A mysterious CO2 anomaly in the atmosphere - how 2.5Gt of carbon came in 1988 and went in 1992

There is an unexplained atmospheric CO2 “bubble” centred around 1990. The apparent smooth and continuous rise in atmospheric CO2 concentrations is broken by an anomaly that can be seen in Figure 1 below.

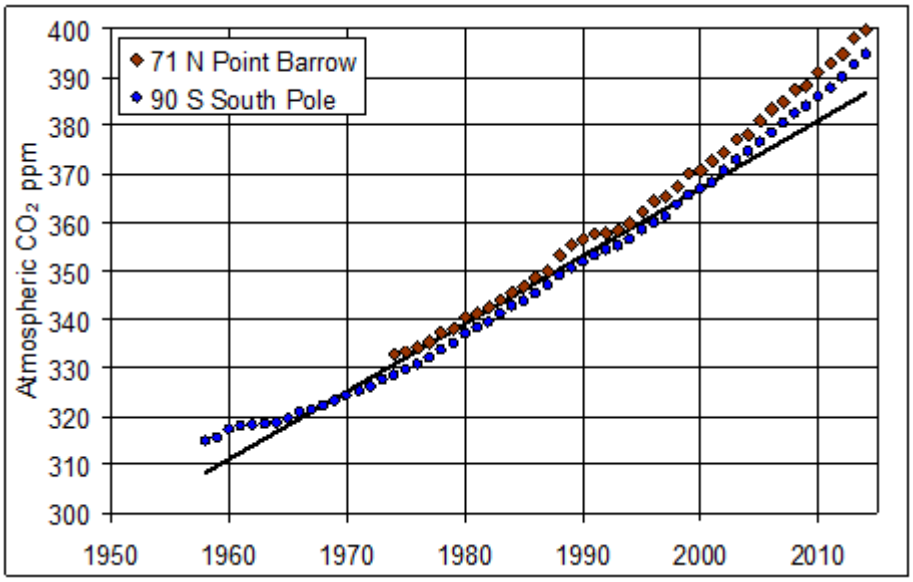

Figure 1: *Average yearly CO2 concentrations at the South Pole and Point Barrow from Scripps measurements. The straight line is a best fit to the South Pole data with an annual increase of 1.5 ppm per year*.

Figure 2 shows the residual differences of measurements from the straight line fit of Figure 1. This shows that as the world cooled in the 1960s excess CO2 accumulated at low annual rates. During the 1970s and 1980s CO2 was accruing at about 1.5 ppm per year, the average rate of the last 55 years. Then suddenly in 1988 a large amount of CO2 was added to and in 1992 withdrawn from the atmosphere. A further turning point occurred in 1995 when the annual rate of increase reached its highest level.

