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Atmospheric CO_2: Exploring the Role of Sea Surface Temperatures and the Influence of Recent Anthropogenic CO_2 Emissions

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Abstract

Close examination of the small perturbations within the atmospheric CO_2 trend, as measured at Mauna Loa, reveals a strong correlation with variations in sea surface temperatures (SSTs), most notably with those in the tropics. The temperature-dependent process of CO_2 degassing and absorption via sea surfaces is well-documented, and changes in SSTs will also coincide with changes in terrestrial temperatures, and temperature-dependent changes in the marine and terrestrial biospheres with their associated carbon cycles. Using SST and Mauna Loa datasets, three methods of analysis are presented that seek to identify and estimate the anthropogenic and, by default, natural components of recent increases in atmospheric CO_2, an assumption being that changes in SSTs coincide with changes in nature's influence, as a whole, on atmospheric CO_2 levels. The findings of the analyses suggest that an anthropogenic component is likely to be less than 10 % of the increase since the mid 1990s, with figures of up to around 6 % being estimated from data acquired since 1995. The inference is that more than 90 % of those increases are of natural origin, and indeed the findings suggest that nature is continually working to maintain an atmospheric/surface CO_2 balance, which is itself dependent on temperature. A further pointer to this balance may come from chemical measurements that indicate a brief peak in atmospheric CO_2 levels centered around the 1940s, and that coincided with a peak in global SSTs.

Keywords: Atmospheric CO_2; Sea Surface Temperatures

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1. Introduction

Research into the influence SSTs have on changes in atmospheric CO_2 includes the work by Humlum et al. (2013). When examining phase relationships, they found a maximum correlation for changes in atmospheric CO_2 lagging 11-12 months behind those of global SSTs [1]. A paper by the late Fred Goldberg (2008) noted their correlation by examining El Niño events [2]. He also considered Henry's law [3] in relation to SSTs, i.e. a temperature-dependent equilibrium between atmospheric CO_2 and its solubility in seawater. Spencer (2008) also noted similarities between surface temperature variations with changes in atmospheric CO_2 [4].

For the oceans specifically, areas of surface CO_2 absorption and degassing are shown in maps provided by the NOAA [5] and ESA [6]. These maps show that colder sea surfaces towards the poles are net absorbers of CO_2 whilst the warmer surface waters of the tropics are net emitters. An analogy often cited is the greater ability of carbonated drinks to retain CO_2 at cooler temperatures; this ability drops as the drinks get warmer.

A strong correlation between changes in atmospheric CO_2 and SSTs can be readily discerned from the relevant datasets. To illustrate, Fig. 1 shows a graph of atmospheric CO_2 in parts per million (ppm) as measured at Mauna Loa, Hawaii, since 1958. The data [7] has been 'deseasonalized' by NOAA to remove natural annual CO_2 cycles.

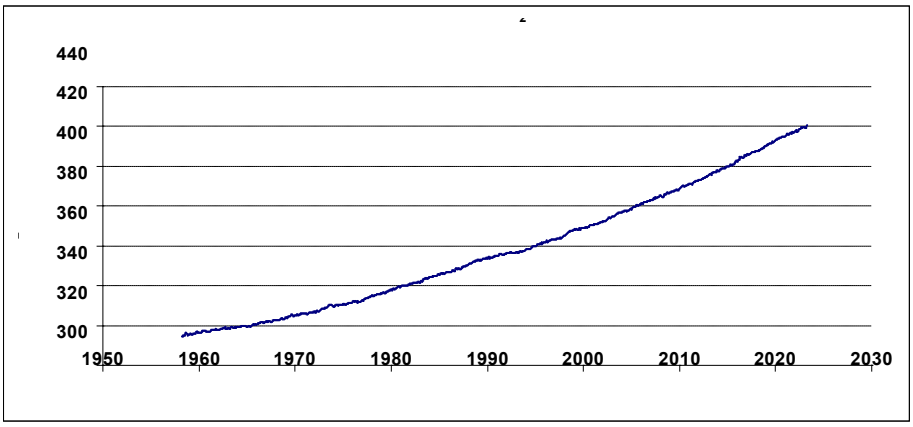

Figure 1: Deseasonalized Atmospheric CO_2 Data, beginning 1958 (Mauna Loa).

It can be seen that the graph's general trend exhibits small perturbations. These can be magnified by plotting the monthly CO_2 ppm increases with time. Fig. 2 plots averaged monthly increases from 1982 onward; averaging removes some of the 'noise' from the trace.

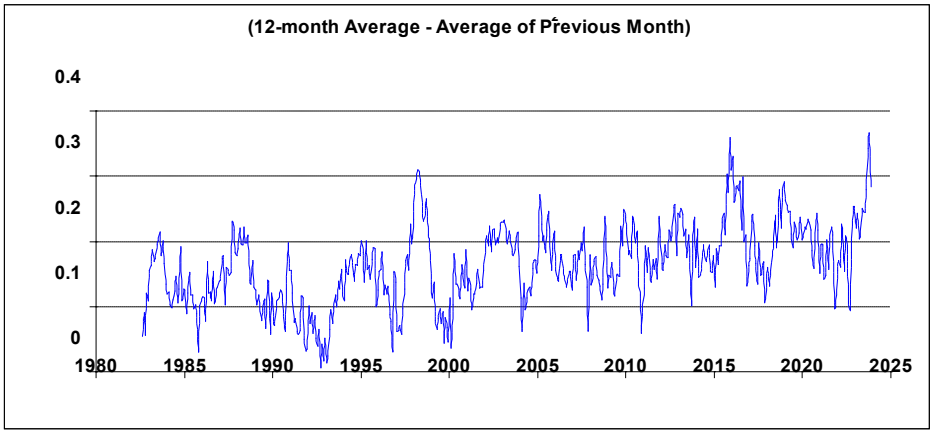

Figure 2: Monthly CO_2 ppm Increases based on Averaged Data

Distinct peaks and troughs are now apparent in the data. If global tropic SSTs [8] are overlaid onto this graph, a strong correlation is observed, Fig. 3.

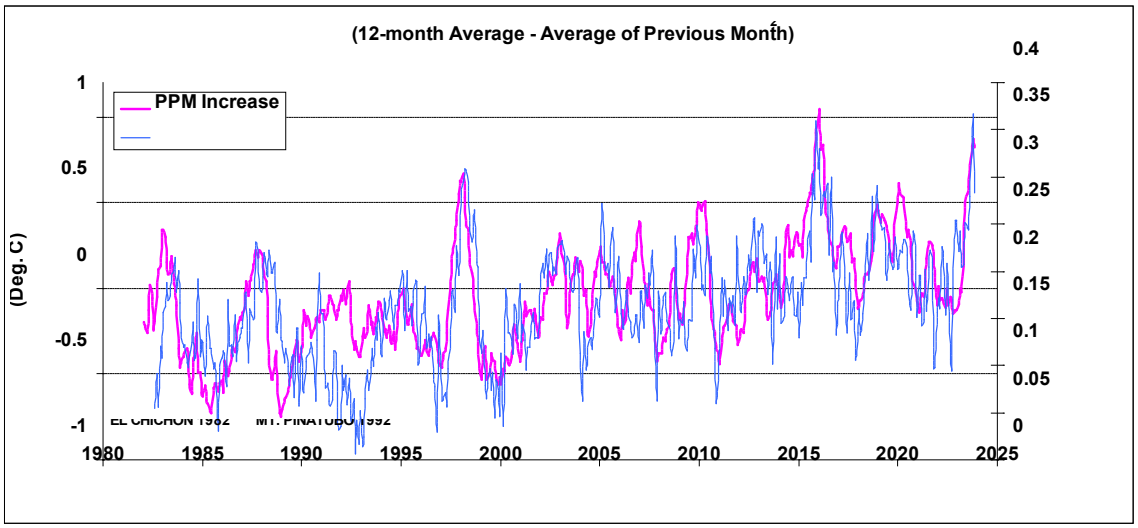

Figure 3: Global Tropic SSTs Overlaid onto Monthly Atmospheric CO_2 Increases (Mauna Loa)

