmospheric CO_2, but not anthropogenic fossil fuel use."

This result is reasonable because the solubility of CO_2 in water varies almost linearly over the general range of contemporary global SST (Figure 18, Carroll et al. [46], Abas et al. [47]).

In the previous report, OWID had published data through 2021, so the multivariate analysis was performed with data up to that year. At the time of writing this paper, OWID data were available through 2022, so a multivariate analysis will be conducted using data till that year.

Atmospheric CO_2 and SST are published up to the year 2023, and SST can predict ΔCO_2 up to the year 2023 based on the results of this multivariate analysis. Therefore, the difference between the published and SST predictions for the total ΔCO_2 until 2023 is compared. This time, fossil fuel-only (FFO) and LUC-included emissions are also used for human emissions.

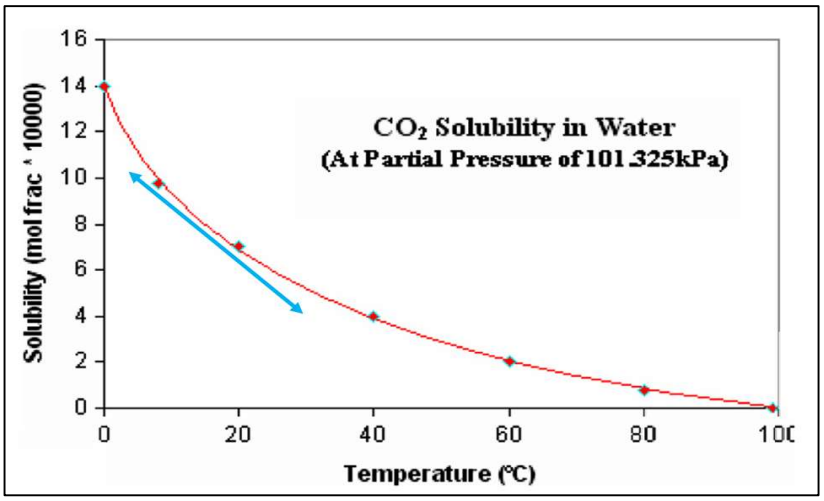

Figure 18. Solubility of CO_2 in water (1 atm), the image is derived from Figure 12 in Abas et al. [47]. The blue arrow was added by the author (Ato).

The analysis procedure was the same as in the previous report (Ato [12]). Three types of SSTs were also used. In this update analysis, ΔCO_2 was performed with new data (NOAA, [20], downloaded June 2, 2024 JST). There was a subtle correction (0.01-0.02 ppm) in the post-2017 data. Furthermore, the study in the next section with the ΔCO_2 simulation was also performed with these new data for ΔCO_2.

Figure 19 shows the diagram of UAH-SST and human emissions for ΔCO_2. Overall, the diagram shows the same aspect as in the previous report: the diagram for ΔCO_2 and UAH-SST is shown until 2023.

