An estimate of the climate change significance of the decline in the Northern Hemisphere's uptake of carbon dioxide in biomass

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Introduction

It has been shown by Curran and Curran (2016) that the ability of the Northern Hemisphere biosphere to absorb carbon dioxide (CO_2) from the atmosphere during the northern summer was increasing rapidly during the 1960s and early 1970s, reached a peak in 2006, and experienced a small reduction since then.

This is a worrying feature, since the ability of the biosphere to absorb CO_2 from the atmosphere is critical to the subsequent sequestering of that carbon in forms that prevent it building up in the atmosphere. For the terrestrial biosphere, those forms will be in woody plant materials, in carbon compounds contained in roots and surrounding soils, and in peat deposits and sediments.

If that process begins to fail or decline, then more CO_2 will increasingly remain in the planetary atmosphere and consequently accelerate climate change.

It is useful to try and estimate the relative importance of the decline in Northern Hemisphere bioaccumulation in terms of its contribution to atmospheric CO_2 and thereby to climate change.

Figure 1 shows the rise and subsequent fall in the magnitude of the intra-annual drop (illustrated in Figure 2, and identified as *d*) in CO_2 derived by Curran and Curran (2016) from the weekly data from the Mauna Loa Observatory (Scripps Institution of Oceanography, 2015). This recurring intra-annual drop is driven by the processes of bioaccumulation during the northern summer. If the early rate of increase in the Northern Hemisphere's ability to absorb CO_2 had continued over the full period to 2013, then, by that time, the intra-annual drop in CO_2 would have achieved a value of 8.9ppm rather than the actual value of 7.5ppm, as shown in Figure 1.

Analysis

It can be assumed, as a first approximation, that the increase in peak CO_2 from one year to the next, from the Mauna Loa data, will be a result of the global emissions of CO_2 to the atmosphere in the preceding year plus a proportion of the intra-annual drop in CO_2 from the previous year, as some of that carbon – stored in the Northern Hemisphere biosphere – is released back into the atmosphere during the northern winter through natural biodegradation. This is illustrated in Figure 2.

A multiple regression can be run, across the 54 years of available data, for the increase each year in peak CO_2 (*D*, ppm) against the previous year's intra-annual drop in CO_2 (*d*, ppm) and the previous year's global man-made CO_2 emissions (*E*, $MtCO_2$). Annual global carbon emissions are available from the Carbon Dioxide Information Analysis Center (CDIAC, 2016), with the source data multiplied by 3.667 to convert from MtC to $MtCO_2$. The values of both *D* and *d* are derived from the Mauna Loa weekly time series (Scripps Institution of Oceanography, 2015).

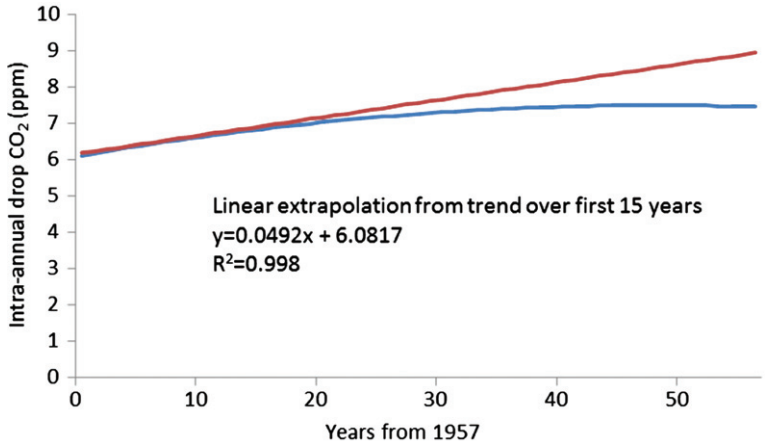

Figure 1. This is the original Figure 2 (lower line) from Curran and Curran (2016) with the addition of a linear regression (upper line) applied to the first 15 years of data only (1958–1972). The linear regression is extended to the end date of 2014.