The similarity between the two traces is striking: short-term fluctuations in CO_2 readings at Mauna Loa appear particularly sensitive to tropic conditions (if tropic SSTs are substituted for global SSTs in Fig. 3, the correlation is less strong). Warm tropical seas, with surface temperatures typically around 25-30 ºC, cover almost one third of the earth's surface. The most prominent peaks in the figure coincide with strong El Niño events. Taken at face value, and ignoring any influence from anthropogenic emissions, Fig. 3 suggests that if the tropic SST anomaly dropped to around -1 ºC (with related drops globally) then the concentration of CO_2 in the atmosphere, as measured at Mauna Loa, would level off.

An important point is that changes in SSTs will coincide with those of terrestrial temperatures, temperature-dependent changes to both terrestrial and marine carbon cycles and, taking into consideration the research by Humlum et al. (2013) who found that changes in atmospheric CO_2 followed changes in SSTs, an assumption in the work presented here is that nature's influence on atmospheric CO_2 levels, as a whole, follows on from changes in SSTs.

The basis behind such an assumption is examined in more detail as follows:

In a 2022 article, Schrijver [9] summarizes his interpretation of recent events regarding atmospheric CO_2, writing: *"The... increase in the average global temperature has resulted in a higher annual natural emissions from land and sea… The increase in both natural and anthropogenic emissions has led to more CO_2 in the atmosphere...The higher concentration results in a greater down-flux to both sea and land...The increase in concentration in the atmosphere is the result of a combination of increased temperature and human emissions."*

For the oceans, and considering Henry's law, Schrijver describes how both atmospheric CO_2 concentrations and water temperature influences the exchange of CO_2 at the sea surface: higher atmospheric concentrations result in an increased CO_2 absorption, whereas a higher water temperature results in reduced CO_2 retention. The implication is that some 're-balancing' of seawater CO_2 concentrations takes place.

For the land, he says: *"About half of the CO_2 that plants absorb through photosynthesis disappears almost immediately into the atmosphere in the form of plant respiration. The other half is converted into biomass (leaves, wood, roots, etc.) that ends up on or in the ground."* He also discusses the temperature-dependency of soil respiration. On this subject, Harde (2023) [10] concluded: ***"**Particularly soil respiration in the tropics and mid-latitudes can be identified as the main natural source of CO_2 emissions."*

Regarding the significance of the tropics in relation to atmospheric CO_2 increases, Harde and Salby (2021) [11] say in their abstract: *"Thermally-induced emission, especially from tropical land surface, is found to represent much of the observed evolution of net CO_2 emission"* and they conclude: *"Net emission of CO_2, which is the resultant of all contributions, is concentrated at tropical latitudes".*

It might be suggested that it is increases in anthropogenic CO_2 that are driving SSTs in Fig 3. However, by way of example, referring to the prominent 1998 peak in the figure, the CO_2 increase in 1998 was three times that in 1999. If this was a result of human emissions then these would have been three times as much in 1998 as '99. Data supplied by the GCB website [12] suggest these were about 24.9 Gt in 1998 and 25.4 Gt in 1999: very similar. The 1998 CO_2 peak therefore points to a natural origin and corresponds to a strong El Niño event with its associated warmer SSTs.

The observations described above serve as a starting point for the data analyses presented here, which first seek to identify and estimate an anthropogenic CO_2 signature from within this apparent natural atmospheric CO_2/SST relationship. Microsoft® Excel® is used throughout for data processing, graphics (except Fig. 11), linear regression trend lines and curve-fitting. In the discussion the results are compared to the findings of others, whose results are determined by different means.

2. Analysis 1: Using a Short Time Window

The first analysis method uses the relationship between a prominent short-term fluctuation in both SSTs and atmospheric CO_2 to try to discern and roughly-quantify a human component from the data given in Fig. 3. Data prior to 1995 is excluded due to the 1982 El Chichon & 1992 Mt. Pinatubo volcanic eruptions that suppressed atmospheric CO_2 levels. GCB data [12] suggests roughly half of all anthropogenic CO_2 emissions have occurred since 1995 with annual emissions increasing by about 60 % since then. The analysis procedure is as follows:

• Using only data from a short time window, identified by inset box in Fig. 4, establish the monthly CO_2 ppm increase as a function of the SST anomaly. The window chosen incorporates the 1998 El Niño event with a broad range of SST values to help optimize analysis accuracy. Due to the short time-frame for this window, this SST/CO_2 relationship is essentially independent of any longer-term ppm increase from anthropogenic emissions.

• Now apply this relationship to the whole SST dataset and calculate, from the SST values, the cumulative CO_2 ppm increase for every month since 1995.

The measured deseasonalized CO_2 increase at Mauna Loa was 62 ppm. If the calculated cumulative value (CCV) from the SSTs is about the same then this points to a non-discernible human component of CO_2. If the CCV value is less than 62 ppm then this could suggest the difference is a possible human component. For example, if the CCV is 52 ppm then the difference of 10 ppm might be attributed to anthropogenic emissions of CO_2.

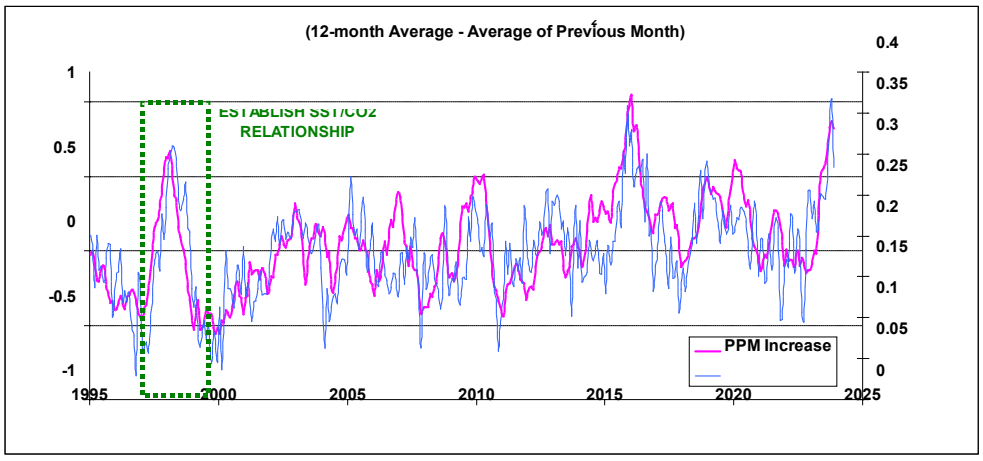

Figure 4: The 1998 El Niño Data Window Used to Establish the CO_2/SST Data Relationship

Using only the data within Fig. 4's inset box, SST and CO_2 values with the same time stamp are plotted as x-y values in Fig. 5.

