# Quantifying the anthropogenic contribution to atmospheric CO2

Posted on May 6, 2015 by curryja | 2,119 Comments

by Fred Haynie

I conclude that, the IPCC's model assumptions that long-term natural net rate of accumulation is constant and anthropogenic emission rates are the only contributor to total long-term accumulation of atmospheric CO2, is false.

All the data I have analyzed are evidence that reported monthly averages are measurements of a global distribution of background levels of CO2. Event flask measurements that were exceptionally high (that could be from local anthropogenic sources) have been flagged and were not included in monthly averages. The result is a consistent global uniformity with no significant variation with longitude and a latitude dependent seasonal variation. That seasonal variation is the greatest and relatively constant north of the Arctic circle. There are similar but lesser seasonal variations in the Antarctic.

The Scripps data set from sites that were selected to represent background, http://scrippsco2.ucsd.edu/data/atmospheric_co2.html, has the longest time coverage for both CO2 and 13CO2 index. Much more data measured around the globe are published at the World Data Centre for Greenhouse Gases . The seasonal variations are caused by natural processes which are temperature dependant. Anthropogenic emissions are not temperature dependent. Therefore, evidence for an anthropogenic increase in atmospheric CO2, is more likely to be observed in long term changes with the seasonal variations factored out.

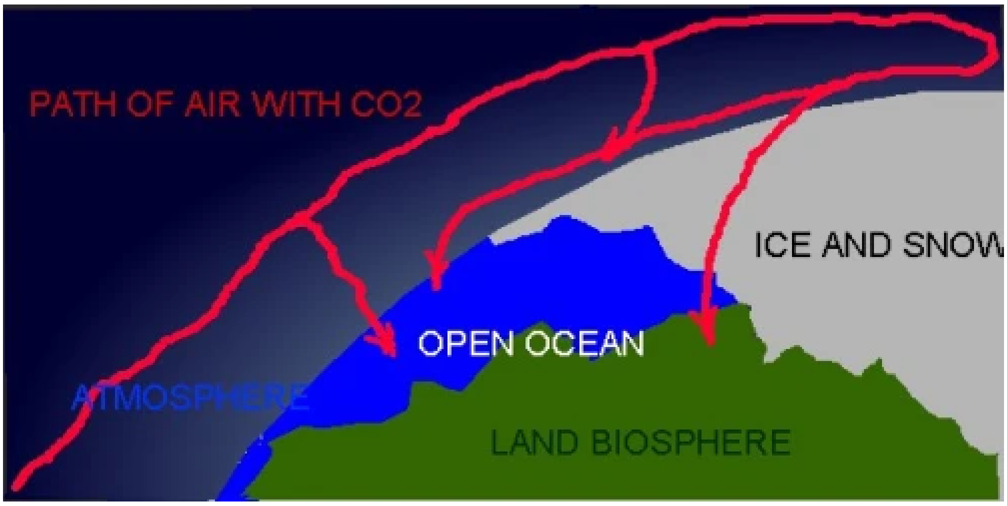
Year to year increasingly negative 13CO2 index values indicate that the atmosphere is accumulating the lighter CO2 faster than it does the heavier. Since the lighter is more from organic origin and the heavier more from inorganic, it has been assumed that the consistently increasing burning of fossil fuel has caused the difference. This assumption does not consider long-term changes in natural source and sink rates. The long-term proxied ice core data for atmospheric CO2 concentrations indicate that these natural changes are significant and should be considered in any mass balance type of calculation.

The C 13/12 ratio is calculated as:

Delta C13= ((C13/C sample)/(C13/C PDB)-1)*1000.

If we assume that all the CO2 from organic origin can be represented by an average Delta C13 value of somewhere between -15 and -30, and that from inorganic origin has a value of 0 represented by the PDB standard, we can make a first estimate of the organic origin fraction by dividing the index by say -20. Actually, both fractions have ranges of values and there are inorganic fractionation processes that can produce values within the organic range. To get a better estimate of the average organic origin index value, regress the measured values of atmospheric concentration on the measured index values. The resulting concentration coefficient is an estimate of the average organic origin index value for the time period regressed. The ratio of the measured 13CO2 index to this value gives an estimate of the organic fraction. This simple conversion of the Delta C13 index to an organic fraction has no effect on the accuracy of values and reverses the sign so that the accumulation is shown as positive.

The Arctic data has both the highest background concentration values and the greatest seasonal variation. The seasonal variation is likely the results of the ever-changing unfrozen sink area (both ocean and land biosphere). We should be able to get a more accurate $CO_2$ mass balance using these data from this primary sink area. Nearly all of the $CO_2$ is coming from the south and is being delivered in the upper atmosphere.




So what do the Arctic data tell us? Take a look at what I have found at the two sources referenced above. The following plots are based on the monthly averaged data from all the land based measuring sites located north of 60N.

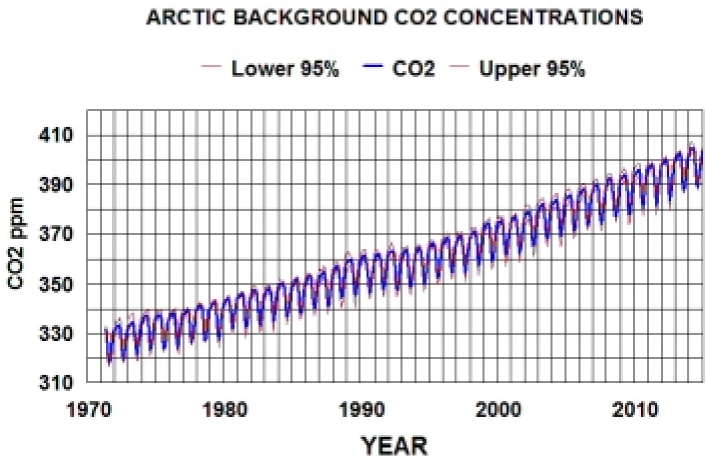



Fig 1. Arctic background $CO_2$ concentrations as a function of time.

The above plot is point to point on averages of monthly averages of 18 sets of data. The average of all the two standard deviations is only 2.2 ppm. Any locational differences appear to be insignificant.

A similar analysis of $^{13}CO_2$ index data yields the following plot.

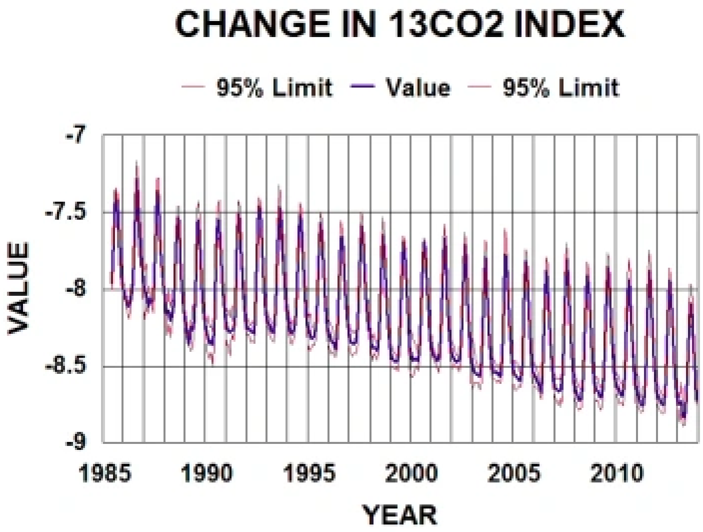



Fig 2. Change in 13CO2 index in the Arctic as a function of time.

