Digesting 400 ppm for global mean CO_2 concentration

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On 2 May 2013, it was reported in *Nature*[1] that *hourly* values of CO_2 concentrations at Mauna Loa, Hawaii crossed the symbolic milestone of 400 ppm (parts per million) in April 2013 several times, and could record a *daily-mean* concentration of more than 400 ppm within another month. Indeed, daily mean value of 400 ppm was recorded on 9 May 2013. Interestingly, this value has not been reached for a few million years at this site. Humanity's fossil fuel (e.g. coal, petroleum) emissions in the industrial era and large-scale modification of the landscape (e.g. conversion of forests to croplands) in the past several millennia have been implicated for this rise in CO_2. In the most recent decade, fossil fuel emissions and land cover change have respectively, contributed approximately 90% and 10% to total CO_2 emissions[2,3]. CO_2 absorbs infrared radiation emitted by the planet and hence has a tendency to increase the heat content and temperature of the planet. What does this symbolic milestone of 400 ppm represent? Should we be concerned?

First, we should recognize that the value reported in *Nature*[1] refers to the global mean atmospheric CO_2 concentration. Values much larger than this have been recorded on local and regional scales depending on the strength of local sources and sinks of CO_2 and local atmospheric stability conditions. For instance, cities with large industrial and vehicular emissions could record local values twice this symbolic number when mixing of atmospheric air is highly restricted. The Mauna Loa Observatory is located at an altitude of 3400 m in the northern subtropics in a remote location. CO_2 measured here truly represents the globally averaged, horizontally and vertically, CO_2 concentration since there is very little local influence at this site.

Next, to appreciate the magnitude of humanity's impact on atmospheric composition, one needs to know how big a ppm is on a global scale. Using simple arithmetic involving the mass of the global atmosphere and molecular weights of dry air and CO_2, one can show that 1 ppm is equivalent to approximately 2 billion tonnes of carbon or 7.5 billion tonnes of CO_2. In the recent years, humanity's CO_2 emissions have averaged at about 10 billion tonnes of carbon per year. Out of this, about 50% (5 billion tonnes of carbon) has stayed in the atmosphere and the other half has been removed by terrestrial plants and oceans. Hence, the atmospheric loading of carbon is increasing at about 5 billion tonnes of carbon or 2.5 ppm of CO_2 per year (Figure 1).

The effect of global-scale photosynthesis by terrestrial plants can be appreciated by looking at the regular *annual rhythm* (like heart beats) in the time series (red curve in Figure 1) – the global mean CO_2 has lower values in summer when plants actively take up CO_2 and higher values in winter when plants are dormant. The average difference between winter and summer is about 6 ppm. Had the distribution of land and hence terrestrial plants been equal between northern and southern hemispheres, this seasonal see-saw would have been absent. Because of these seasonal swings, it will be a while, perhaps a few years, before the global CO_2 concentration averaged over an entire year, passes 400 ppm. The annual mean CO_2 values for 2011 and 2012 were 390.48 and 392.5 respectively. It is likely that the annual mean value of 400 ppm will be recorded in 2015.

In what way is this current trend in CO_2 unique? In the past several million years, in the absence of human influence, CO_2 has naturally fluctuated between 180 and 280 ppm during glacial and interglacial periods. Thus, the current level of CO_2 is unusual and signifies the footprint or mark of human civilization on this planet. One might even wonder if we have taken the destiny of the planet in our hands. People could be endlessly debating the role of humans on the recent global warming because of the inherent variability in surface temperature, but there can be very little doubt that anthropogenic emissions are responsible for the CO_2 rise and humans are changing the chemical composition of the atmosphere. The increased atmospheric CO_2 has already invaded the global oceans altering ocean chemistry and resulting in ocean acidification and disruptions to marine life. If we continue to burn fossil fuels, CO_2 concentration in the atmosphere will reach levels last seen in the Cretaceous period (150–66 million years ago) when

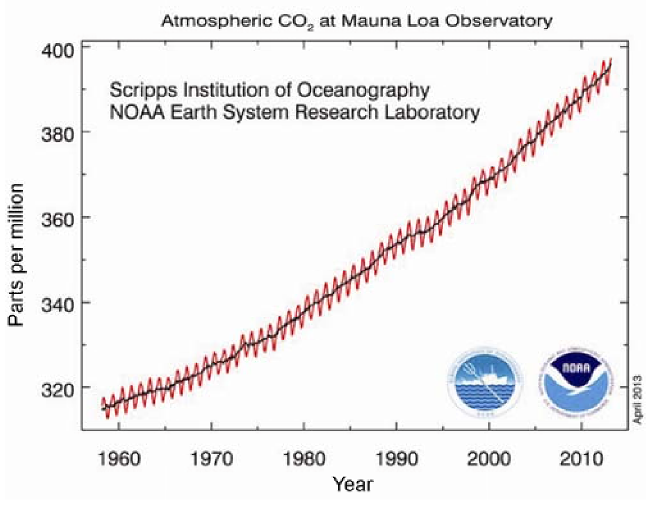

Figure 1. Atmospheric CO_2 concentration (red curve) in ppm (parts per million), measured at Mauna Loa, Hawaii represents the global mean concentration of CO_2. One ppm of CO_2 means one molecule of CO_2 for every million air molecules. The measurements were started by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a facility of the National Oceanic and Atmospheric Administration (NOAA), USA. The black curve represents the seasonally corrected data. (Figure taken from http://www.esrl.noaa.gov/gmd/ccgg/trends/) This is probably one of the most important observational records with profound significance for humanity since Kepler's observations in astronomy.

tropical-like moist and hot conditions prevailed in the polar regions and inland seas flooded vast areas of the continents[4]. Unlike today, this and similar past hot-houses were accompanied by CO_2 build-up rates that were much smaller than what we are witnessing now. The current 100 ppm increase in the last century would have taken tens of thousands of years then.