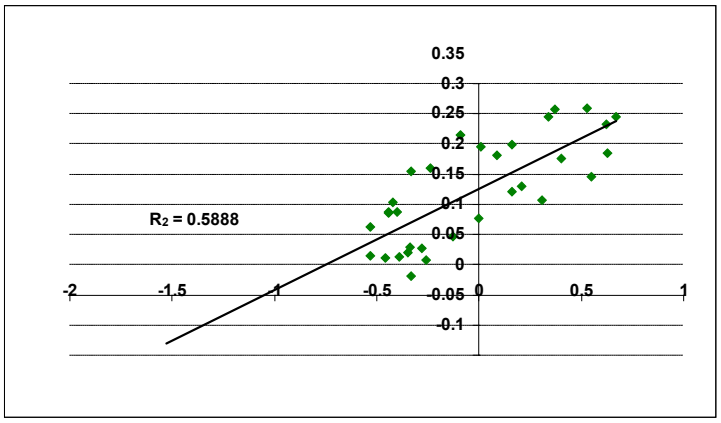

Figure 5: CO_2/SST Data Relationship for the 1998 El Niño Event

The trend line equation is then applied to the whole SST dataset (1995-2024). The calculated ppm increases for each month are then summed over the 28-year period. The final CCV and the measured ppm increase are in close agreement at about 62 ppm, Fig. 6.

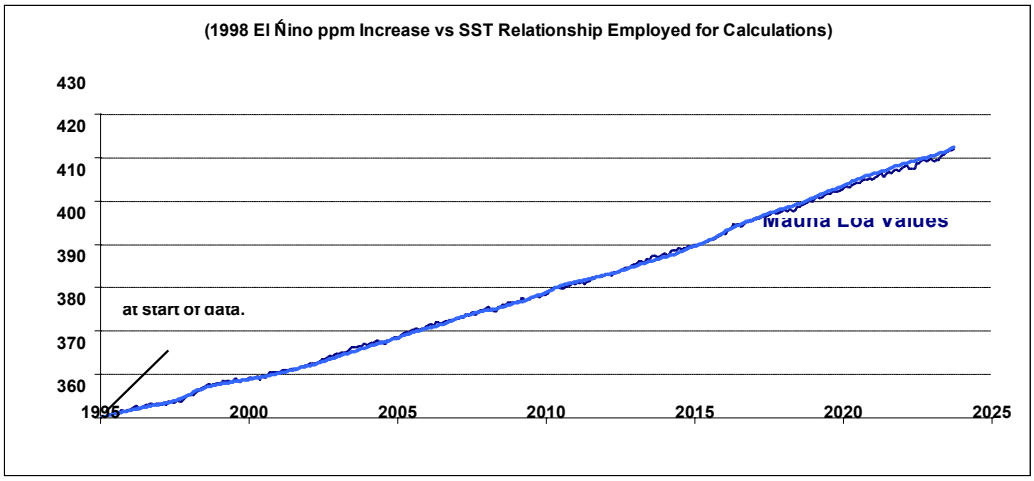

Figure 6: Calculated Cumulative CO_2 PPM Increase

3. Analysis 2: Using a Moving SST Window

With the same aim as Analysis 1, this second method uses the same data sets, and again the years prior to 1995 have been excluded to avoid possible biasing of the results due to the 1982 & 1992 volcanic eruptions. This method takes 'slices' through the data at different SSTs. Fig. 7 shows a typical 0.2 °C 'slice' or 'window'.

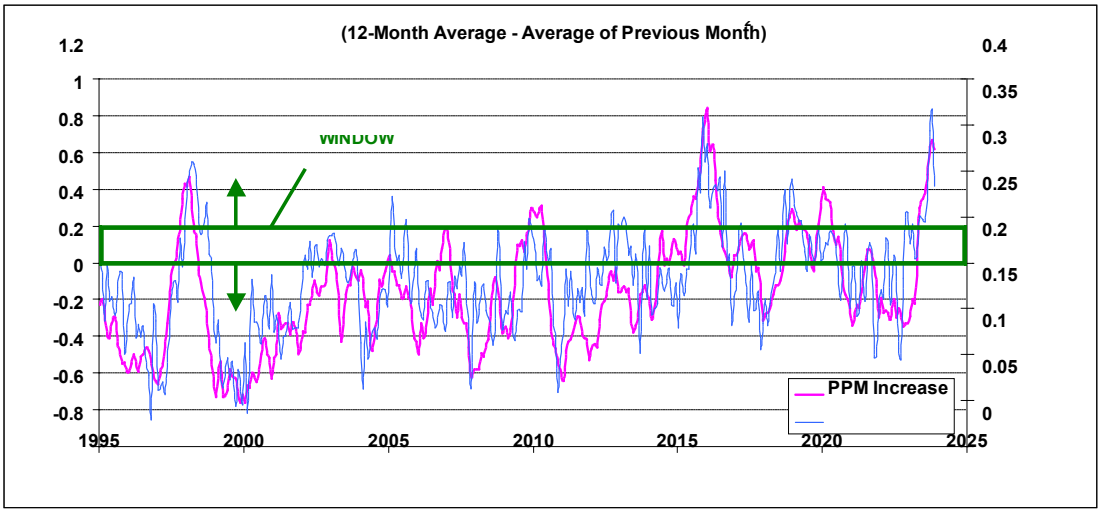

Figure 7: A Typical 'Slice' or 'Window' for a 0.2 °C Range of SSTs (1995 Onwards)

This method analyses SST data that is only within the chosen window. Monthly CO_2 increases, with the same timestamp as this SST data, are then plotted as a function of time. An assumption when using this method is that, if there is no influence from anthropogenic emissions, then there should be no upward trend in these increases as time progresses. However, if increasing annual anthropogenic emissions are contributing to those increases (GCB data suggests they have increased by about 60 % since 1995), then this may show up in the resulting trends.

Fig. 8 shows the trend in monthly ppm increases from the window identified in Fig. 7. The fitted trend line shows a very slight positive gradient resulting in a change in monthly increase of 0.0084 ppm since 1995, as calculated from the trend line's gradient.

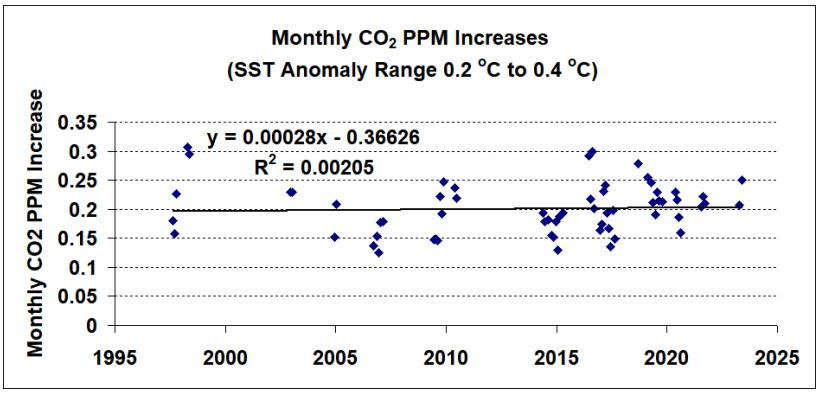

Figure 8: Monthly CO_2 PPM increases for the SST Anomaly Range 0.2 to 0.4 °C

This exercise is repeated as the window moves between -0.3 and 0.6 °C in steps of 0.1 °C, resulting in the trend lines, with equations, in Figs. 9(a-h). The highest and lowest SSTs are excluded from the analysis due to there being insufficient data points.