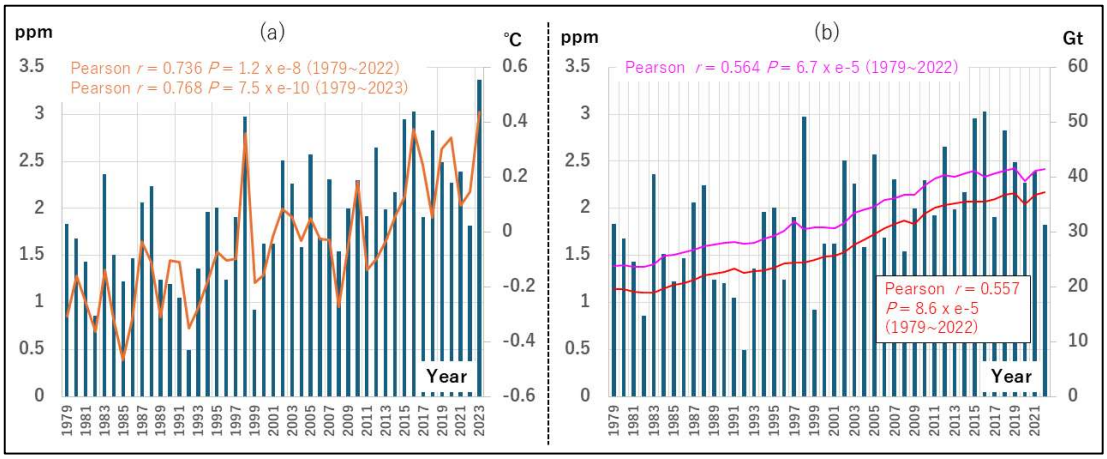

Figure 19. ΔCO_2, UAH-SST, and human emissions (a) ΔCO_2 and UAH-SST, (b) ΔCO_2 and human emissions, ΔCO_2 (blue bar graph), UAH-SST (orange line, anomaly, difference from the average for 1991-2020), human emissions (red: FFO, pink: including LUC, as CO_2)

As 2023 is a globally warmer year, with ΔCO_2 about two times that of 2022, this is impressive. This aspect is also symbolic, since it can be expected that human emissions will be little different from previous trends (+0.201 Gt/year for FFO and +0.095 Gt/year for including LUC from 2011 to 2022).

Table 5 shows the results of the linear multiple regression analysis. Again, only SST was a statistically significant determinant of ΔCO_2. Human emissions were not an explanatory factor.

Table 5. Results of linear multiple regression analysis. B: regression coefficient, Constant: a constant in the regression equation, for example, in the combination of UAH-SST and human emissions FFO, ΔCO_2 = 1.968 x UAH-SST + 1.780

		Human emissions Fossil Fuel Only			Human emissions Including Land Use Change		
Year	Explanatory Factors	*B*	*P*	*Model R^2*	*B*	*P*	*Model R^2*
1979 ~2022	Constant (ppm)	1.780	7.1 x e-05	R^2 = 0.546	1.695	0.0012	R^2 = 0.547
	UAH-SST (ppm/°C)	1.968	3.8 x e-05	P = 9.2 x e-8	1.947	4.6 x e-05	P = 8.8 x e-8
	OWID Emission (ppm/Gt)	0.009	0.54		0.010	0.50	
1959 ~2022	Constant (ppm)	1.165	1.3 x e-04	R^2 = 0.639	1.264	0.0033	R^2 = 0.639
	HAD-SST (ppm/°C)	1.964	3.4 x e-04	P = 3.2 x e-14	2.096	4.0 x e-04	P = 3.1 x e-14
	OWID Emission (ppm/Gt)	0.007	0.97		-0.004	0.83	
	Constant (ppm)	0.983	1.0 x e-04	R^2 = 0.647	1.020	0.0039	R^2 = 0.647
	GISS-SST (ppm/°C)	2.376	1.6 x e-04	P = 1.6 x e-14	2.452	1.9 x e-04	P = 1.6 x e-14
	OWID Emission (ppm/Gt)	0.001	0.94		-0.001	0.95	

Table 6 shows the total ΔCO_2 up to 2023 and the sum of the predictions by each SST. In this study, the prediction by the combination of HAD-SST and emissions FFO (1.40-ppm underestimation) or the combination of GISS-SST and emissions including LUC (1.49-ppm overestimation) had the small error, while UAH-SST showed an error of about 10 ppm, as in the previous study.

Table 6. Sum of published ΔCO_2 and SST-predicted ΔCO_2, Unit: ppm, FFO means the model using human emissions of FFO, LUC means that of including LUC.