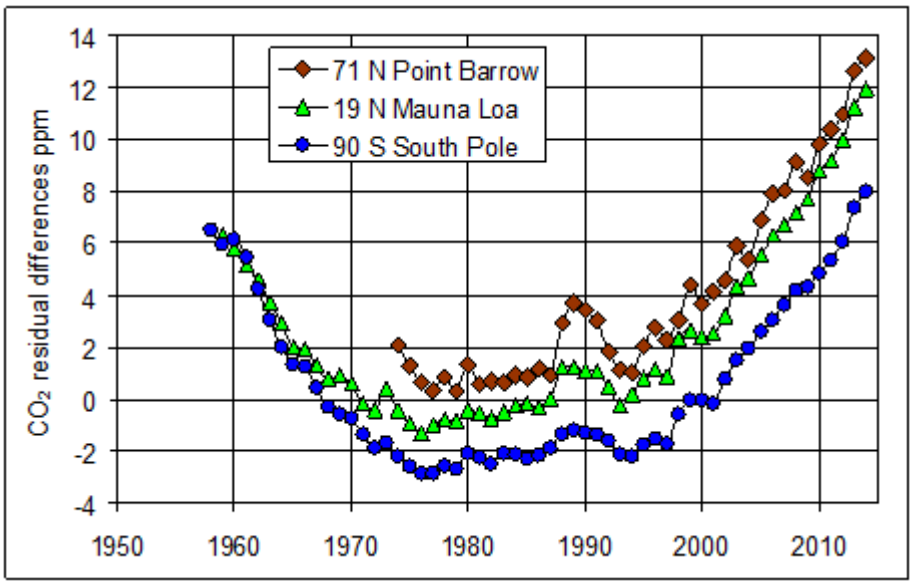

Figure 2: *Residual differences from a straight line fit to average yearly CO2 concentrations at the South Pole (see Figure 1 above) and also similar residuals for Mauna Loa and Point Barrow. Note the break in the trends in 1977 and 1995 at the times of phase changes in the Pacific and Atlantic Decadal Oscillations*[1]

The fine details of the anomaly have been analysed by finding the residual CO2 values from a least squares fit to the years 1978 to 1987, 1993 and 1994 The anomaly does not vary significantly from summer to winter as shown in Figure 3 below despite seasonal variations of 16 ppm at Point Barrow, 71N and 1 ppm at the South Pole 90S.

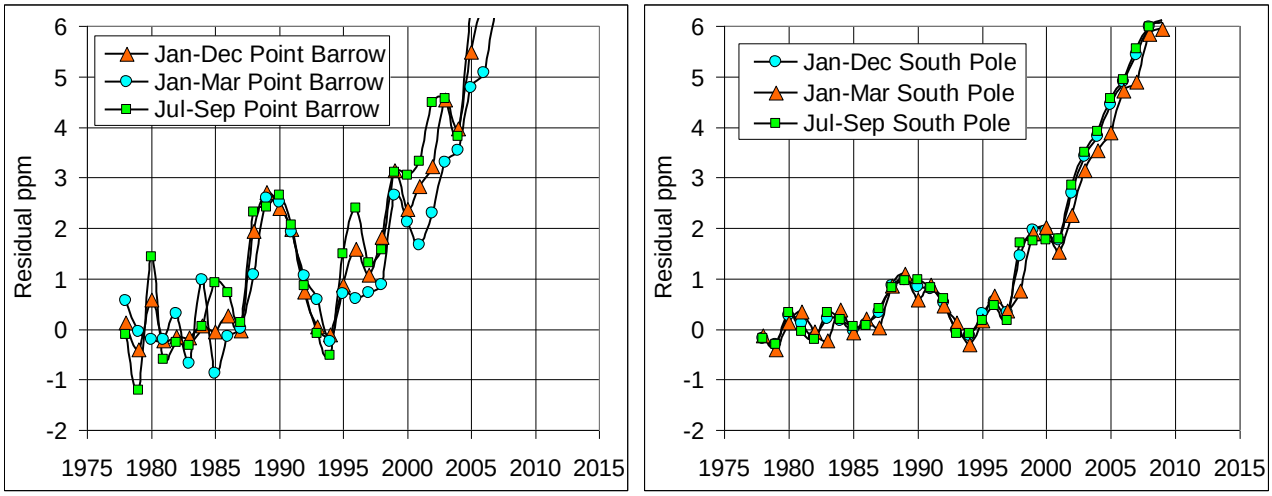

Figure 3: *Residual differences from straight line fits to measurements from 1978 to 1987,1993 and 1994 for annual, summer and winter periods for* ***Left)*** *Point Barrow 71N and* ***Right)*** *the South Pole 90S. There is no significant difference for the results in summer and winter.*

