Carbon dioxide and global warming

We have but one planet, and both the physical and economic processes that are driving climate change have enormous inertia. If a big ocean liner were steaming into dense fog in polar seas, only a fool would maintain full speed on the basis that the technicians were still discussing the distance to the first big iceberg [1].

There are several views about the current levels of CO_2 in earth's atmosphere and whether its apparently inexorable rise is the result of human activity. For over 50 years, in a series of measurements initiated by Charles Keeling, atmospheric CO_2 concentration has been monitored on a daily basis and data is made available by way of a so-called Keeling curve (see Figure 1) [2]. A short video giving some historical background is also available [3].

One criticism of the data depicted in the Keeling Curve is that we might be experiencing 'natural variation' and that the rise in CO_2 should not be a cause for concern. Indeed, there are some powerful voices who do not believe the evidence that links rises in carbon dioxide levels with a rise in global temperatures. In an interesting piece, Ward has suggested [4] that on his next visit to the UK, President Trump should be presented with a copy of a recent publication co-authored by HRH the Prince of Wales [5] so that the President might more fully understand the science involved.

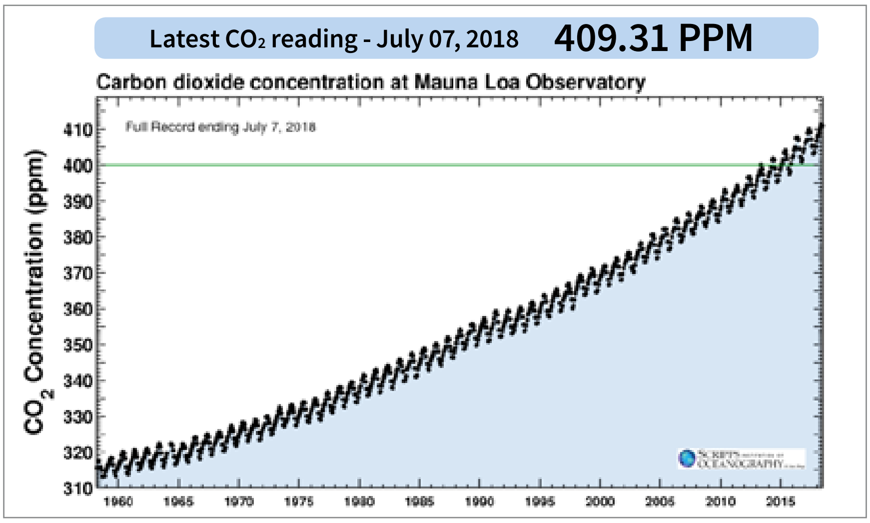

Figure 1 - CO_2 levels as measured at the Mauna Loa Observatory, Hawaii [2].

The 'natural variation' interpretation is not supported by studies of CO_2 levels in ice-core samples as shown in Figures 2-3 below. Data from samples from as long ago as 800,000 years (Figure 3) confirm that we do indeed have unprecedented levels of CO_2 in the atmosphere.

The relationship between elevated CO_2 levels and human activity is, for the overwhelming majority of climate scientists, well-established.

CO_2 produced from fossil fuels and industrial activity accounts for some 65% of so-called greenhouse gases (see Figure 4).

At SSERC, we have been looking at ways of bringing climate science alive by looking at ways to investigate CO_2 concentrations in the classroom. The following experiments might serve as a practical context for discussing issues around climate change. >>

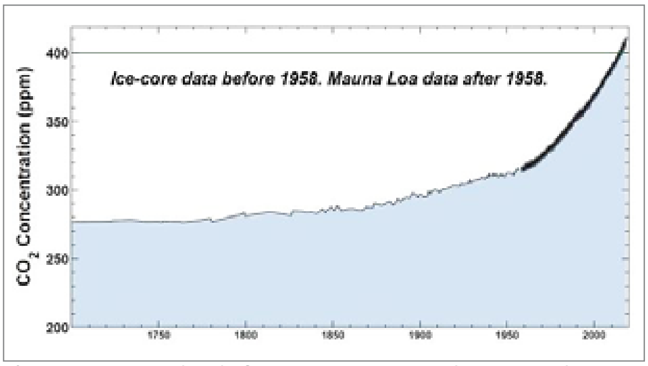

Figure 2 - Ice-core data before 1958, Mauna Loa Observatory data after 1958 [6].