Year	Published ΔCO_2	SST	FFO	LUC
1979~2023	86.81	UAH	75.76	71.97
1959~2023	107.34	HAD	105.94	114.39
		GISS	105.10	108.83

In any case, the essence of what the previous (Ato, [12]) and current analyses show is the same. The human emissions and their annual fluctuation cannot statistically explain the level of atmospheric CO_2. And since this result was shown for the period after the second half of the 20th century, the same must be assumed for the period before that, when human emissions were much lower. Therefore, together with the explanations above, the flaw in the assumption of 280 ppm at the time of the onset of the Industrial Revolution is again indicated.

9. Data simulation in the previous paper's data and the meaning of the results for human emissions as an explanatory factor

This analysis is performed to illustrate the effectiveness of linear multiple regression analysis from a different view. It is a simulation, so to speak. For simplicity, this analysis will be performed only for data from 1979 to 2021, the period for which multivariate analysis was performed in the previous paper. Only UAH will be used for SST, and emissions will use FFO as before. However, for ΔCO_2 updated data are used as described above. The total ΔCO_2 was not changed, but the data for each year were slightly flattened.

Table 7 shows ΔCO_2 before and after the change. Figure 20 shows UAH-SST, anthropogenic emissions, and simulated ΔCO_2. The correlation between ΔCO_2 and UAH-SST decreased, while that with human emissions strengthened.

Table 7. Actual and simulated ΔCO_2 data in the analysis (1979 ~ 2021)

year	Actual ΔCO_2	Simulated ΔCO_2	year	Actual ΔCO_2	Simulated ΔCO_2	year	Actual ΔCO_2	Simulated ΔCO_2
1979	1.83	1.83	1994	1.96	1.95	2009	2	2
1980	1.68	1.68	1995	2.01	2.01	2010	2.3	2.3
1981	1.43	1.43	1996	1.24	1.24	2011	1.92	1.92
1982	0.86	1.86	1997	1.91	1.91	2012	2.65	2.65
1983	2.36	1.36	1998	2.97	1.97	2013	1.99	1.99
1984	1.51	1.51	1999	0.92	1.72	2014	2.17	2.17
1985	1.22	1.21	2000	1.62	1.62	2015	2.95	2.15
1986	1.47	1.47	2001	1.62	1.62	2016	3.03	2.53
1987	2.06	2.06	2002	2.51	2.51	2017	1.91	2.39
1988	2.24	2.24	2003	2.26	2.27	2018	2.83	2.85
1989	1.24	1.24	2004	1.59	1.59	2019	2.49	2.5
1990	1.2	1.2	2005	2.57	2.57	2020	2.27	2.29
1991	1.05	1.05	2006	1.69	1.69	2021	2.39	2.37
1992	0.49	1.49	2007	2.31	2.31	Total	81.62	81.62
1993	1.36	1.36	2008	1.54	1.54			

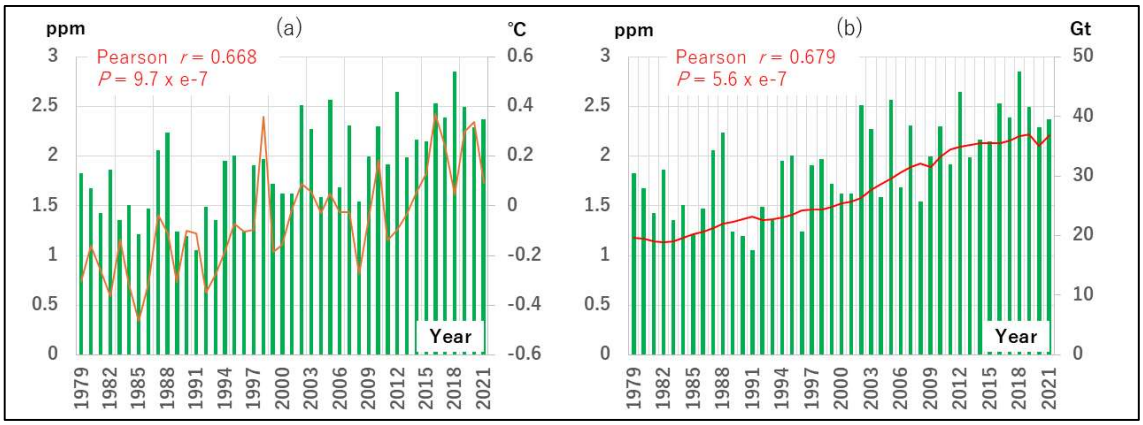

Figure 20: ΔCO_2, UAH-SST and human emissions (simulation), the green bars: simulated ΔCO_2, the other contents are the same as of Figure 19.