This plot is based on eight sets of flask data from the same region north of 60N. The observed variations in both plots appear to be mirror images as one should expect.

To reduce the error estimates and improve the signal to noise ratio, both sets of data were smoothed by calculating running three months averages. Since we want to determine the relative natural and anthropogenic contributions, and anthropogenic emissions are rates, we are more interested in accumulation rates rather than the amount accumulated as shown in the above plots. The total seasonal short-term rates were calculated as running two month differences (i.e. 6*(Mar. – Jan.). The long-term values are running twelve month differences (i.e. Jan. 2000 – Jan. 1999). Anthropogenic Emissions assumes uniform global distribution with no sink rate and is shown for comparison with the net measured rates.

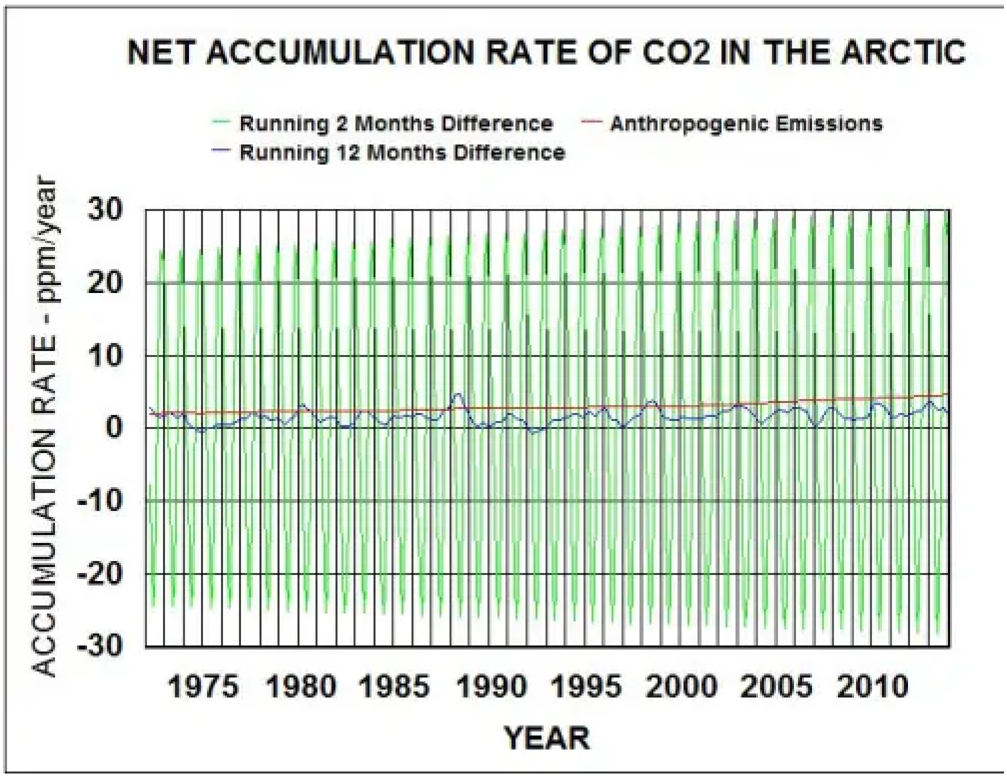



Fig 3. Comparison of net short-term and long-term accumulation rates with anthropogenic emissions.

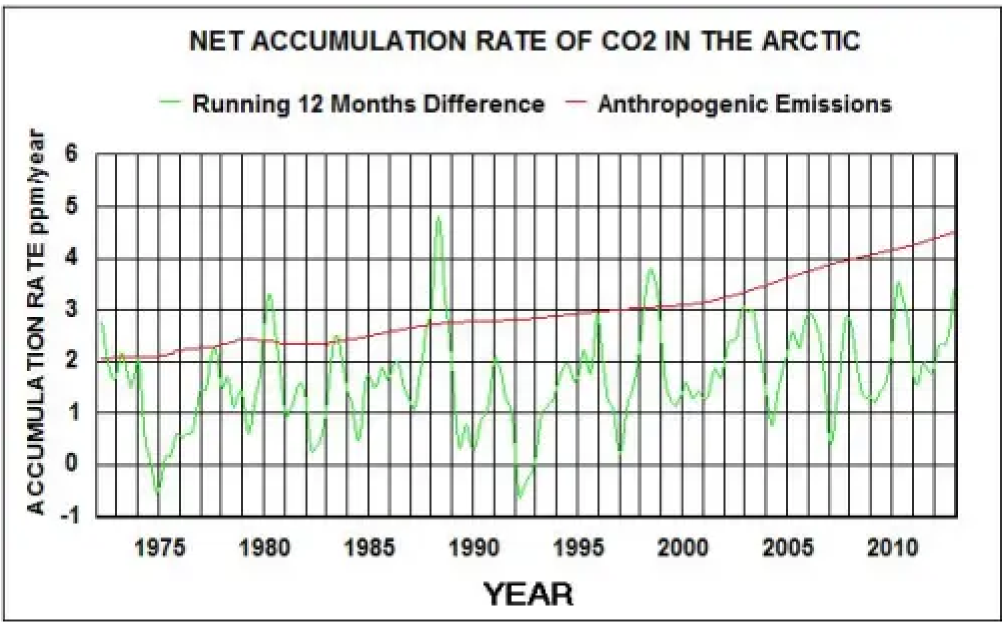



Fig. 4. Comparison of net long-term accumulation rates with anthropogenic emissions.

The seasonal variations (running 2 months) in all of these plots are orders of magnitude greater than the year to year variations (running twelve months). The two months net rates primarily reflect natural processes but may include anthropogenics that have cycled through the system.

The following are similar plots for the smoothed 13CO2 index values.

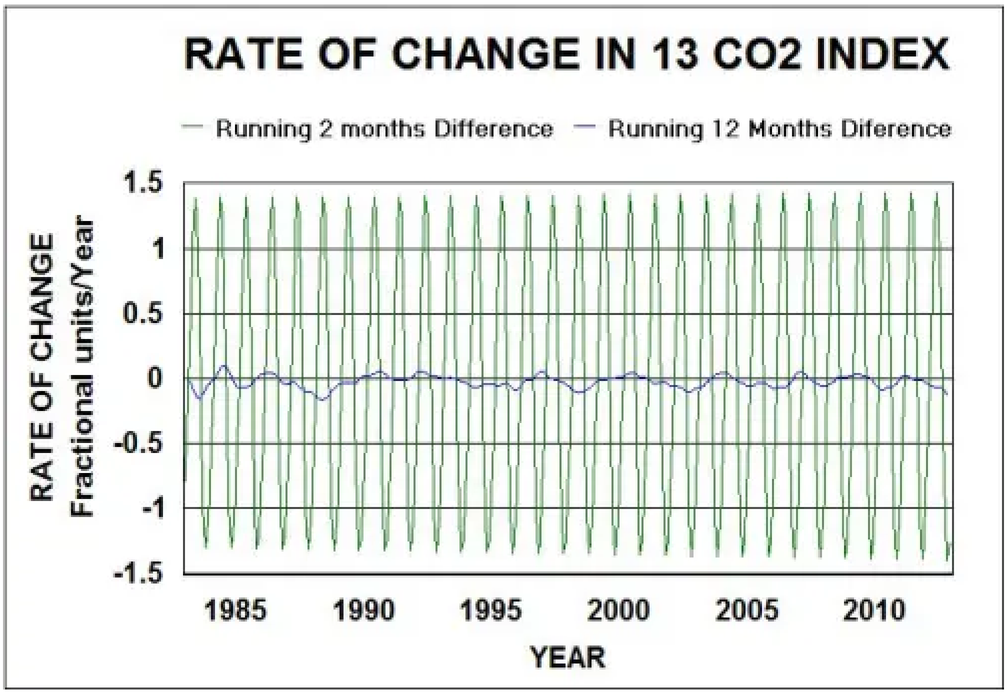



Fig. 5. Short and long-term rates of change in the 13CO2 index.