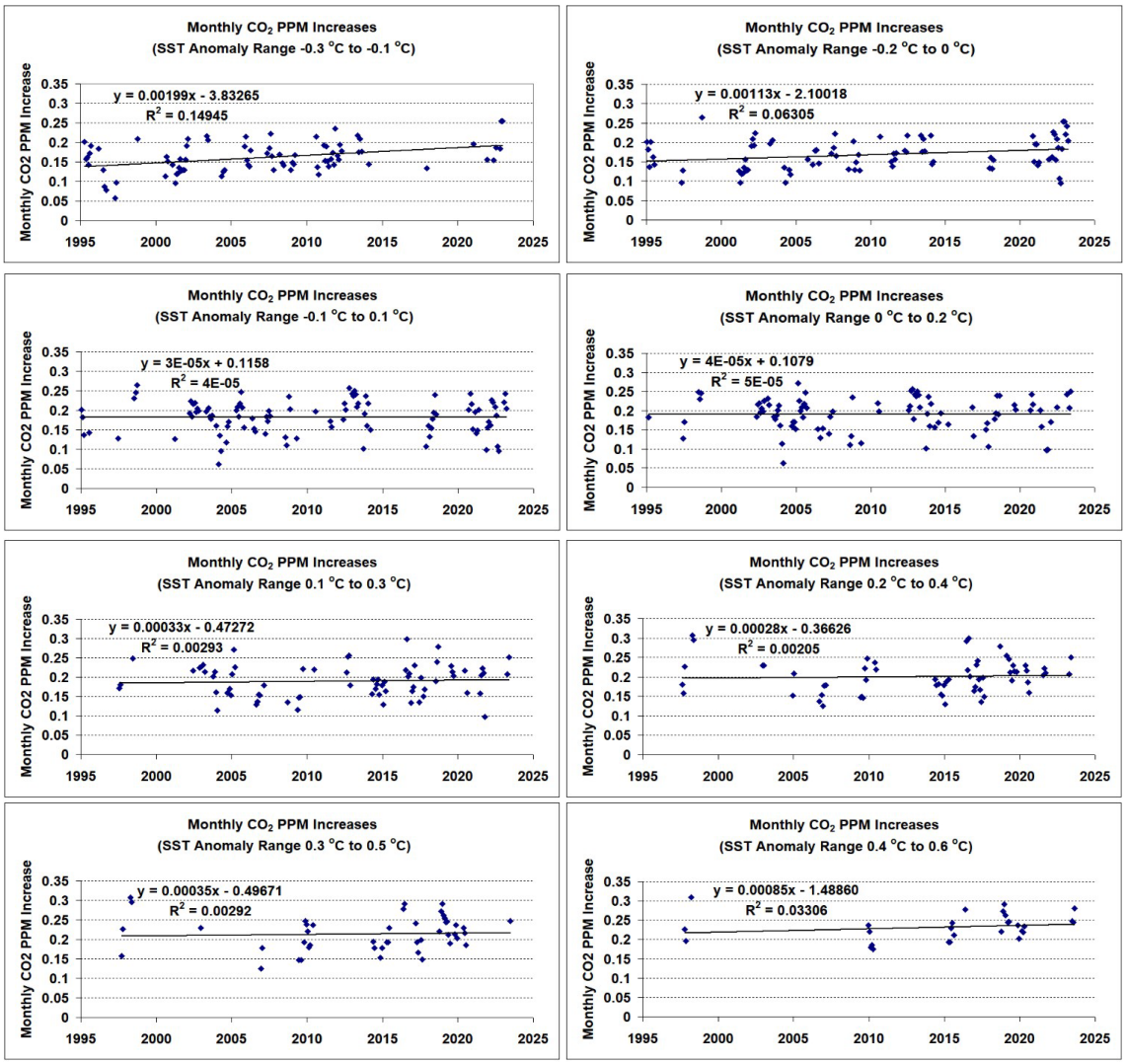

Figure 9 (a-h): Monthly CO_2 PPM increases for a Moving 0.2 °C Window of SST Anomalies

The average trend line gradient from all eight 'slices' is +0.000625 ppm change in the monthly increase, per year. At the end of the 28-year period this equates to a change of +0.0175 ppm/month (this figure can be approximately derived by visually examining the change in trend line end point values for each graph, and then averaging). Assuming that this change could be attributed to

anthropogenic emissions, an estimate can be made of the percentage contribution of these emissions to the total atmospheric CO_2 increase as follows:

• Assuming a linear increase in annual anthropogenic emissions since 1995 (see Fig. 10) calculate the change in ppm increase for each month, based on the 0.0175 ppm end-point figure. So, for example, the monthly change halfway through the period would be half of that value.

• For all 336 months over the 28-year period, sum each incremental monthly change with respect to the start of 1995, which is assigned a start value of zero. These are illustrated graphically in Fig. 11.

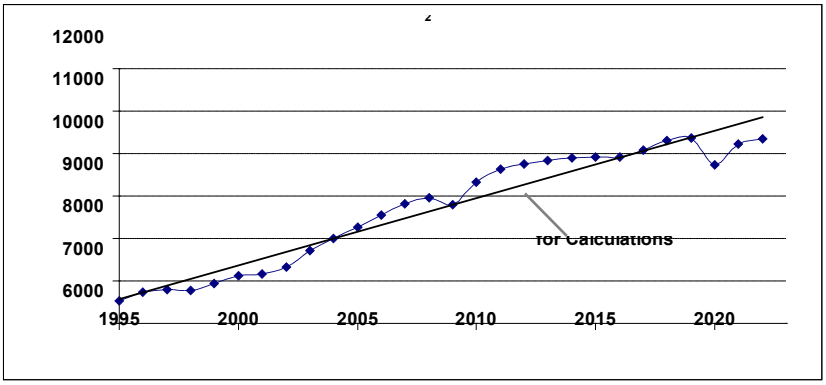

Figure 10: Increases in Anthropogenic CO_2 Emissions (1995-2023) are Assumed to be Linear

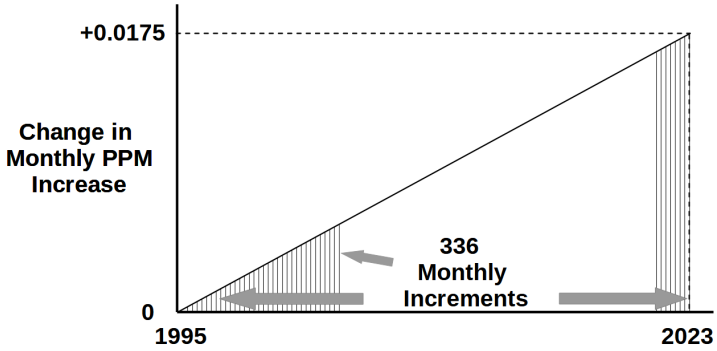

Figure 11: 336 Monthly Increments - Summed Together in the Calculations

The cumulative sum of all 336 incremental changes comes to almost 3 ppm. Mauna Loa data suggests the total atmospheric CO_2 ppm increase over this period is about 62 ppm. Thus the above calculations suggest a possible human contribution of 3 ppm out of 62 ppm, or about 5 % over the 28-year period.