Table 8 shows the results of linear multiple regression analysis with ΔCO_2 as the objective variable. Both UAH-SST and human emissions significantly predicted ΔCO_2, but the predictive power of human emissions was slightly higher. The simulation result means that the anthropogenic theory could be proven correct (at least partly), as the fluctuation in ΔCO_2 was closer to that in anthropogenic emissions.

In other words, the hypothesis is that humans have caused the increase in atmospheric CO_2. The results also show that a multivariate analysis is effective. However, in reality, we must acknowledge that the anthropogenic theory is definitely rejected statistically, using the real data.

Table 8. Results of linear multiple regression analysis (simulated ΔCO_2 B: regression coefficient)

Year	Explanatory Factors	*B*	*P*	*Model R^2*
1979 ~2021	Constant (ppm)	1.113	0.0010	R^2 = 0.540
	UAH-SST (ppm/℃)	0.869	0.012	P = 1.8 x e-7
	OWID Emission (ppm/Gt)	0.0308	0.0068	

10. Discussion

In Sections 2 and 3, problems with ice core reconstructions of past atmospheric CO_2 in Antarctica are described. Even the samples of the relatively young air bubbles from the mid-19th century onward show several unexplainable data values (Figure 2). The data also show the discrepancy between the hypothesized nearly constant absorption rate of nature over about 60 years relative to human emissions, and the changes that have occurred before that time. These can be understood through basic numerical analysis alone.

Furthermore, the decline in methane in the early 21st century disproves the theory that the rise in methane since the Industrial Revolution has been entirely due to human influence. In addition, this aspect also clarified the problem of reconstructing gas concentrations using ice cores. And the data that show a dramatic increase since the Industrial Revolution are the same for CO_2 (Figure 7).

Therefore, in the following Section, the conflict of original core reports in this area of research was pointed out (Table 3). The research group that reconstructed CO_2 stated that the age shift of the gas was appropriate from a carbon isotope standpoint. On the other hand, the group that reconstructed the methane said it was virtually impossible, at least in their data.

Jaworowski's response to the research process was thorough and comprehensive (Table 4). In particular, he was extremely critical of age shifting in gases. Jaworowski further summarized the

various difficulties associated with reconstructing gas concentrations from ice cores.

Numerous physical and chemical influences are inevitable in the process from snowfall to snow accumulation and over long periods of time. Therefore, the assumption that the past state is preserved without any changes is not valid. The values of ΔCO_2 found in ice core data from the mid-19th century that have not been seen since the late 20th century, is particularly emblematic of this problem (Figure 2).

Therefore, the assumption of an atmospheric CO_2 concentration at the time of the Industrial Revolution of 280 ppm is no longer valid. The various related studies that assume this hypothesis are all equally inappropriate. And an update of the previous report by the author (Ato) showed that, in the same manner, SSTs are the sole determinant of annual ΔCO_2 and that human emissions have no predictive power related to the atmospheric content of CO_2 (Table 5).

Most important, SST is consistent in its ability to predict CO_2 with a small final error. Therefore, it is most likely that SST is the primary driver of atmospheric CO_2, not human emissions. Thus, it is a natural phenomenon, even today with the massive use of fossil fuels. And this analysis supports the validity of the existing reports [13-16, 23,24, 31,32, 34-36, 45].