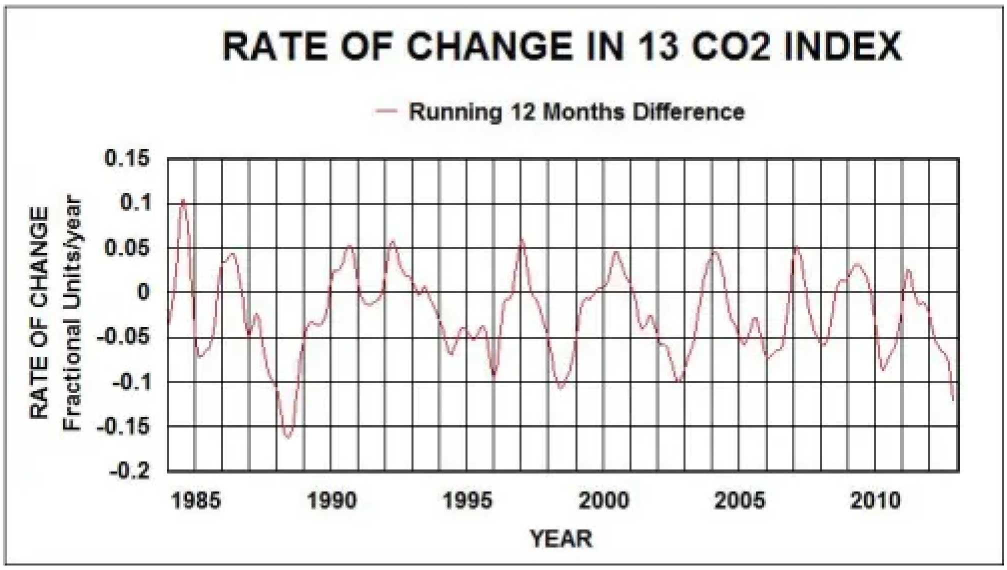



Fig. 6. Long term rates of change in the 13CO2 index.

Both sets of running two months differences fit a triangular wave form (cosine function with one harmonic) and an interaction with time term. The resulting R squares are greater than 0.99. Regressing the short-term CO2 accumulation rates on the 13 CO2 index rates and time times the index yields an index coefficient of -19.78 with 2 standard deviations (95% confidence limits) of 0.13. This is a best estimate of the organic fraction average 13 CO2 index mostly from natural sources. With this value I was able to calculate the organic and inorganic fractions of the natural annual cycles and estimate the relative contributions of each.

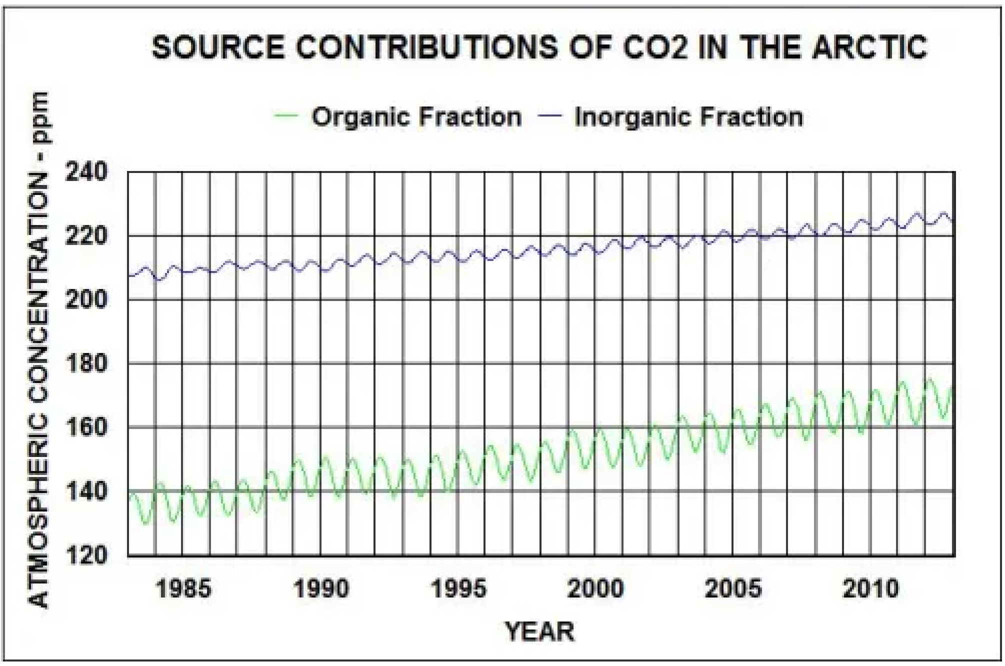



Fig. 7. Relative contribution to Arctic CO2 concentrations from organic and inorganic sources.

The long-term linear trends accumulation rates are 1.17 ppm/year for organics and 0.57 ppm/year for inorganics. The seasonal variation of the organics is greater than the inorganics and with an opposite phase.

The running 12 months difference data indicate much lower rates that change significantly from year to year. The contribution of anthropogenic emissions should be evident in these data but does not account for the variability.

Regressing the long-term CO2 accumulation rate on both the long-term rate of change in the 13CO2 index, anthropogenic emission rates, and their possible interaction
yields the following results.

| LONG-TERM ACCUMULATION RATE REGRESSION RESULTS | | | |
|---|---|---|---|
| Constant | | | 0.451 |
| Std. Err. of Y Est. | | | 0.508 |
| R Squared | | | 0.688 |
| No. of Observations | | | 357 |
| Degrees of Freedom | | | 353 |
| Independent Variables | X1*X2 | X1(13CO2) | X2 (Anthro.) |
| X Coefficients | -2.871 | -6.016 | 0.290 |
| Std. Err. of Coefficent | 0.987 | 3.050 | 0.055 |
| Note: Anthropogenic emissions affect both the rate of accumulation and the rate of change in the 13CO2 index requiring an interaction Variable in the regression. | | | |

Table I. Results of regressing long-term CO2 accumulation rates on long-term 13CO2 index rate of change, anthropogenic emissions, and their interaction.

The following plot graphically presents these results for the anthropogenic contribution to the total long-term accumulation rate of atmospheric CO2.