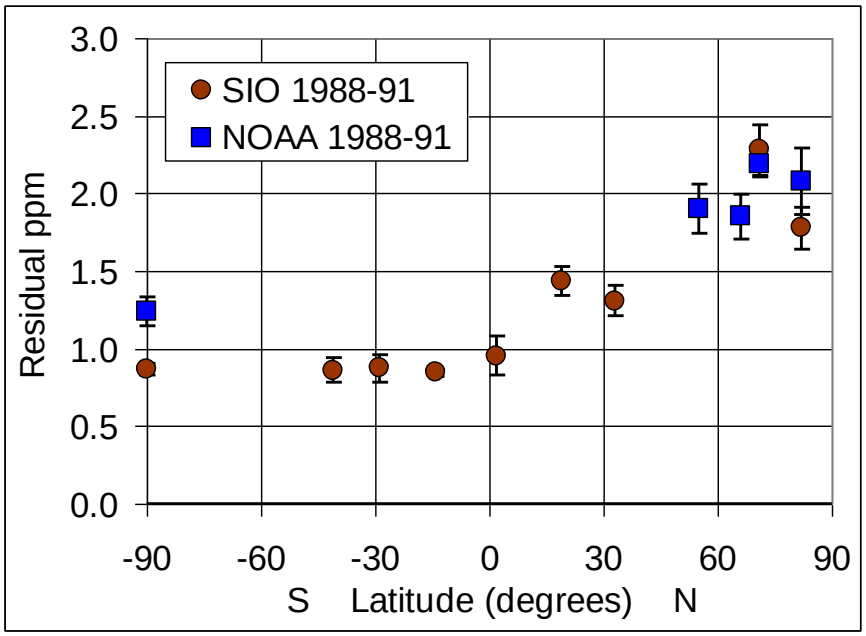

Figure 4: *Residual differences in the annual value of the CO2 anomaly by latitude for SIO and NOAA measurement stations at the peak years of 1988 to 1991.*

Figure 4 above shows the residual differences in the annual value of the CO2 anomaly by latitude for SIO and NOAA measurement stations at the peak years of 1988 to 1991. This anomaly extends from the north to the south latitudes and is the equivalent of 2.5 +/- 0.4 GtC of CO2 entering and leaving the atmosphere.

Notice also that there is no reduction in the anomaly in the Southern Hemisphere where the oceans are said to be the main sink of CO2 as the CO2 concentration declines by 2.5 ppm from the Equator to the South Pole (see Figure 5 below).

The conclusion from this first part of the analysis is that the anomaly appears to ride over the top of seasonal variations of CO2 and in the Southern Hemisphere, a decline in CO2 concentrations.

Either this indicates that the sources and sinks behaviour is not understood or the sinks are full, yet after 4 years they are able to remove this anomaly.

The explanation may be that the oceans, land and fossil fuel emissions are all contributing to the increase in atmospheric CO2.

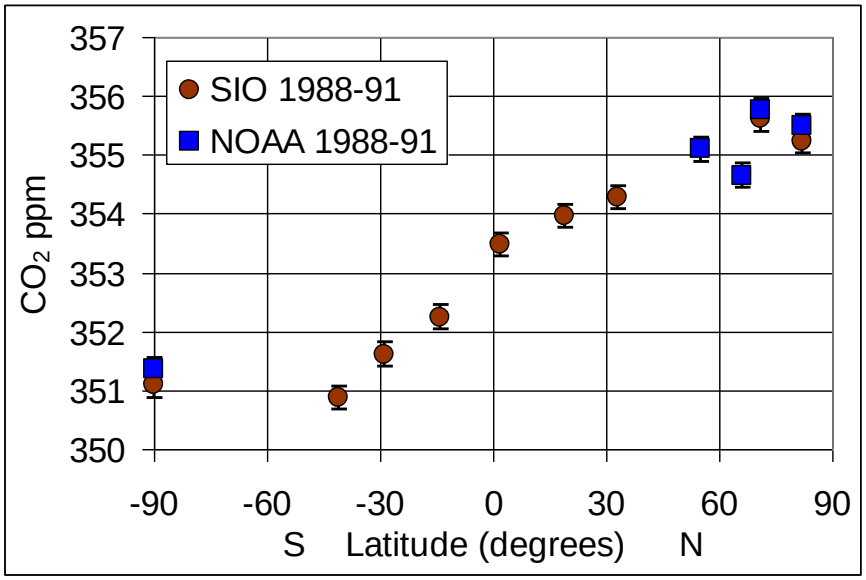

Figure 5: *Average measured CO2 atmospheric concentrations for 1988 to 1991. Note the decline of 2.5 ppm from the Christmas Island (2 N) to the South Pole (90 S).*

Where did the CO2 come from?