The IPCC has maintained that CO_2 from human emissions will remain in the atmosphere for a long time, separate from natural sources. However, as a fact, CO_2 is the same whether it comes from natural or fossil fuel sources.

Berry [48] showed that the residence time (turnover time, as defined by the IPCC) of $^{14}CO_2$, derived from $\Delta^{14}C$ data, is 10.0 years, making the $^{12}CO_2$ residence time less than at least 10 years. Salby and Harde showed that the residence time for atmospheric CO_2 is only several years regardless of its origin [49-52]. Furthermore, recently, Koutsoyiannis [53] also showed that the residence time of atmospheric CO_2 including human emissions is about 4 years.

This means that the residence time will not be long term even with respect to human emissions, and not semi-permanent as the IPCC says. These reports [48, 49] are also consistent with this series of analyses [12-16, 23,24, 31,32, 34-36, 45].

And the key SST fluctuations will be mainly due to the Sun. It is also certain that intrinsic factors of the Earth are involved to a certain degree. Such factors are represented by El Niño, La Niña, and volcanic activity. These phenomena of the Earth itself are certain to have an impact on the short term. A precise analysis of their influence and interaction awaits future research.

Finally, a few words about future perspectives. The previous and current multivariate analyses were conducted solely on data up to the beginning of the 21st century. Currently, human emissions account for less than one-twentieth of the entire global CO_2 cycle (NASA, [54]).

If the amount of human CO_2 emissions increases dramatically in the future by a factor of 2 – 3 or more, it might have a noticeable effect on the concentration of atmospheric CO_2, but this is hardly possible.

One possibility of such a situation is when the difference widens between the predicted values from SST and the actually measured values, as shown previously [12] and in the current work by the author. Or, when the predictive power of multivariate analysis is weakened. This means that the multiple regression model becomes less accurate and weaker in terms of the probability of significance (larger P-value). Also, the case can be considered where the P-value of the SST and of the constant in the multivariate model become larger, and that of the human emissions become smaller. These changes possibly suggest the effects of human emissions.

Yet still, mankind does not need to worry about it at all; rather, it is something to be welcomed. This is because of mankind's contribution to the increase of photosynthesis and organisms [2 - 6].

11. Conclusions

This paper shows that the assumption of 280 ppm CO_2 concentration in the atmosphere at the onset of the Industrial Revolution, which is the premise for modern climate change research, is flawed.

There is no doubt that the figure of 280 ppm is a significant underestimate. The various inexplicable phenomena and contradictions seen in the CO_2 reconstruction values from Antarctic ice cores symbolize the flaws in the data. This is due to the inherent limitations of the ice core reconstruction method itself.

The main cause of the rising atmospheric CO_2 is the rising SST, which acts much like the universal gravitation. And of course, it is also the result of the overall effects on the carbon cycle due to various factors on Earth, such as photosynthesis and respiration, as well as the atmospheric temperature that affects them. Furthermore, anthropogenic emissions have had no significant effect on the atmospheric CO_2 from the statistical standpoint.

Therefore, the increasing CO_2 is largely due to natural phenomena. Analysis of the external and internal factors that cause variation in SST and the degree of their influence awaits further study.

Funding

The author did not receive any funding of the work.

Declaration of competing interest

The author declares no conflict of interest. Dai Ato, an autonomous and private researcher, authored this article as an academic activity based on the guaranteed right of freedom in an academy for the Japanese (Article 23) and the Supreme Law provided in Article 98 of the Constitution of Japan.

Guest-Editor: Stein Storlie Bergsmark; Reviewers: anonymous.

Acknowledgements

The author appreciates all the institutes and the researchers for providing the data and the knowledge related to this study.

Appendix

Pointing out typical misinformation on the Internet about the previous study (Ato, [12])

1. Comments that correlation does not prove causation (and therefore, implying the paper is wrong)

It is common scientific knowledge that correlation alone cannot prove causation. However, if there is a clear mechanism behind the correlation, it is possible to consider causation. As described above, there is a causal relationship between water temperature and CO_2 solubility, and within the range of water temperatures in the Earth's oceans, the relationship is close to linear (Figure 18).