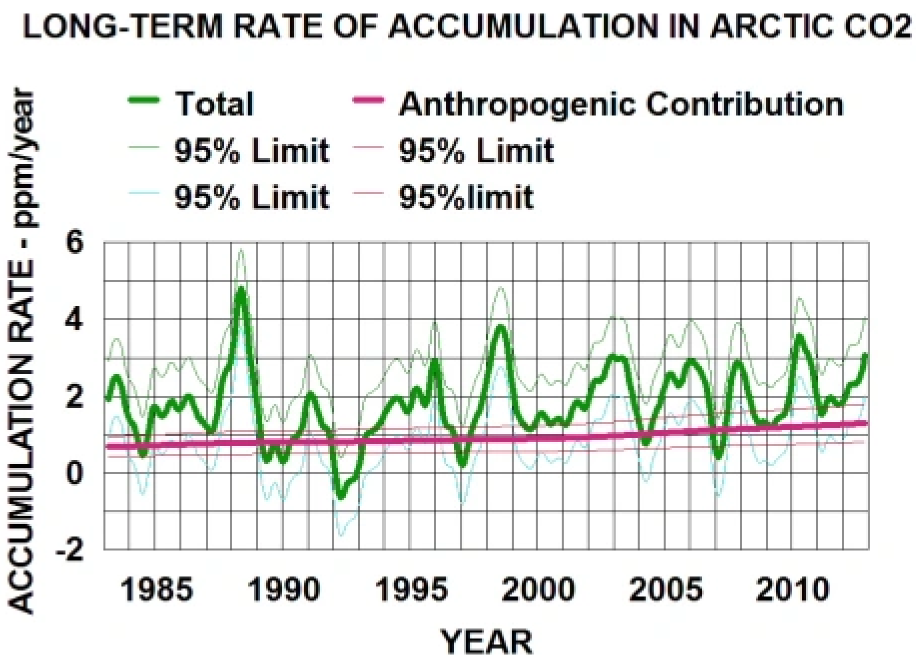



Fig. 8. Relative contribution of anthropogenic CO2 to the long-term rate of accumulation in the Arctic.

I used the anthropogenic emission rate coefficient and related estimate of error to estimate the accumulation of anthropogenic CO2 in the atmosphere/surface system. The surface includes water, soil and biosphere that are affected by cycles with wave lengths of less than around 500 years. For example, the decay of forest litter has a cycle wave length of about 10 years. Phytoplankton decay is expected to cycle CO2 faster. The results are shown in the following plot.

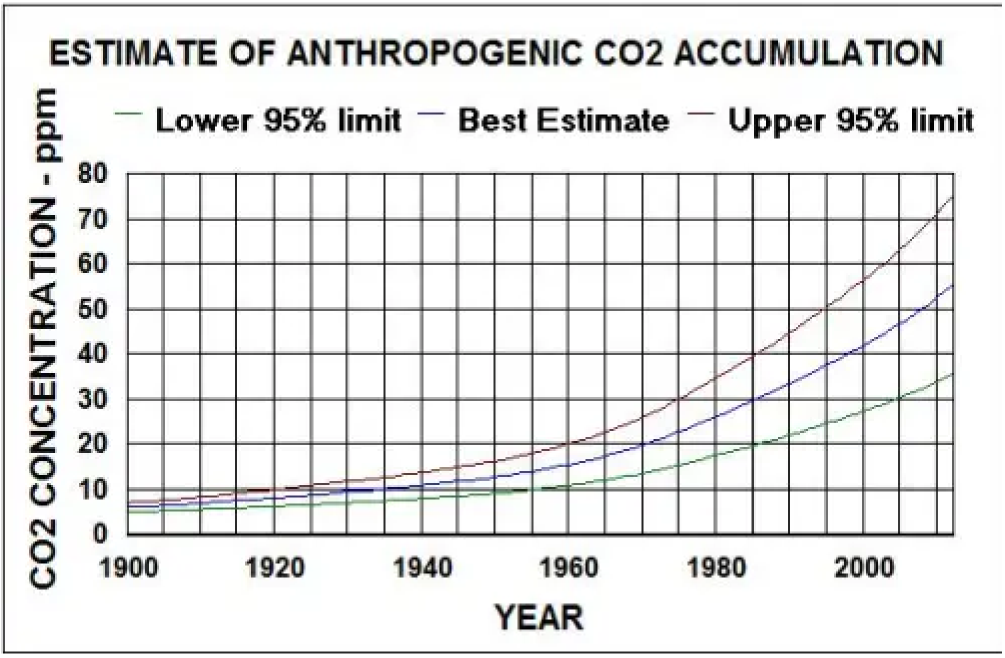



Fig 9. Estimate of anthropogenic CO2 accumulation in the global atmosphere/surface system from Arctic atmosphere data.

Subtracting the anthropogenic accumulation from the total long-term accumulation (with seasonal variations factored out) gives the net natural long-term accumulation. the following plot shows the results for the Arctic.

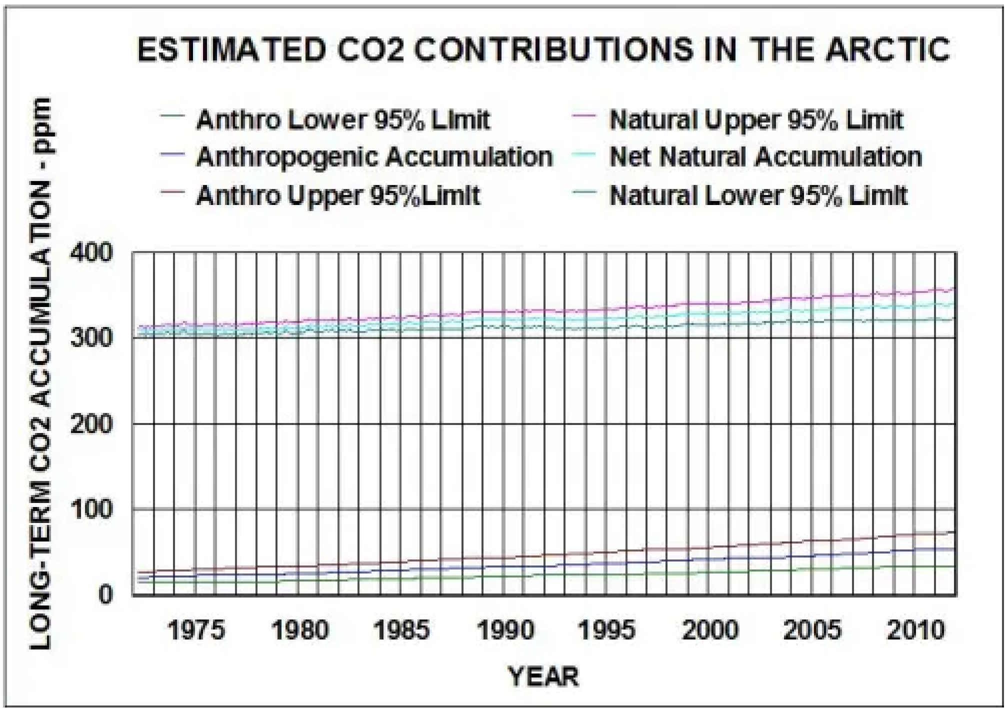



Fig. 10. Estimated contributions to atmospheric CO2 concentrations in the Arctic.

Both anthropogenic and natural emissions have been rising, with anthropogenics rising faster than naturals. This relative rise rate is shown in the following plot.