It might be argued that the 'large' 0.2 °C window, used above, may inadvertently bias the trend line gradients in a more positive direction, due to a net increase in SST values (and associated ppm increases) within the window, as time progresses. If so, this would exaggerate any possible human contribution. To minimize any bias, if it exists, the above exercise was repeated for seven thinner 0.1 °C 'slices' or windows in steps of 0.1 °C over the SST anomaly range of -0.2 to 0.4 °C. This repeated exercise suggested a possible human contribution of just under 4 ppm out of 62 ppm, or about 6 %. Going to thinner windows still is not practical, due there being too few data points in each window.

The two analysis methods just described produce approximate results and so are useful for estimation only. Broadly-speaking, they suggest a quantifiable atmospheric CO_2 increase, possibly attributed to human emissions, of less than 10 %, and perhaps closer to 5 %, of the total over the last three decades, thus inferring that more than 90 % is of natural origin.

4. Analysis 3: Longer-Term Data Trends

Using a broadly similar technique to that described by the late Lance Endersbee (2008) [13], this third analysis method plots atmospheric CO_2 against longer-term trends in SSTs. To do this, the spreadsheet software applies a two-degree polynomial curve fit to tropic and global SST datasets, essentially acting as a low-pass filter that smooths out the peaks and troughs that are principally a consequence of El Niño and La Niña events.

4.1 3a. Global Tropic SSTs since 1982

Fig. 12 shows a polynomial curve fit to the global tropic SST data of Fig. 3.

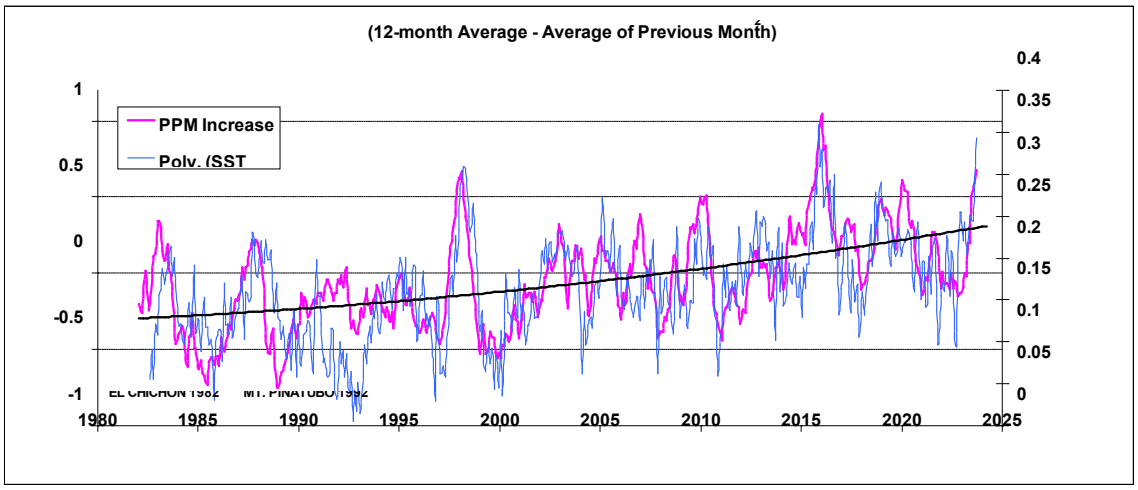

Figure 12: Polynomial Curve Fit to Global Tropic SSTs Since 1982

The equation for this curve fit is then used to plot the trend of atmospheric CO_2 as a function of the 'smoothed' tropic SST data, both parameters possessing the same timestamp for each data point, Fig. 13.

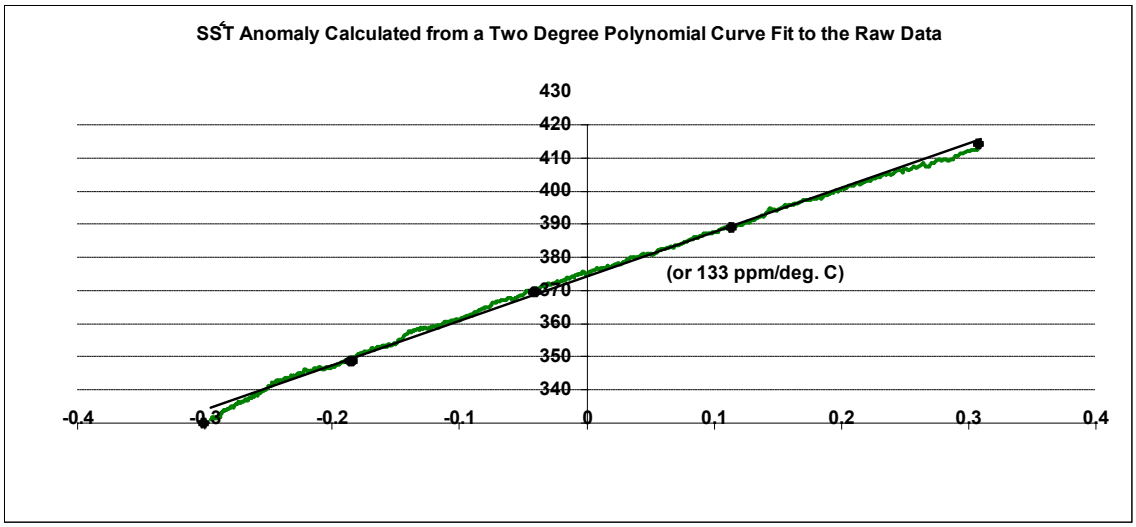

Figure 13: Atmospheric CO_2 as a Function of the Global Tropic SST Trend Since 1982

Date stamps are shown at selected CO_2 ppm levels. The linear trend line through the data produces a gradient of 133 ppm/ ^{0}C increase in tropic SST.

4.2 3b. East Pacific Tropic SSTs (81W-179W, 27S-27N) Since 1951 (NOAA Data [14])

This data goes back to 1950. Again, the spreadsheet software applies a two degree polynomial curve fit to the data, Fig. 14. Note that the SST anomalies for this dataset are assumed to be in Fahrenheit, and not Celsius as was stated on the website that the data was downloaded from.