In fact, a strong linear correlation was found between ΔCO_2 and SST. And most important, human emissions were simultaneously input into the multivariate model, however, they were not a

determining factor of ΔCO_2. If the amount of CO_2 emitted by humans really does affect the annual ΔCO_2, then this should be analyzed statistically. The results in Section 9 indicate that, this is not the case in the real world. Therefore, it is reasonable to conclude that SST has a causal relationship with ΔCO_2 based on the analysed data.

Furthermore, the following points are largely common to those who emphasize that "correlation does not prove causation". First, there is no mention of the fact that there was no predictive power at all for the quantity of emissions by humanity. Furthermore, it is also common scientific knowledge that "if there is no correlation, even after adjusting for appropriate related and/or confounding factors, then the causal relationship is denied". This refers to the emissions of humanity, which were defeated by SST in the multivariate model.

2. Comments that make it look like Ato [12] is insisting on strong correlations

As mentioned above, correlation alone does not prove causality. However, it is necessary to regard the correlation coefficient as an objective indicator of prediction accuracy. Furthermore, the final differences of the prediction formula are shown, in both the previous and current article. If the final predicted value is significantly different, the prediction formula is not appropriate.

Figure A1 shows an example where a strong correlation is seen even with a large final error. This is simply halving the predicted value of ΔCO_2 using HAD-SST. However, the Pearson correlation coefficient is same. Therefore, a strong correlation does not guarantee that the prediction formula is correct, the final difference is also essential.

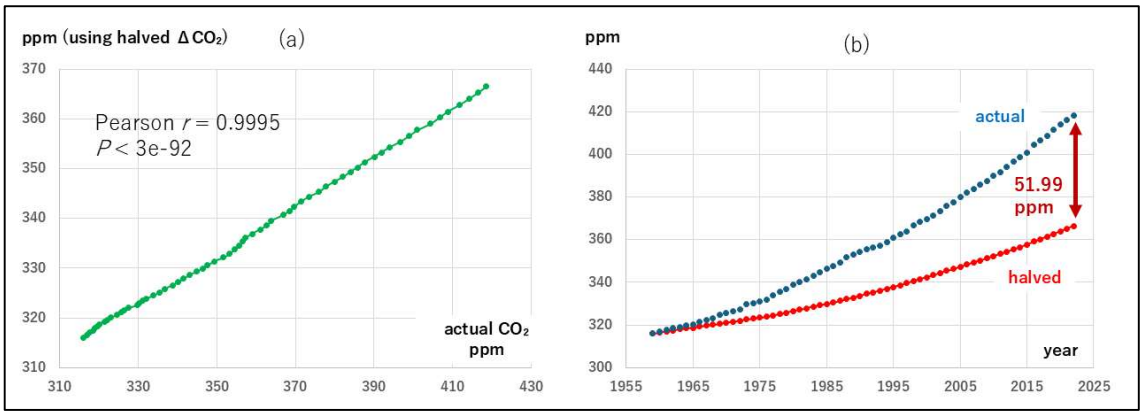

Figure A1. Comparison of actual CO_2 with predicted CO_2 of halved ΔCO_2 estimated by HAD-SST (1959~2022), (a) actual atmospheric CO_2 and simulated (halved ΔCO_2) atmospheric CO_2, ΔCO_2 was calculated as (2.006 × HAD-SST + 1.143) / 2, (b) yearly change of actual and simulated atmospheric CO_2, the difference in 2022 is 51.99 ppm. The actual CO_2 data are the same as in the previous article (downloaded from NOAA on 27, Aug, 2023), note that the correlation coefficient is based on the data between 1960 and 2022 (not including 1959). The reason for not including 1959 in the correlation analysis is that ΔCO_2 in 1959 cannot be fully trusted because the measurement in Hawaii was not performed in all of 1958.