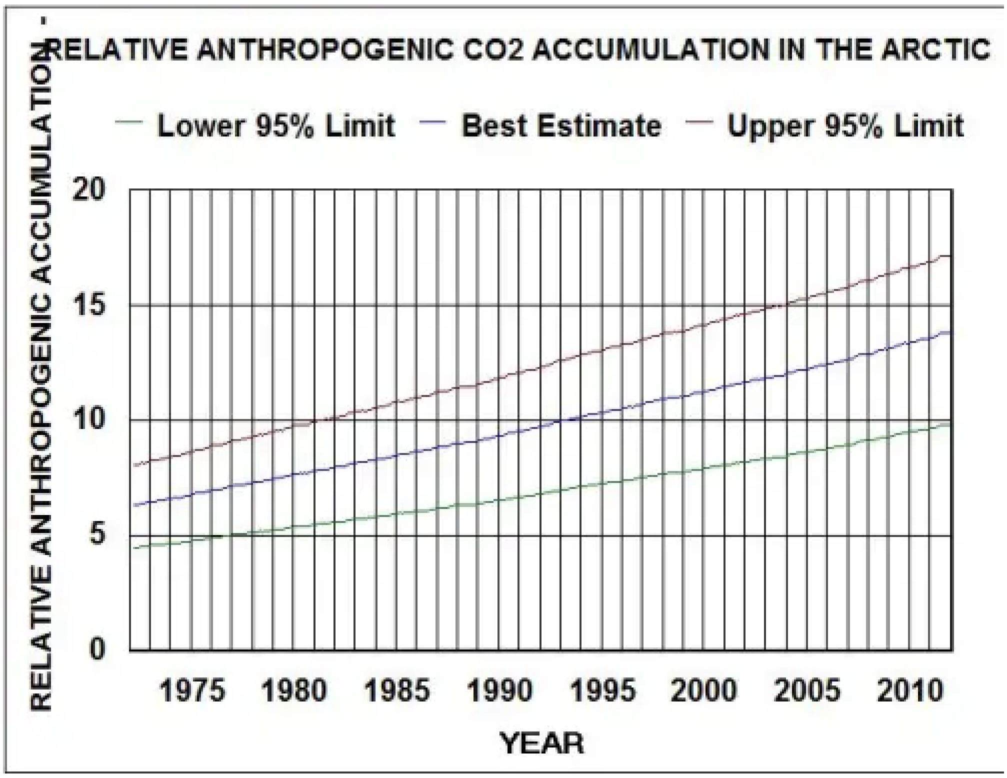



Fig. 11. Relative contribution of anthropogenic emissions to the atmospheric accumulation of CO2 in the Arctic.

This plot indicates that lowering global anthropogenic emissions to 1990 levels would likely lower the accumulation in the Arctic by less than 5%.

To show that the Arctic is representative of the global distribution of atmospheric CO2, I similarly analyzed both the Mauna Loa and Antarctic (south of 60S) data. There are multiple data sets of CO2 and 13CO2 index for both locations.

The following plots compare the results with that obtained from the Arctic data.

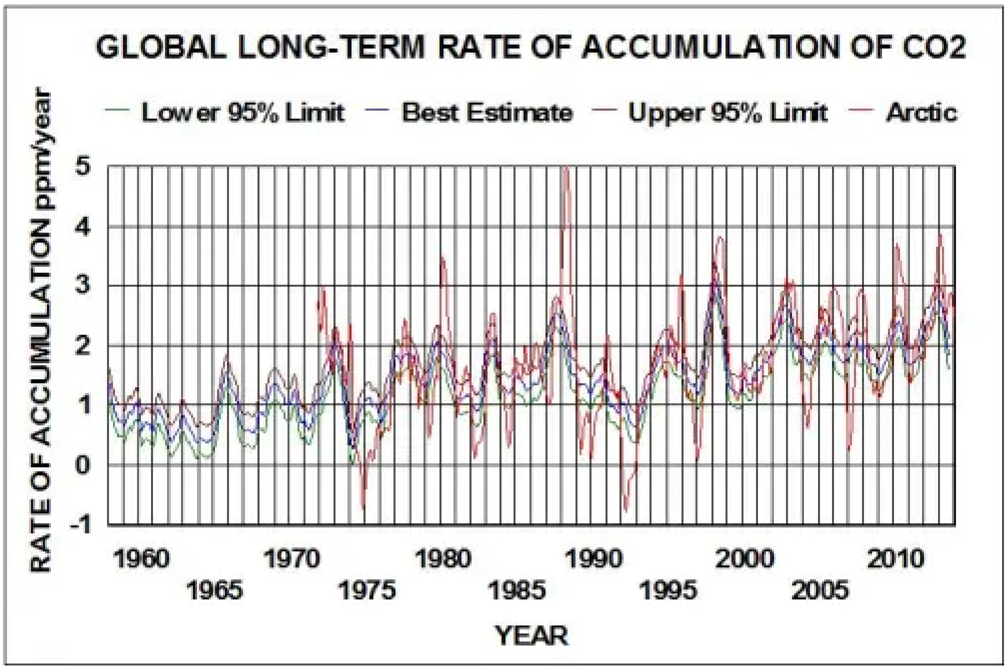



Fig. 12. Global long-term rates of accumulation of CO2 for Mauna Loa and Antarctica compared with Arctic.

The trends are similar but the Arctic data is much more variable and the peaks appear to lag by a few months.

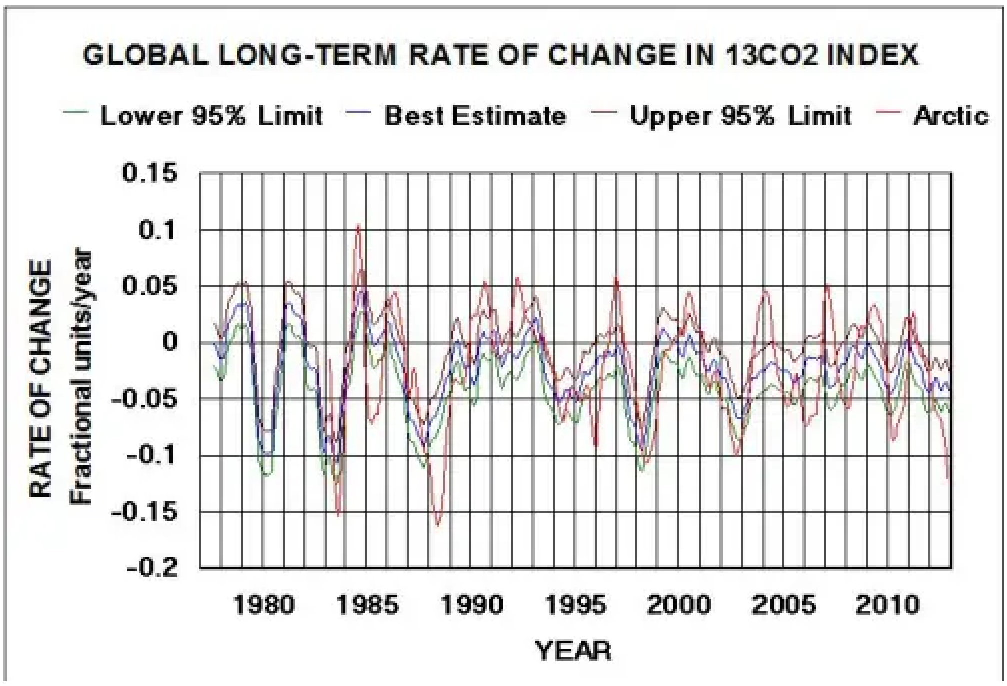



Fig. 13. Global long-term rate of change in the 13CO2 index for Mauna Loa and Antarctic compared with Arctic.