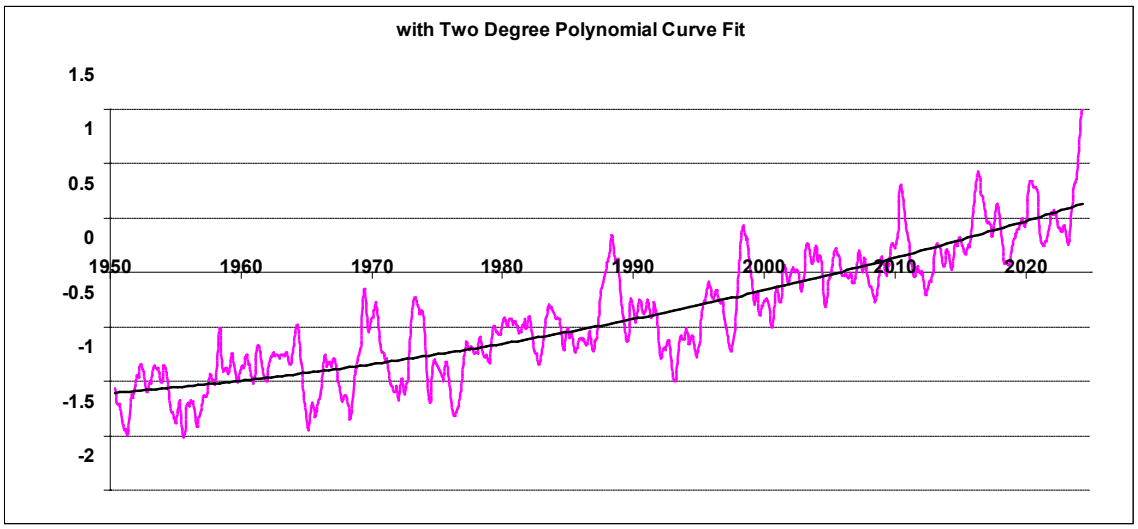

Figure 14: East Pacific Tropic SSTs Since 1950 (Degrees Fahrenheit Assumed)

The SST anomaly can take on any zero reference point and is the difference from a chosen baseline, which is normally a mean SST value averaged between two earlier dates. Using the data from the smoothed SST curve fit, above, the resulting trend of atmospheric CO_2 as a function of SST is shown in Fig. 15.

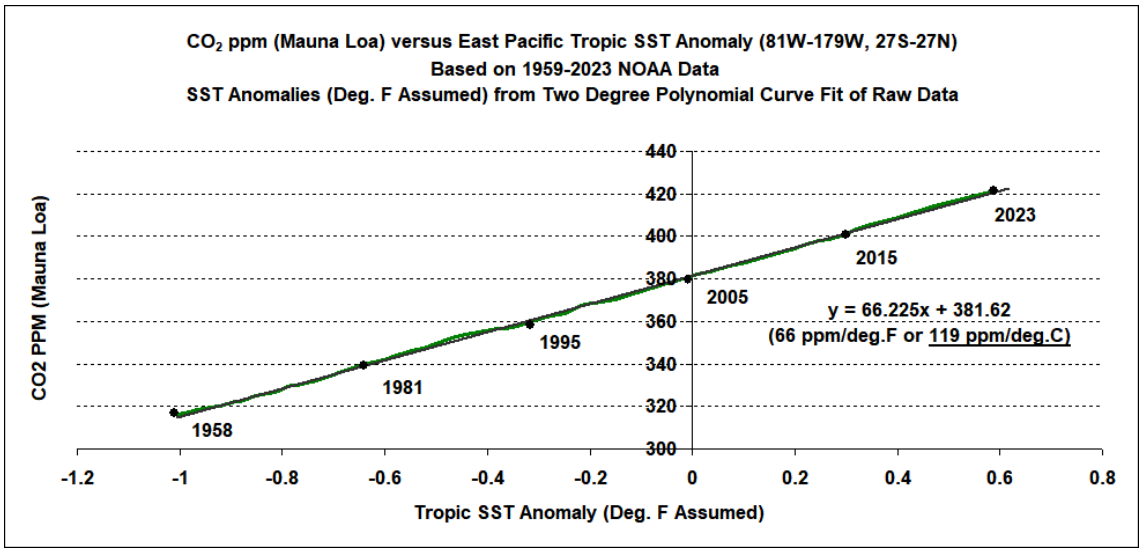

Figure 15: Atmospheric CO_2 as a Function of East Pacific Tropic SST Trend Since 1958

This linear trend line, which almost hides the graph due to the graph's linearity, produces a gradient of 66 ppm/ ^{0}F, or 119 ppm/ ^{0}C, increase in Eastern Pacific Tropic SST. This compares to a value of 133 ppm/ ^{0}C from Analysis 3a.

4.3 3c. Global SSTs Since 1958

The exercise is repeated here using global SST data [15] as compared to tropic SST data. A two degree polynomial curve is once again fitted using the spreadsheet software, producing the equation shown in Fig. 16.

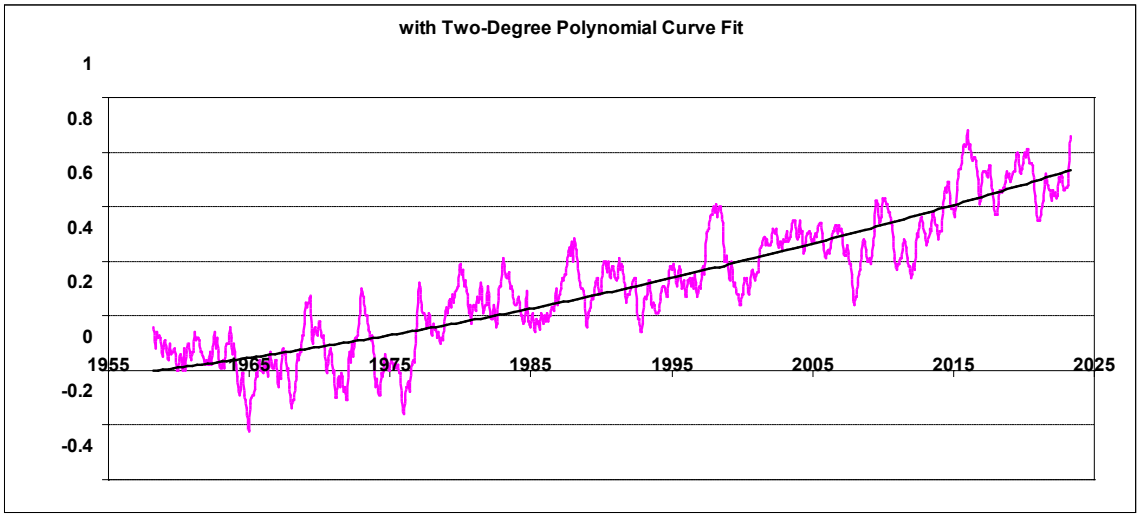

Figure 16: Global SSTs Since 1958

Using the data from the smoothed SST curve fit, above, the resulting trend of atmospheric CO_2 as a function of global SST is shown in Fig. 17.