The isotopic composition of the CO2 indicates whether the source is the ocean, or biological. Carbon has two stable isotopes and is 99% carbon-12 and 1% carbon-13. The changes in carbon-13 from measurements at SIO sites at the South Pole, Mauna Loa and Point Barrow are shown in Figure 6. The measure $\delta^{13}C$ is the difference in tenths of a percent of total carbon from a carbon standard where the ocean is $\delta^{13}C \sim 0$. Plants (alive or dead - fossil fuels) are $\delta^{13}C \sim -26$. This is the result of photosynthesis depleting the fixing of carbon-13 as the lighter carbon-12 CO2 is favoured by having a higher reaction rate.

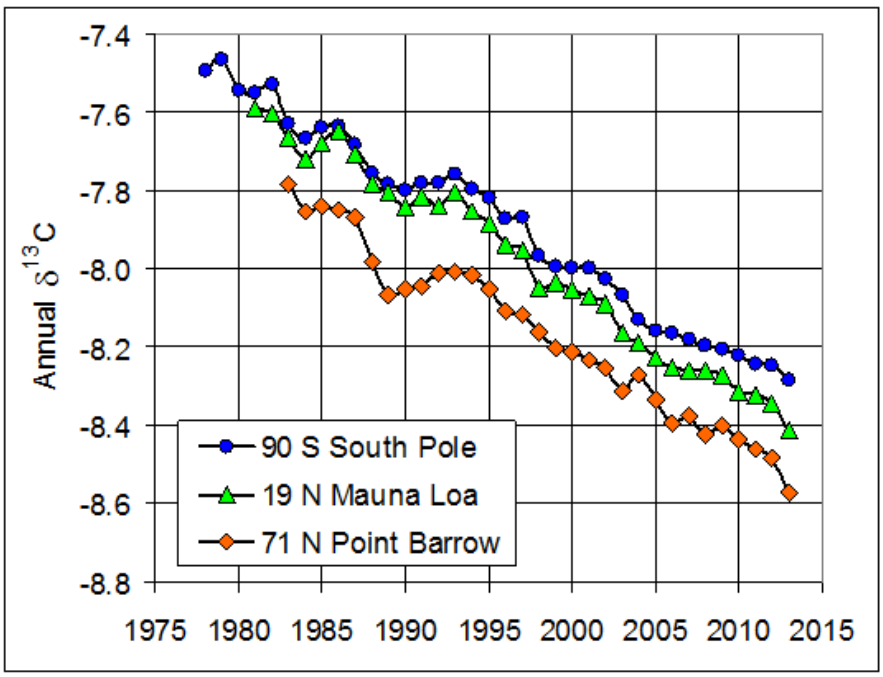

Figure 6: *Annual values of $\delta^{13}C$, a measure of the isotopic composition of atmospheric CO2 for the South Pole Mauna Loa and Point Barrow*

There is a step like decrease in $\delta^{13}C$ with step changes particularly in 1983, 1987 and 1997 at the time of El Nino's. The trends from 1989 to 1994 show an increase in $\delta^{13}C$.
Now a simple analysis is to consider the ocean and plants as the two original sources of CO2. The isotopic composition of the CO2 is known so the components in the atmosphere can then be found. These contributions are shown below in Figure 7. There is no peaking in the ocean source CO2 in 1988-91 but a peak in the plant source.