The same differences are observed in these results, but they are not as pronounced. Like the Arctic data, there is a strong relationship between the CO2 accumulation rate and the 13CO2 index for the Mauna Loa and Antarctic data. The latter should be a better global signature for atmospheric CO2 distribution and composition. I used the strong correlation ( R > 0.99 ) to calculate 13CO2 values back to 1957 (beginning of Scripps CO2 measurements). I then regressed the long-term CO2 values on anthropogenic emissions and an interaction term between anthropogenic emissions and the long-term rate of change in the 13CO2 values. The results are in the following table.

| GLOBAL LONG-TERM ACCUMULATION RATE REGRESSION RESULTS | | |
|---|---|---|
| Constant | | 0.749 |
| Std. Err. of Y Est. | | 0.264 |
| R Squared | | 0.798 |
| No. of Observations | | 669 |
| Degrees of Freedom | | 666 |
| Independent Variables | 13CO2*Anthropogenic | Anthropogenic |
| X Coefficients | -4.135 | 0.219 |
| Std. Err. of Coefficent | 0.136 | 0.015 |
| Note: Anthropogenic emissions affect both the rate of accumulation and the rate of change in the 13CO2 index requiring an interaction Variable in the regression. | | |

Table II. Results of regressing long-term CO2 accumulation rates at Mauna Loa and the Antarctic on anthropogenic emission rates and an interaction between anthropogenics and long-term rates of change in the 13CO2 index.

Comparing the results in Table II. with those in Table I. shows the correlation for Mauna Loa/Antarctic is better than for the Arctic. R is greater and the error terms are significantly less. The anthropogenic coefficient for Mauna Loa/Antarctic is less with less associated error, but well within the lower 95% confidence limit for the Arctic anthro coefficient. This coefficient is a better estimate of the fraction of anthropogenic emissions that is accumulating in the earth's surface environment (water,soil, and biosphere). This coefficient was used to calculate the values for the following plot.

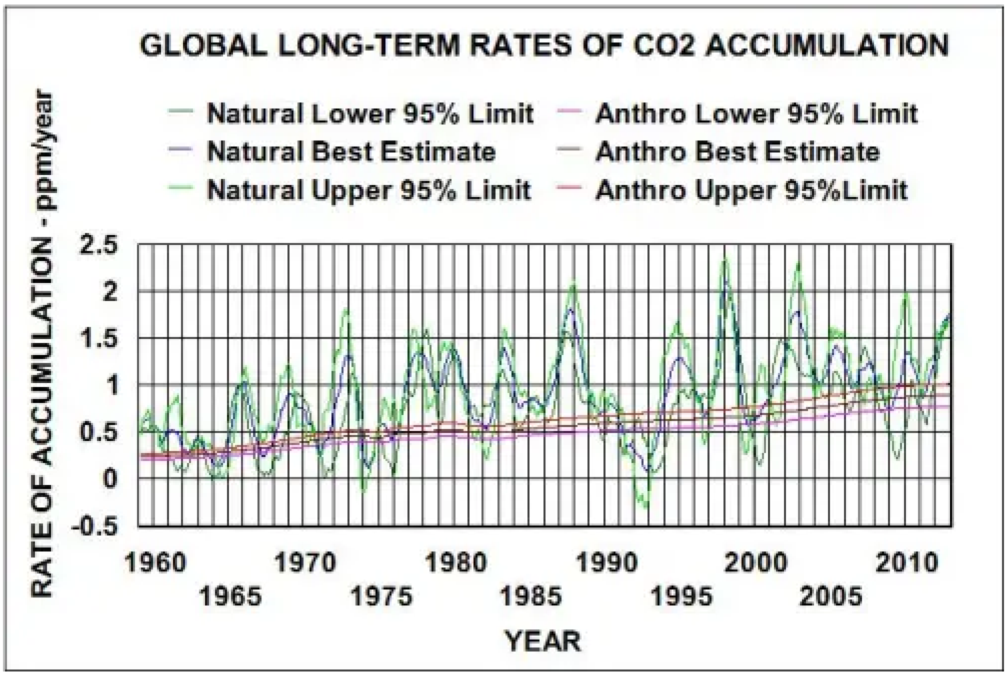


Fig. 14. Natural and anthropogenic emissions contributions to global long-term rates of accumulation of CO2 in the atmosphere. The natural contribution is the total long-term rate minus the anthropogenic emissions accumulation rate.

The natural component global signature looks like it was written by ENSO with matching variations and long-term change. I downloaded the NCDC v4 ERSST for the ENSO area (20S to 0 and 120E to 280E) from Climate Explorer, smoothed it with a 13 month running average, and regressing the long-term natural CO2 accumulation rates on these values and a cylical time function. The best fit is obtained with the CO2 accumulation rates lagging the SSTs by two months and a longer term lag associated with a 30.9 year wavelength cycle. The results are shown in the following plot.

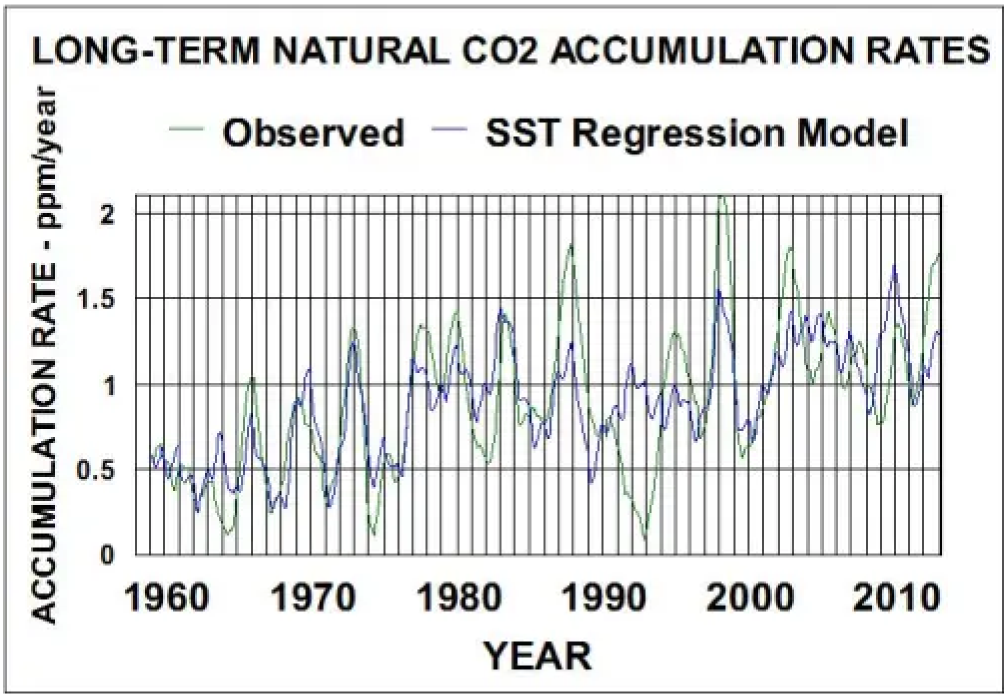



Fig. 15. Relation between natural long-term CO2 accumulation rates and sea surface temperatures in the ENSO area (20S to 0 and 120E to 280E) cycles lagged.

The two months lag indicates temperature is controlling natural emissions of CO2 rather than CO2 concentrations controlling temperature. The mechanism is likely the processes of evaporation/condensation/absorption/convection/freezing that occurs in tropical thunderstorms. These clouds are pumping air containing water vapor and CO2 out their tops where the water freezes and releases CO2. Much of the cold water returns absorbed CO2 to the surface in rain. This cyclical process tends to fractionate the CO2 isotopes with more of the lighter isotopes going out the top. The concentration of the lighter fraction in the upper atmosphere should be a function of the number of cycles. By the time that upper atmospheric air reaches the Arctic, CO2 will have gone through many cycles, resulting in the highest concentrations of the lighter fraction. This effect is added to the biological fractionation effect that, also, is temperature dependant.