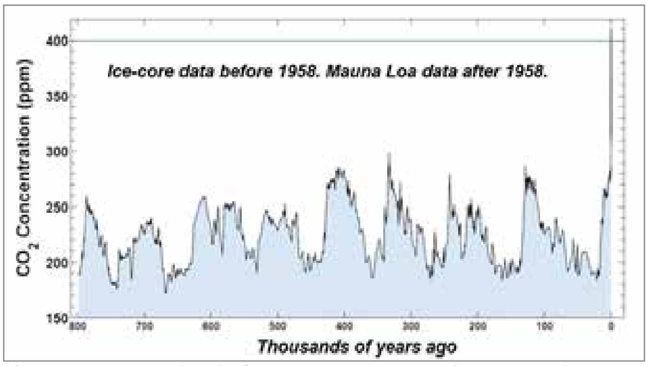

Figure 3 - Ice-core data before 1958, Mauna Loa Observatory data after 1958 [6].

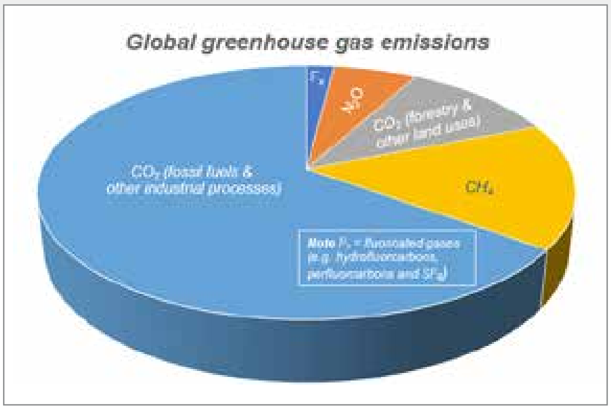

Figure 4 - Global greenhouse gas emissions by gas. Adapted from [7].

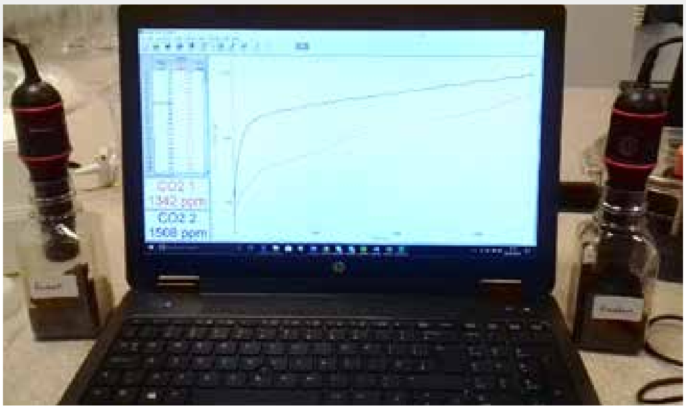

Figure 5 - Experimental set-up using a Pasco PS-3208 sensor.

Some 'Soil Science' experiments

1) Samples from different locations

With a CO_2 probe it is possible to measure the rate of release of CO_2 from soils as a result of respiration from microorganisms within the soil. Protocols for such experiments have been published before [8, 9]. Briefly, we obtained a given mass of soil (typically 100 g) and this was placed into an airtight container (see Figure 5). CO_2 levels were monitored over time using either a Vernier Carbon Dioxide Gas Sensor or a Pasco PS-3208 sensor.

The data in Figure 6 shows the rate of CO_2 release from soils taken from 2 different habitats.

There are a number of reasons why differences in the rates of respiration between garden and forest soils are observed. One key factor is that forest soils are rich in lignin which is more 'difficult' to break down than cellulose leading to lower respiration rates in such soils. Another factor which may be at play is the greater numbers and variety of organisms which might be present in garden soils. Other possible areas for investigation might include (the list is not exhaustive!):

- the effect of temperature;
- moisture content which can affect the nature of respiration (aerobic vs. anaerobic);
- pH;
- presence of pesticides;
- season(s) when samples are collected.

2) 'Permafrost'

The rise in global surface temperatures correlates well with the elevated levels of CO_2 present in the atmosphere. As the earth's surface temperature rises there is concern about the rise in sea levels that will occur as water from the polar ice-caps is released. Other, possibly less well-known, impacts of rising temperature include the thawing of regions of permafrost (ground which remains frozen for two or more consecutive years) across the globe. For example, it has been reported [10] that rising temperatures in the Arctic have triggered a significant increase in carbon dioxide emissions from thawing permafrost. It is believed that CO_2 emissions are now outpacing the uptake of CO_2 during the spring and summer growing season. In a recent article Taterka and Cory [11] consider how the potential rise in CO_2 concentration arising from thawing of permafrost can be measured experimentally in the school laboratory and we have adapted some of their ideas here. In Figure 7 we show data from a soil sample which was frozen overnight and then allowed to thaw (thereby mimicking thawing permafrost). The second sample was left at room temperature as a control. In both cases CO_2 levels were monitored for 7 hours.