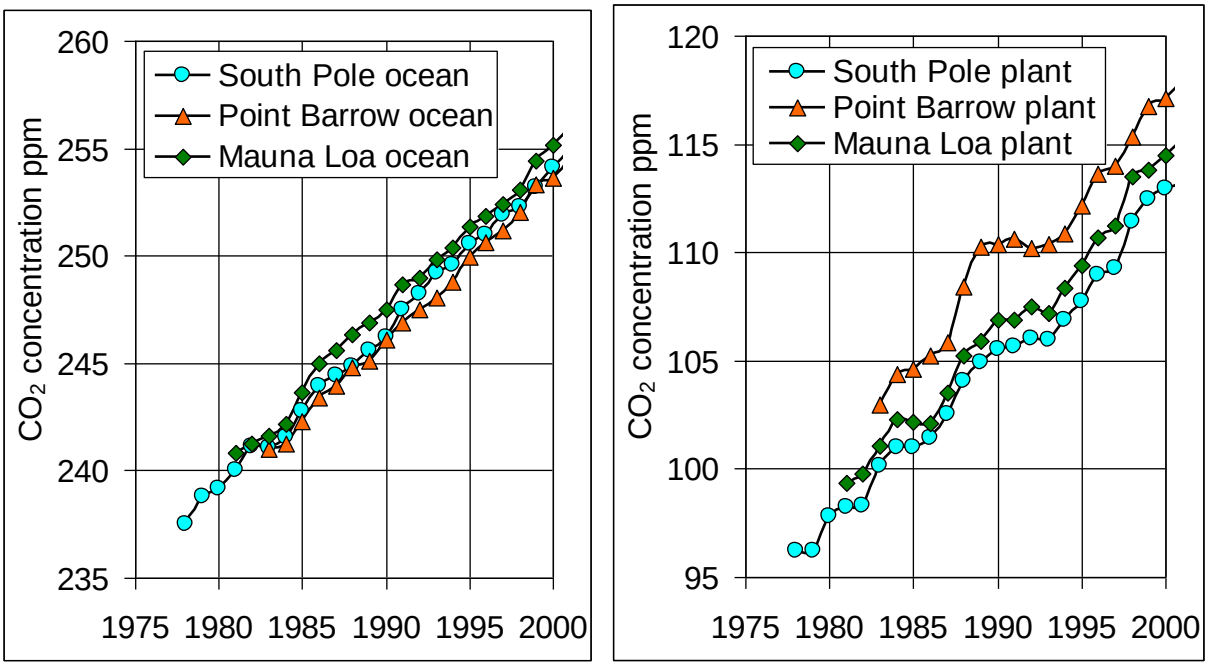

Figure 7: *Decomposition of atmospheric CO2 into components for* ***Left)*** *ocean with* $\delta^{13}C = 0$ *and* ***Right)*** *plants (alive or dead - fossil fuels) with* $\delta^{13}C \sim -26$

The residual contribution for the peak can be obtained from the atmospheric decomposition using the same analysis that was applied for the total CO2 concentration measurement analysis shown in Figures 3 and 4. So the ocean residual differences in the CO2 anomaly show no contribution by latitude for SIO and NOAA measurement stations at the peak years from 1988 to 1991. Thus the original source of the anomaly is a plant contribution. But notice again that there is a constant component in the Southern Hemisphere with no detectable evidence of an ocean mixing interaction.