In the previous study, UAH-SST data from 1979 onwards were used, from the perspective of data accuracy only. Before 1978, there were no UAH-SST data. The results of the multiple regression analysis were striking, but an error that should have been taken into account occurred in 2022 (underestimation of 14.5 ppm). However, the fact that the emissions of mankind were rejected by the analysis is even more significant.

Therefore, additional multiple regression analyses with HAD and GISS-SST data from 1959 onward were carried out to confirm the results. The conventional SST is fraught with measurement and data integration issues similar to those of land surface measurements. However, it is essential and significant to confirm whether the same results can be obtained. As the fluctuations in HAD and GISS-SST are smaller than those in UAH-SST, and show a similar trend (Figure 2 in Ato, [12]), they were considered worth analysing.

And the results of multiple regression analysis were similar. The error between the predicted value using HAD-SST and the actually measured value in 2022 was 1.45 ppm, which is a satisfactory level of accuracy, for a total concentration change of approximately 100 ppm which has increased since 1959. When this error is on the same level as that predicted from UAH-SST, it means that other factors that cannot be explained by SST alone should be considered.

Therefore, in the previous and current articles, final differences, which are just as important as correlation coefficients, are also listed (abstract, main text, and Figure 4 in [12]). However, misleading commentators on the Internet do not realize, or ignore, this.

3. Commenting that a too high correlation indicates a rather erroneous analysis

As noted above, in the previous and current reports, ΔCO_2 was estimated by coefficients and constants based on the results of linear multiple regression analysis. The result was an absolute rejection of human emissions. Therefore, the prediction formula is appropriate. The fact that the correlation coefficient between the measured and predicted values is remarkably high is a concrete result of an analysis. This, per se, cannot be used as an argument that the analysis itself is erroneous.

4. The accusation: Only data after 1959 were considered, to hide the discrepancy between CO_2 and SST before that time, without explaining, where and why it is failing

As mentioned shortly in Section 2, it is impossible to use ΔCO_2 data from ice cores prior to 1958 for the analysis. Since there are many reasons why ΔCO_2 cannot be explained by human emissions at that time, the use of these data for statistical analysis is impossible. Publishing them means disseminating artificially and falsely created statistical results.

5. Ato [12] adjusted (or manipulated) the data and/or mathematical formulas to achieve the desired result.

In other words, it implies scientific fraud. This is not only frivolous but also a very serious defamatory accusation that is only intended to defame the author. The data are at hand with the supplemental Excel® dataset [12]. Since the data used only included seven variables and for about only 60 years (CO_2, ΔCO_2, three types of SST, and two types of human emissions), for a real expert, verification is a simple and easy task. The data sources are also listed in the reference. Furthermore, linear multiple regression analysis can be performed using Excel®. A tutorial is also available. The same is true for other statistical analysis software.

In the first place, if fraud really exists, scientific practice is to send specific comments to the journal to point this out. And if the journal SCC refuses to respond, then and only then can they criticize it, including other journals. After all, implying fraud without pointing out concrete details is not scientifically ethical.

6. Criticism of modelling ΔCO_2 using only SST and a constant

As noted above, there is a firm mechanism for the relationship between SST and ΔCO_2. The SST was then entered into a multiple regression model along with human emissions, resulting in a strong predictive ability of the SST.

The essence of the results of the previous and current studies is the same. Therefore, there is no statistical problem in predicting ΔCO_2 using these figures. Other factors (biosphere and volcanic activity) are not expected to be as accurate as annual ΔCO_2, SST, and anthropogenic emissions.

It is risky to put numbers with large uncertainties into a multivariate model. As with the pre-1958 ΔCO_2 described above, there is a high risk of producing artifacts. In the future, however, if the accuracy of other indicators improves dramatically, there may be room for consideration.

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