To place the relative contributions to global long-term accumulation of atmospheric CO2 in perspective, I used the rates to back calculate 95% confidence limits for both natural and anthropogenic components . The results are shown in the following two plots.

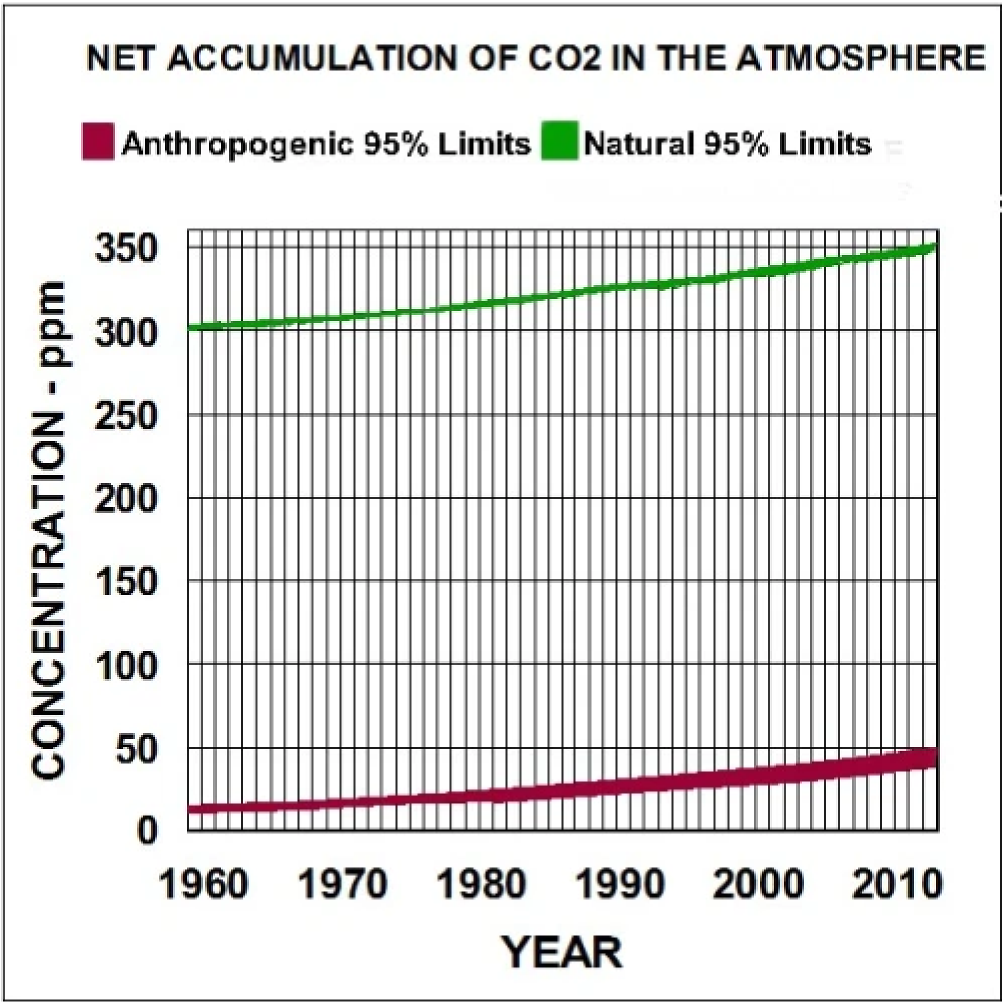



Figure 16. Global net accumulation of anthropogenic emissions and natural emissions of co2 in the atmosphere.

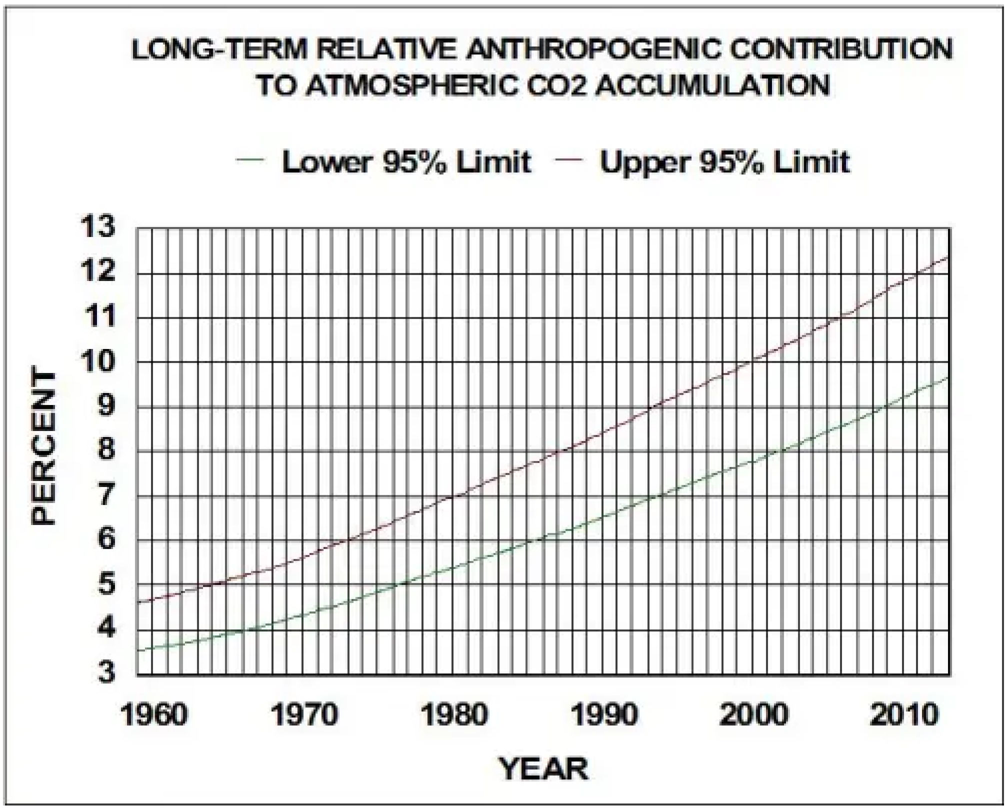



Figure 17. Global long-term relative anthropogenic emissions contribution to atmospheric CO2 accumulation.

Both natural and anthropogenic emissions have been increasing for over 50 years. Although anthropogenics represent a relatively small fraction of the total accumulation, that fraction has nearly tripled in the same time period. So what should we expect in the future and what effect would controlling anthropogenic emissions have on Global concentrations?