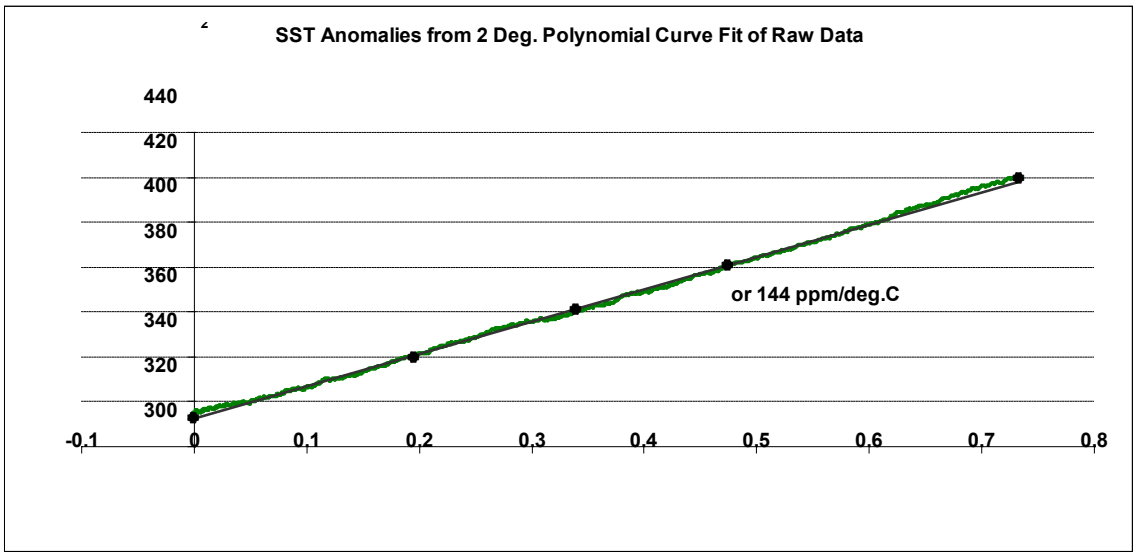

Figure 17: Atmospheric CO_2 as a Function of Global SST Trend Since 1958

This linear trend line produces a gradient of 144 ppm/ ^{0}C increase in global SST, slightly higher than the previous values of 133 and 119 ppm/ ^{0}C derived for the tropic SSTs. As a point of reference, GCB data suggests more than 80 % of human CO_2 emissions have occurred since 1958.

5. Discussion

The above analyses suggest that nature accounts for more than 90 %, perhaps nearer 95 %, of increases in atmospheric CO_2 since 1995, with an apparent almost linear longer-term relationship between SSTs and atmospheric CO_2 since at least the late 1950s.

As for anthropogenic CO_2, published figures suggest a roughly linear relationship between cumulative emissions and atmospheric CO_2 levels. If it's reasoned that this mostly accounts for the >100 ppm/ ºC trends in Analysis 3, this reasoning would not fit with the findings of the first two analysis methods.

5.1 What Others have to Say

A number of recent papers and articles put forward a case for recent increases in atmospheric CO_2 being mostly natural. Conclusions are drawn from several different lines of reasoning, and the approaches used to derive anthropogenic and natural contributions to recent increases are different from this present paper. Here are some examples in alphabetical order by author:

Ato (2024) [16] says in the abstract: "*this study is the first to use multiple regression analysis to demonstrate that the independent determinant of the annual increase in atmospheric CO_2 concentration was SST"* and concludes: *"The global SST has been the main determinant of annual increases in atmospheric CO_2 concentrations since 1959. No human impact was observed."*

Harde (2023) [17] says in the abstract: *"... we derive an anthropogenic contribution to the observed increase of CO_2 over the Industrial Era of only 15%."*

Koutsoyiannis (2024) [18] says in the abstract: "…*findings confirm the major role of the biosphere in the carbon cycle and a non-discernible signature of humans."*

Salby and Harde (2021) [19] conclude: *"Thermally-induced emission in the tropics closely tracks observed net emission of CO_2. It thus accounts for the preponderance of CO_2 net emission, which in turn determines anomalous CO_2. For this reason, the thermally-induced response to observed warming in the tropics represents nearly all of the observed increase of atmospheric CO_2."*

Schrijver (2024) [20] concludes: *"Due to the dominant role of natural changes in the biosphere under the influence of higher temperatures, one can conclude that the present CO_2 concentration can be regarded as a 'natural' level."... "With a single residence time for all carbon dioxide in the atmosphere the human contribution based on fossil fuels is approximately 4.3%..."*

Schroder (2022) [21] says in the abstract: *"Over the industrial era, the natural emission increased three times as much as the man-made. The result is that only about 25 percent of the increase in atmospheric CO_2 is man-made"*

Shelley (2024) [22] says in a recent on-line article: "... *I propose that the observed ocean warming since 1905… has resulted in the release of oceanic CO_2, which is the main reason why atmospheric CO_2 has increased by 140 ppm."*

Skrable (2022) [23] says in the abstract: **"***Our results show that the percentage of the total CO_2 due to the use of fossil fuels from 1750 to 2018 increased from 0% in 1750 to 12% in 2018…"*

Summarizing the above figures of human atmospheric CO_2 contributions since the start of the industrial revolution, these are: 25 % (Shroder), 15 % (Harde), 12 % to 2018 (Skrable) and 4.3 % (Schrijver). Both Ato and Koutsoyiannis suggest no discernible human contribution.

By comparison, the maximum estimated figure from the analyses in this present paper is ~6 % since 1995, and GCB data suggests that roughly half of total human emissions have occurred since 1995. Simple extrapolation of the 6 % figure back to the start of the industrial revolution is therefore roughly double at ~12 %. This simple extrapolation should be viewed with a little caution, but may be useful as a comparison to the above figures, falling roughly midway between the 25 % figure and no discernible human contribution.

With regards to the ppm/ ºC trend line gradients derived in Analysis 3 of this present paper, these gradients (averaging ~130 ppm/ ºC) are broadly-similar to the graph in Fig. 3 of Harde's 2017 paper [24], for surface temperatures of the last fifty years or so.

Referring again to the findings of Analyses 1-3 in this present paper, factors that may explain these findings are now considered (note that most of these factors are discussed by the aforementioned authors).

5.2 A Natural CO_2 Surface/Atmosphere Balance?

The idea of a natural CO_2 surface/atmosphere balance is certainly nothing new. In his 2008 paper, Goldberg, for example, considered Henry's law as a fundamental contributor to such a balance. This states that the amount of gas dissolved in a liquid is directly proportional to the gas's partial pressure above the liquid. The law applies to any water exposed to the atmosphere, from ocean surfaces to cloud droplets, and the associated temperature-dependency means that cold water is able to retain more CO_2 than warm water.

When considering the oceans, most of the absorbed CO_2 undergoes chemical dissociation, or ionization: the vast majority seemingly 'prefers' to take the form of bicarbonate and carbonate ions. When CO_2 is released from the oceans, the chemistry works in the reverse direction. Henry's law applies to CO_2 as a gas only, not to its associated ionic species, and simple calculations suggest that this law, when used in isolation from any other chemistry, results in a CO_2 ppm/ ºC figure that's about an order of magnitude smaller than the >100 ppm/ ºC values derived in Analysis 3. If that's the case (and some hypothesizing is required here) then perhaps the reversible chemical changes taking place during ocean absorption and degassing might serve to 'enhance' the Henry's law effect: the suggestion being that most of the CO_2, upon absorption, is essentially removed from the balance determined by this law, through the process of ionization, so allowing more CO_2 to be absorbed; the reverse taking place for CO_2 degassing.

CO_2 solubility in water is also pressure-dependent: water at 100m depth, for example, can retain about seven times more CO_2 than at the surface [25]. Perhaps water mixing between different depths, or general upwelling of deep CO_2-rich waters, might also be factors that enhance CO_2 exchange between the ocean and atmosphere.

Returning to the wider picture, I've again assumed that changes in the terrestrial and marine biospheres, and associated carbon cycles, would coincide with changes in SSTs, much as others have concluded. All are interlinked through global temperature changes and associated changes to weather patterns, and all would have a part to play in any temperature/CO_2 relationship. As Humlum et al. noted, changes in both air temperature and naturally-sourced atmospheric CO_2 follow changes in SSTs and my assumption is that nature's carbon cycle as a whole adjusts to changes in climate, which in turn are initiated by changes in SSTs.