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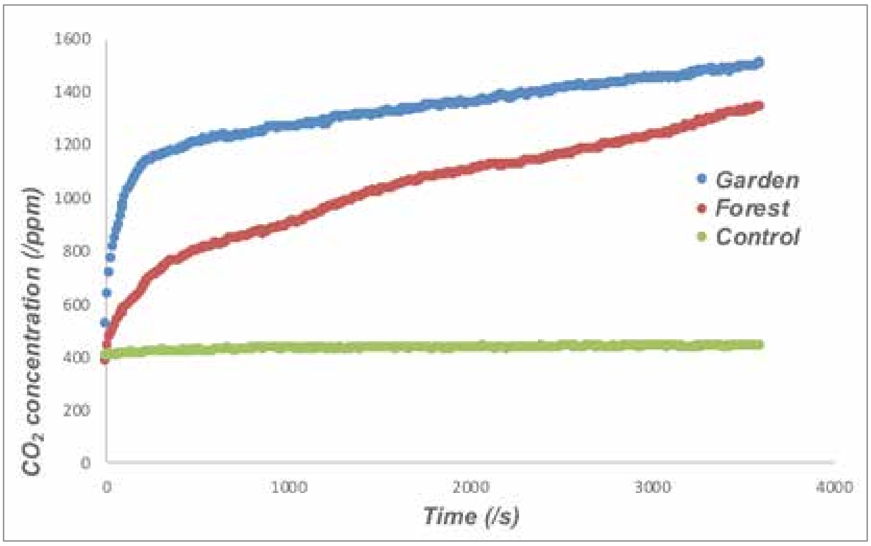

Figure 6 - CO_2 levels as a function of time for soil samples taken from garden and forest habitats. A control is also shown.

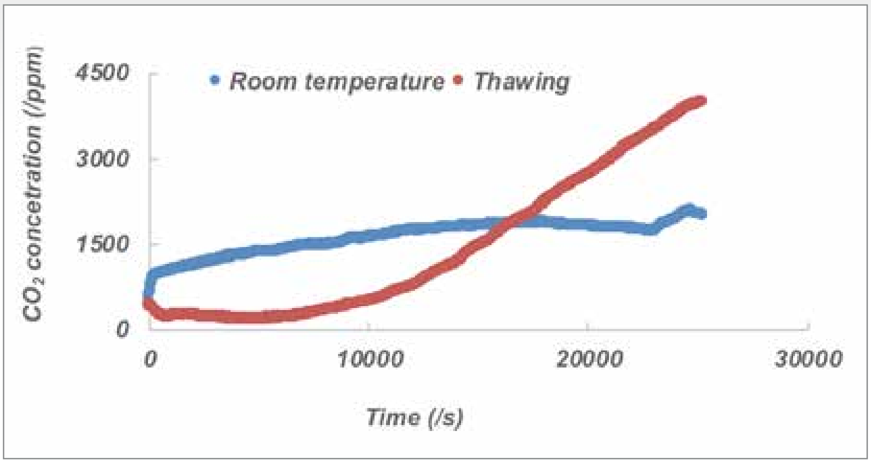

Figure 7 - CO_2 levels as a function of time for soil which had been frozen prior to measurement or left at room temperature.

Respiration in the 'frozen' sample is slow for the first 5000 seconds but then as the sample thaws there is a steady rise in the rate of CO_2 production. CO_2 levels increase slowly in the 'room temperature' sample and after some 5 - 6 hours reach a plateau. The shape of curve for the 'frozen' sample is interesting and merits some explanation. It has been reported that there is an increase in the amount of free amino acids and soluble sugars after freezing, which provide a pool of easily utilised organic matter for survivors to consume after a thaw [12]. Additionally, the spike in respiration during initial thaw may partially be a stress response because the spikes in respiration are less pronounced with subsequent freeze-thaw cycles [13]. The thaw itself and the availability of liquid solute in the substrate may also be triggering microbial metabolic activity as well as microbes simply becoming 'active' as the temperature increases [14].

The experiments described here were undertaken by Amy Molotoks a PhD student at the University of Aberdeen. Amy spent a period of 3 months with us funded through a BBSRC EASTBIO doctoral training partnership scheme. <<

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