What is the concern now? In December 2009 at Copenhagen, world governments agreed to limit global warming to 2°C above the preindustrial period. If climate change is to be stabilized at 2°C above preindustrial level – models tell us – CO_2 concentration cannot exceed 450 ppm. Reaching the symbolic milestone of 400 ppm is just another grim reminder about how fast we are approaching 450 ppm. At the current rate of CO_2 emissions, we could reach the 450 ppm target as early as 2035. It should not be surprising if we reach the target earlier than this date given the accelerating emissions in recent years.

Why is the target focused on CO_2 while there are other climate warming agents like black carbon or methane? The trouble with CO_2 is that it has a long lifetime in the atmosphere. While black carbon has a lifetime of 2 weeks and methane about 10 years, CO_2 is estimated to have a lifetime of about 100–300 years. This refers to the time for CO_2 to get into the deep ocean where it is permanently sheltered from the atmosphere. But the climate system is too complex and the deep ocean does exchange its water with the surface ocean on thousands of years timescale. Recent studies[5] show that about 10–25% of emitted CO_2 will be still around in the atmosphere even after 10,000 years. Therefore, large emissions could take the planet back to one of those hot-house conditions that prevailed in the geologic past when global mean temperatures were 5–10°C warmer than today. Sea levels in such a hot-house world with ice-free poles will be higher by 120 m. This should worry anyone who is concerned about the long-term habitability and fate of human civilization on this planet.

1. Monastersky, R., *Nature*, 2013, **497**, 13–14.
2. Ballantyne *et al*., *Nature*, 2012, **488**, 70–73.
3. Global Carbon budget, 2012; http://www.globalcarbonproject.org/carbonbudget/
4. Caldeira, K., *Sci. Am*., September 2012, 78–83.
5. Archer, D. *et al*., *Annu. Rev. Earth Planet. Sci*., 2009, **37**, 117–134.

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COMMENTARY

Conserving the endangered Mahseers (*Tor* spp.) of India: the positive role of recreational fisheries

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A third of all freshwater fishes globally are threatened with extinction[1,2] making them one of the most important vertebrate groups in need of urgent conservation attention. Freshwater fishes are increasingly threatened by a range of factors, including habitat loss, overexploitation and biological invasions[1,3]. Conserving freshwater fishes is therefore a complex challenge requiring a combination of proactive strategies, on a continuous and sustained basis[4,5]. To be successful, conservation measures also require the political will of national and regional authorities, and the participation of local communities[6].

Many countries, especially those in the tropics where much of the freshwater fish diversity is concentrated, invest little time and effort on their conservation. For example, in India, freshwater fishes have been 'out of sight' and 'out of mind' of the policy makers and general public[7]. This is in spite of the fact that the country harbours the greatest number of endemic freshwater fishes in continental Asia[8], many of which are threatened[4,9] and some probably extinct[10,11].

Mahseers of the genus *Tor* are large cyprinids endemic to continental Asia, and popular cultural icons of economic, recreational and conservation interest in their native range[12,13]. Due to the large sizes they attain, mahseers find a place among the 20 'mega fishes' of the world[14], and have often been called the 'tiger of the water'[15], and the world's hardest fighting fish[16]. There are no reliable estimates of the number of *Tor* species found in Indian waters, mainly due to the taxonomic uncertainties within this genus[12]. However, they comprise one of the most threatened groups of freshwater fish in the country. Of the currently valid species, five are listed as 'Endangered' (*Tor khudree*, *T. kulkarni*, *T. malabaricus*, *T. mussullah* (see Note 1) and *T. putitora*) and two as 'Near Threatened' (*T. tor* and *T. progenius*) in the IUCN Red List of Threatened Species[17].

The report of the National Commission on Agriculture (NCA) in 1976 was probably the first to highlight the plight of the mahseers and the need for their conservation[18]. Several studies have since revealed that overfishing and habitat alteration have resulted in severe population decline of different *Tor* species, including the golden mahseer, *T. putitora* and the tor mahseer, *T. tor* in the Himalayan rivers[19,20] and the Deccan mahseer, *T. khudree* in the Western Ghats[21]. More recently, the escalating list of anthropogenic threats to mahseer populations has been synthesized to include a broad range of individual and combined effects such as catchment fragmentation, water and aggregate abstraction, and the prevalence of illegal and highly destructive fishing methods such as small mesh nets, plant-derived toxins, electricity and dynamite[22].