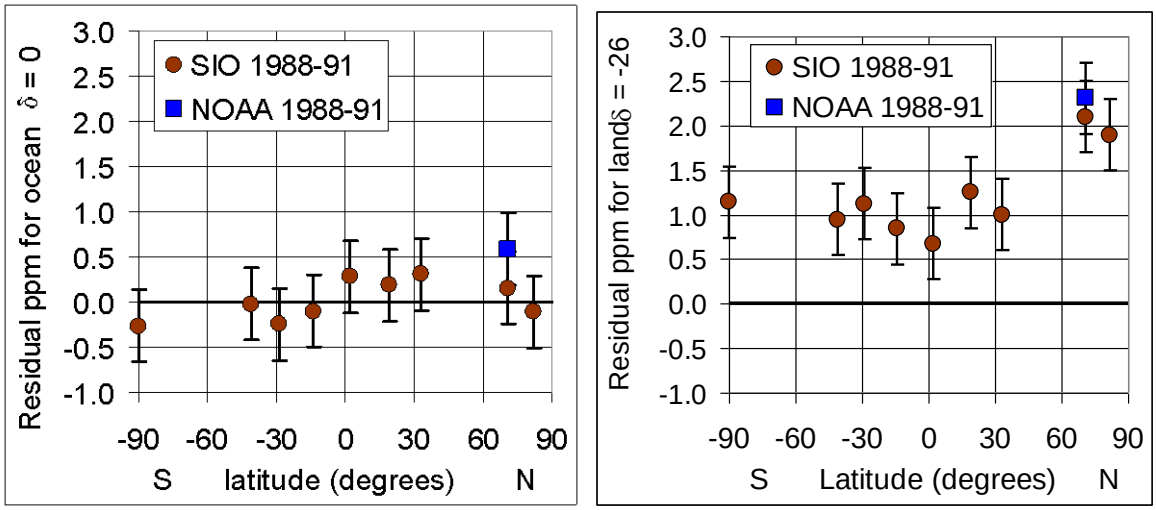

Figure 8: *Residual differences in the annual value for the isotopic decomposition of the CO2 anomaly by latitude for SIO and NOAA measurement stations at the peak years of 1988 to 1991 for* ***Left)*** *the ocean contribution with* $\delta^{13}C = 0$ *and* ***Right)*** *plants (alive or dead - fossil fuels) with* $\delta^{13}C \sim -26$ *.*

The cause of the anomaly might be variations in sea surface temperatures and winds or biological activity.

In 2000, Hare and Mantua published a detailed study[2] of 100 time series for biological and physical measurements that showed "regime shifts" in 1977 and 1989 in the Northern Pacific [redacted] the Bering Sea. The shifts included significant falls in fish growth and size of catches.

So the explanation may be that the fall off in biological activity is due to a fall off in phytoplankton growth as phytoplankton are at the base of the food chain Wind changes will drive ocean current changes with consequent changes in the level of nutrients in the water and these may limit the growth of phytoplankton. This is found in El Nino years on the west coast of South America[3].

The loss of phytoplankton results in less CO2 being removed from the ocean and hence less removed from the atmosphere. So in 1988 the atmosphere becomes enriched in carbon-12 CO2 with a dramatic fall in $\delta^{13}C$.

This 2.5 +/- 0.4 GtC bubble is natural variability on a significant scale. For comparison total fossil fuel emissions were 6.1 GtC in 1990 and only some 50% of these emissions would be absorbed by the oceans according to the present accepted explanation.

This analysis raises the question whether the sources and sinks of CO2 are fully understood.

Indeed a simple resolution of the behaviour seen in this analysis would be if the oceans as well as the land and fossil fuel emissions were all net contributors to the increases in atmospheric CO2 concentrations.

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[1] Tom Quirk: Did the Global Temperature Trend Change at the End of the 1990s? **Asia-Pacific J. Atmos. Sci**., 48(4), 339-344, 2012 DOI:10.1007/s13143-012-0032-4
https://ipa.org.au/library/publication/1339463007_document_break_paper_apjas_ipa.pdf

[2] S.R. Hare, N.J. Mantua: Empirical evidence for North Pacific regime shifts in 1977 and 1989. **Progress in Oceanography** 47 (2000) 103–145

[3] Michael J. Behrenfeld, Robert T. O'Malley, David A. Siegel, Charles R. McClain, Jorge L. Sarmiento, Gene C. Feldman, Allen J. Milligan, Paul G. Falkowski, Ricardo M. Letelier & Emmanuel S. Boss: Climate-driven trends in contemporary ocean productivity: ***Nature*** Vol. 444|7 December 2006| doi:10.1038/nature05317