I did curve fitting on both the 95% limits of observed total long-term accumulation of CO2 and the estimated accumulation that is probably associated with anthropogenic emissions. I used a Fourier series type model for the total accumulation and an exponential model for anthropogenic emissions. The regression results for the total accumulation are given in tables III and IV.

| LOWER 95% LIMIT GLOBAL LONG-TERM CO2 ACCUMULATION REGRESSION RESULTS | | | | |
|---|---|---|---|---|
| Constant | | | | 372.29 |
| Std. Err. of Y Est. | | | | 0.52 |
| R Squared | | | | 0.999 |
| No. of Observations | | | | 654 |
| Degrees of Freedom | | | | 649 |
| Independent Variables | cos(Z/195) | sin(Z/195) | cos(Z/39) | sin(Z/39) |
| X Coefficients | -55.035 | -8.419 | 0.614 | -1.004 |
| Std. Err. of Coefficent | 0.119 | 0.264 | 0.042 | 0.033 |
| Note: Z = 2*PI*t where t is time in years. | | | | |

Table III. Lower 95% limit for global long-term accumulation of atmospheric CO2.

| UPPER 95% LIMIT GLOBAL LONG-TERM CO2 ACCUMULATION REGRESSION RESULTS | | | | |
|---|---|---|---|---|
| Constant | | | | 400.55 |
| Std. Err. of Y Est. | | | | 0.55 |
| R Squared | | | | 0.999 |
| No. of Observations | | | | 654 |
| Degrees of Freedom | | | | 649 |
| Independent Variables | cos(Z/246) | sin(Z/246) | cos(Z/49.2) | sin(Z/49.2) |
| X Coefficients | -78.869 | 32.377 | -0.528 | 1.826 |
| Std. Err. of Coefficent | 0.787 | 0.401 | 0.065 | 0.067 |
| Note: Z = 2*PI*t where t is time in years. | | | | |

Table IV. Upper 95% limit for global long-term accumulation of atmospheric CO2.

The anthropogenic emissions CO2 accumulation best fits:

Lower 95% Limit = exp(-42.851+.0231*t),and

Upper 95% Limit = exp(-42.486+0.023*t), where t is years.

Both fits have R squared values greater than 0.999.

These relationships can be used in "what if" calculations to project what we may probably expect in the future. For example, the following plot indicates that atmospheric concentrations will peak out around 450 ppm around 2060 if emission rates continued as trended.

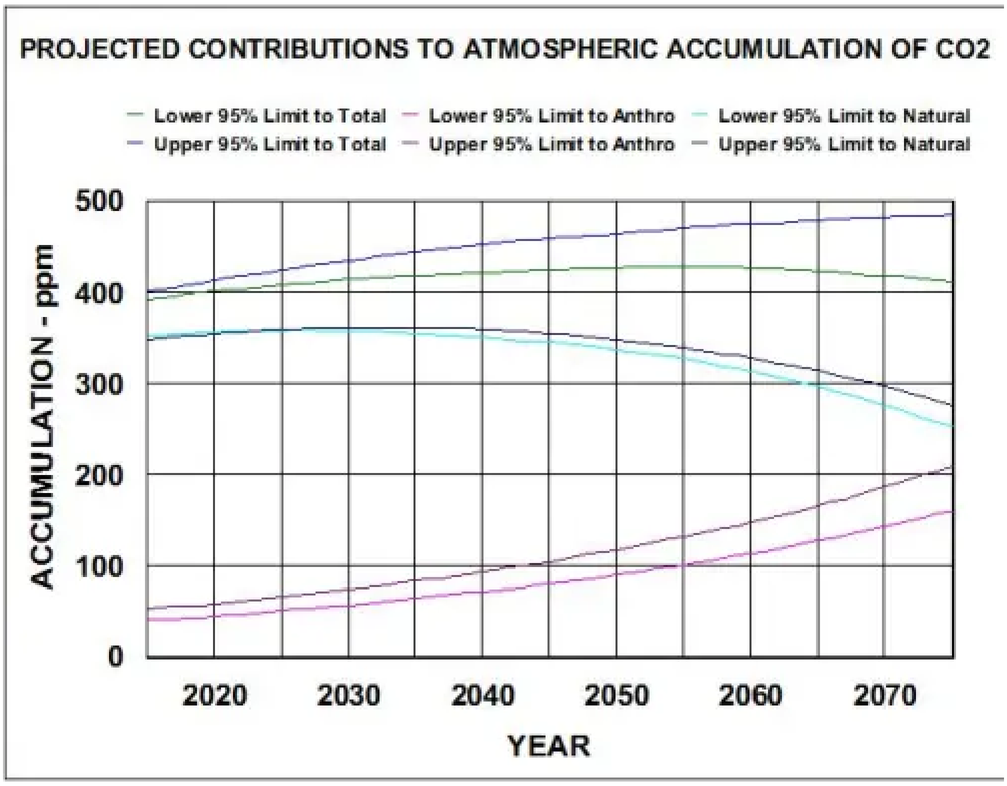



Figure 18. Projected contributions of natural and anthropogenic emissions to the long-term global accumulation of CO2 in the atmosphere.

These should be rather good projections for areas around 15S latitude where seasonal variations are relatively insignificant. Seasonal variations at other latitudes are additive to these long-term projections.

I conclude that, the IPCC's model assumptions that long-term natural net rate of accumulation is constant and anthropogenic emission rates are the only contributor to total long-term accumulation of atmospheric CO2, is false. It should be a simple matter for IPPC programmers to include these "what if" inputs in their models to see if they can produce more realistic projections. Also, they can enter lower anthropogenic emission rates to see how much (or how little) difference it makes in the value and time that atmospheric CO2 is expected to peak out. Economist could have a field day with cost/benefit modeling.

**JC note:** This was originally posted on Fred Haynie's blog, where there are some good comments. This post was mentioned in the comments on a previous thread, where a request was made to discuss this topic at CE. As with all guest posts, please keep your comments relevant and civil.

**Update:** I'm interested in Fred's analysis for these reasons:

- an interest in understanding the role of the Arctic in the carbon cycle
- an interest in understanding the role of multidecadal oscillations in the ocean in the carbon cycle (i.e. natural decadal variations)
- and of course, the stadium wave links the two previous points together to some extent

I am making no personal judgment on Fred's analysis; I find Greg Goodman's comments and ensuing discussion with Fred on the original blog post to be interesting.

Bottom line is that I think the traditional method of analyzing all this leaves out multidecadal natural variability which is relevant on the timescales of interest. Same problem I have with sensitivity analyses (the recent Lewis/Curry paper accounted for some of this in a limited way)

This entry was posted in Data and observations. Bookmark the permalink.

### 2,119 RESPONSES TO "QUANTIFYING THE ANTHROPOGENIC CONTRIBUTION TO ATMOSPHERIC CO2"

**Centinel2012** | May 6, 2015 at 10:35 pm |

Reblogged this on Centinel2012 and commented:
Interesting analysis appears to be real science! So that means no one will consider it.

Like

**Danny Thomas** | May 6, 2015 at 10:53 pm |

Mr. Haynie,
Thank you for your work and for sharing. Would you be willing to offer a bio? This might be of value in addressing Centinel2012's concern.

Like

> **curryja** | May 6, 2015 at 11:08 pm |
>
> From Fred's LinkedIn profile: environmental engineer, retired, formerly with the US EPA ASRL, research expertise on the effects of air pollutants.
>
> Like
>
> **climategrog** | May 8, 2015 at 6:52 am |
>
> This is an interesting article that will need time to digest
> Maybe the EPA background explains why our engineer freind thing running averages and running diffs are a low-pass filter of choice.
>
> Taking fig 6 as an example we see that there is still considerable sub-annual variability in the 12 month diff.
> https://retiredresearcher.files.wordpress.com/2011/11/lt-rate-of-12-co2-change.jpg
>
> This should have be been removed by a decent fitler. In fact most of it will be corrupt, inverted data that this kind of 'filter' produces. I would suggest a simple 6month gaussian which would give a much clearer plot and help to see the longer term changes.