5.3 CO_2 and a Colder Climate

Taken at face value, the observed >100 ppm/ ºC relationship implies that, if surface temperatures were a few degrees cooler, atmospheric CO_2 levels would drop to the point where terrestrial plant life wouldn't survive: the threshold for plant survival is often quoted as ~150 ppm. Clearly, atmospheric CO_2 must have remained above this threshold and this might partly be explained if the ppm/ ºC relationship diminishes in magnitude as the biosphere becomes less active in cooler conditions. Also, a minimum level of atmospheric CO_2 may always be present due to emissions from volcanoes, other fissures within the earth's surface, wildfires and weathering of carbonate rocks. Aquatic CO_2 would still be in abundance and phytoplankton, that synthesize CO_2, are the start of the aquatic food chain, supporting marine life that respires CO_2. Harde (2017) discusses atmospheric CO_2 levels in cooler climates in some detail [24].

5.4 Coincident Peaks Centered Around the 1940s

Temperature records show a peak in SSTs centered around the 1940s. If a natural surface/CO_2 balance holds true, is there any evidence of a coincident increase in atmospheric CO_2 at that time? Mauna Loa data did not come on stream until 1958, but there are numerous data sets of atmospheric CO_2 concentration, measured using chemical methods, going back to the early 1800s. These are described in a paper by the late Ernst-Georg Beck (2008) [26].

Atmospheric CO_2 measurements vary depending on location, time of day and season, and the measurements of the early 1800s were likely to be less accurate than more recent ones. These factors would account for some of the scatter in the data presented in the paper. However, within the collated measurements are several datasets indicating a peak in CO_2 levels in the 1930s-40s. Often-shown 'CO_2 hockey stick' graphs, partly based on ice core derived data, do not show any such peak of course, something which Beck is critical of in his paper[1].

In Fig. 18 a graph is constructed that combines the direct chemical measurement CO_2 trend (1880-1960) from a later, more extensive paper by Beck (2010) [27][2] (see his Table 11) with Mauna Loa data. A graph of global SST trends from1880 onward [28] is shown above the CO_2 trend.

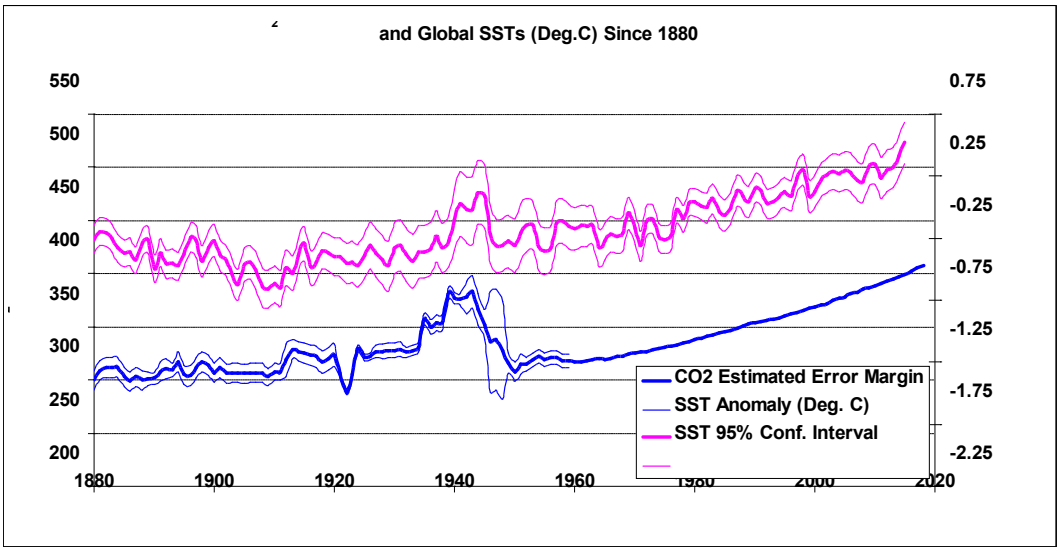

Figure 18: Atmospheric CO_2 ppm (Chemical and Mauna Loa Data) and Global SSTs. The Error Margins and Confidence Intervals are as supplied with the Chemical CO_2 and SST Datasets.

The figure shows broadly-coincident peaks centered around the 1940s[3]. The CO_2 peak's transience would imply a short atmospheric residence time: opinions on this range from less than five years upwards. The peak in global temperatures is documented in both SST and terrestrial records.

Despite Beck's best efforts in analyzing the collated chemical measurements, the presence (and perhaps magnitude) of a CO_2 peak centered around the 1940s is the subject of ongoing debate. Should the CO_2 profile in this figure be a fair representation of reality, then the coincidence of the two peaks is again suggestive of nature working to maintain a surface/ CO_2 balance.

5.5 Further Considerations

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[1] Beck mentions "the unreliability of ice core reconstructions" and cites the work of the late Zbigniew Jaworowski who wrote several publications on this matter, for example Jaworowski et al. (1992) [27].

[2] Beck's 2010 paper contains more refined data analysis compared to his earlier 2008 paper.

[3] Beck also plotted coincident SST and CO_2 peaks in his 2010 paper [28]. His Fig. 26 shows more precise peak alignment and he describes the cross correlation of the traces as having "a lag of 1 year for CO_2 after global SST".

Earth's continually-changing climate has warmer interludes, such as the relatively-recent Medieval, Roman and Minoan warm periods (the present milder climate is sometimes named the Modern Warm Period)[4]. Given these warmer periods and consideration of a natural temperature-dependent surface/CO_2 balance, it seems logical to question whether the present levels of atmospheric CO_2 are anything unusual. As for CO_2 as a greenhouse gas, at the levels we currently experience, it has already done all the warming it can easily do because of the 'saturation effect'.[5]

6. Conclusions

Analyses of SST and atmospheric CO_2 data, acquired since 1995, produce an estimated atmospheric CO_2 increase, possibly attributed to human emissions, of less than 10 %, and perhaps closer to 5 %, of the total increase, thus inferring that more than 90 % of the increase since 1995 is of natural origin. Further data examination points to an almost linear longer-term relationship between SSTs and atmospheric CO_2 since at least the late 1950s, and is suggestive of nature working to maintain a temperature-dependent atmosphere/surface CO_2 balance. Recent historical evidence of such a balance may come from chemical measurements that indicate a brief peak in atmospheric CO_2 levels centered around the 1940s, and that coincided with a peak in global SSTs.

Human emissions of CO_2 are about 1/20th of the natural turnover, and the findings of the analyses presented here suggest that this relatively-small human contribution is being readily incorporated into nature's carbon cycles as they continually adjust to our constantly-changing climate.

As for surface temperatures, the research by Humlum et al. concluded that changes in atmospheric temperature are an 'effect' of changes in SSTs and not a 'cause' as some might advocate. And Humlum's 'take home' message from a recent presentation was: 'What controls the ocean surface temperature, controls the global climate' [31]. He suggests the sun would be a good candidate, modulated with the cloud cover.

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[4] The fact that these warmer interludes are roughly 1000 years apart is almost certainly no coincidence. There are multiple climate cycles spanning decadal to millennial time scales, each of different phase and amplitude and contributing to a complex pattern of warming and cooling trends. There is considerable recent research on this topic e.g. Ludecke et al. (2017) [30].

[5] The CO_2 'saturation effect', the physics of which the IPCC doesn't dispute, is explained eloquently by physicist Will Happer in his many presentations and articles.

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