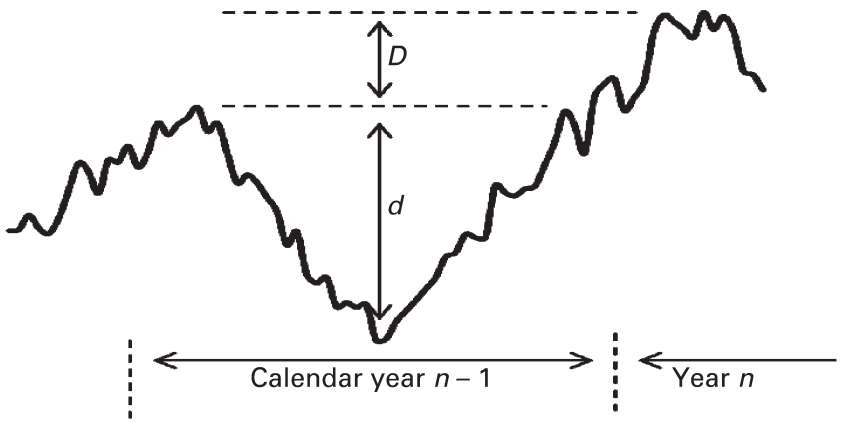

Figure 2. A typical section of the Keeling Curve – the time series plot of atmospheric CO_2 concentrations at the Mauna Loa Observatory. This illustration covers a period of about 1.5 years. Roughly, the peak value is now around 400ppm; the increase in peak value each year, D, is around 2ppm; the intra-annual drop, d, is around 7ppm.

The result is:

$$D(n) = 2.85 - 0.44\,d(n-1) + 7.3 \times 10^{-5}\,E(n-1), \text{ where } n \text{ is year from 1959} \quad (1)$$

F-statistic = 18.5 with $P = 9.0 \times 10^{-7}$

Adjusted $R^2 = 0.40$

For the first regression coefficient, $P = 0.003$, and for the second coefficient, $P = 1.9 \times 10^{-7}$

Standard error of estimate = 0.56, $n = 54$

Further analysis of the residuals does not reveal any significant autocorrelation, which suggests that the regression provides a good model.

There is no specific term in Equation 1 to describe the net annual flux of CO_2 into the oceans. Lee *et al.* (1998) have estimated that the inter-annual variability of this flux is low (standard deviation is approximately 10% of the flux) and that the main cause of year-to-year variation in the rate of atmospheric CO_2 accumulation is the variable sequestration of carbon by the terrestrial biosphere. Similarly, Sarmiento *et al.* (2010) show that the net carbon flux into the oceans between 1960 and 2006 increased somewhat, but with little inter-annual variation. By contrast, the net land flux, which is of approximately the same magnitude, exhibited around 10 times greater fluctuation over the same period. Gurney *et al.* (2004) show that the intra-annual, or seasonal, variation in the carbon flux between the atmosphere and both the northern and southern oceans is less than a tenth of the seasonal variation in the flux to the northern land mass.

The implication of the highly significant correlation expressed in Equation 1 is that the peak in atmospheric CO_2 in any year is derived in part from 0.44 (standard error 0.14), or 44%, of the previous intra-annual drop in CO_2. This negative coefficient would suggest that 44% of the carbon absorbed by the Northern Hemisphere biosphere in the summer is not released back into the atmosphere during the following winter, but is permanently sequestered. Further statistical analysis suggests that this proportion does not seem to have changed significantly over time. This value is in reasonable agreement with the estimate by Jansson *et al.* (2010) of net biome productivity of 3000Mt of carbon per year, which, relative to annual emissions (CDIAC, 2016), would be around 33%.

It is possible now to apply Equation 1 to the two situations shown in Figure 1. With the real world conditions of a recent decline in intra-annual drop, described by Curran and Curran (2016) and illustrated by the lower curve in Figure 1, the expected annual increase in peak atmospheric CO_2 for 2012 can be predicted using an intra-annual drop in 2011 of 7.47ppm, and global CO_2 emissions in 2011 (CDIAC, 2016) of 34649MtCO_2, with the result being 2.1ppm. This, of course, is very close to the mean value from observations over the 7-year period centred on 2012, of 2.14ppm with standard error of 0.2ppm. Equally, if we assume that the Northern Hemisphere had not lost some of its ability to absorb, and therefore sequester, CO_2, then the intra-annual drop, from the upper line in Figure 1, would be 8.84ppm in 2011, which would result in an increase in peak atmospheric CO_2 in 2012 of 1.5ppm over the previous year.

Conclusions

This is a very substantial change, and suggests that the atmosphere is now increasing its CO_2 concentration each year by around 30% more than would have been the case without the relative deterioration of Northern Hemisphere bioaccumulation over the past few decades. Such an increase might loosely be imagined as adding another carbon emitter to the global inventory of the size of China (United States Environmental Protection Agency, 2016).

As nations around the world begin to stabilise and reduce their carbon emissions, it is a very worrying prospect that the planet itself may be exhibiting positive feedback and very significantly losing its ability to absorb and lock up carbon within its biosphere. It is essential that efforts are accelerated to reduce man-made emissions as fast as possible.

References

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