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Climate Change: The Atmosphere as an Impaired Air-conditioner

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Climate change: the atmosphere as an impaired air-conditioner

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1. Introduction

Climate change is of great concern to human beings because we have evolved and flourished in a planetary ecosystem delicately locked into a co-evolving atmosphere. However, signs are that human beings themselves have inadvertently made changes to both the atmospheric composition and the vegetation cover of the Earth. The atmosphere and the planetary ecosystem have been set into motion, searching for new states of equilibrium. In this shifting world, the existence of *Homo sapiens* is no longer guaranteed.

Global awareness of the issue has been sharply rising. The realization that Man might be destroying the ozone layer which is critical for the protection against UV radiation led to the Montreal Protocol of 1987. Concerns about “climate change” brought heads of states to the Earth Summit in Rio de Janeiro in 1992, during which a treaty on “biodiversity” was also discussed. It was however quickly realized that dealing with climate change was not just a scientific subject. The 2002 World Summit in Johannesburg originally intended to be a review of the 1992 Summit turned its focus to “sustainable development”, which highlighted the complexity of climate change.

2. Climate

Climate change tends to be taken to mean “the world is getting warmer”. But it is much more than that.

It is important to look at the basics. The Earth’s atmosphere is an anomaly compared with those of Venus and Mars, our neighbours in the solar system. More than 95% of the atmospheres of Venus and Mars is carbon dioxide; it is a meagre 0.04% on Earth. Furthermore, the Earth’s atmosphere has 21% of oxygen and a trace of methane. This is a very unstable mix of chemicals which can burn anytime. There is no parallel in Venus and Mars. The Earth’s atmosphere has come about after billions of years of work by living things, the key process being photosynthesis which took carbon dioxide out of the atmosphere. Life on Earth maintains the chemical instability in the atmosphere too.

The Earth’s surface temperature is determined by the amount of solar radiation reaching the ground and by the amount of infrared radiation sent down by the atmosphere itself. The latter is determined by the amount of so-called greenhouse gases, of which carbon dioxide is a key component. In geological times, living things have exercised a regulating control on the amount of carbon dioxide, such that the temperature has been maintained within limits favourable to the perpetuation of living things collectively (Lovelock 2000).

Thus, when talking about “climate”, three aspects have to be covered at the same time viz.

(a) physical – temperature, rain, wind, etc.

- (b) chemical – carbon dioxide, ozone, methane, etc.
- (c) biological – plants, animals, bacteria, etc.

3. Past climate changes

Studies of air pockets trapped in ice cores in Antarctic (Petit *et al.*, 1999) showed that atmospheric carbon dioxide level in the past 420,000 years has gone through four cycles, fluctuating between about 180-300 parts per million (ppm) by volume, with corresponding changes in global temperature and methane level (Figure C2). The temperature is deduced from measurements of isotopic contents of deuterium and oxygen-18 of ice. The latest work by Siegenthaler *et al.* (2005) has extended the data series to 0.65 million years before the present (B.P.). They found that the carbon dioxide level before 0.43 million B.P. fluctuated within the range of 180-260 ppm.

The broad resemblance in the trends of carbon dioxide, temperature and methane is a reflection of the close relationship between the physical, chemical and biological components of the Earth. Modern human beings viz. *Homo sapiens* emerged during the second-last cold period. Agriculture emerged roughly 10,000 years ago at the peak of the latest warm episode. Empirically one would expect cooling to set in. This was indeed the prevailing view of climatologists at the end of the 1960s and early 1970s.

4. The grand air-conditioner

Engineers might see in the saw-tooth form of the temperature trace in figure 1 some parallel with that recorded in an air-conditioned room. Apparently, a cooling mechanism is switched on when the temperature reaches an upper-bound value, which would be replaced by a warming mechanism when a lower-bound value is reached. Taking this parallel as a hint, we may represent the controls on global atmospheric temperature in the form of the “grand air-conditioner” of the Earth. Basically, it works through controlling the concentration level of carbon dioxide, that is, cooling is achieved by reducing the concentration level of carbon dioxide (Figure 1).

Volcanoes by emitting carbon dioxide serve as the warming mechanism. The burial of plant material on land and the deposition of dead material (shells and bones) on the seabed serve as the cooling mechanism. Considering the very large flux of carbon through the living world, it is obvious that the amount of carbon dioxide in the atmosphere is very delicately related to the dynamic balance among numerous living processes, e.g. photosynthesis, respiration and decomposition after death. While it was mentioned earlier that photosynthesis took carbon dioxide away from the atmosphere, the life-cycle carbon budget of plants is actually close to being neutral in terms of carbon dioxide removal. What is taken away from the atmosphere in fact depends critically on how much (or little) non-decomposed plant material is left and buried, for example. This in turn depends on the activity of the decomposition process which is sensitive to the operation of microbial organisms. Thus the ultimate control of the air-conditioner lies in things like bacteria!

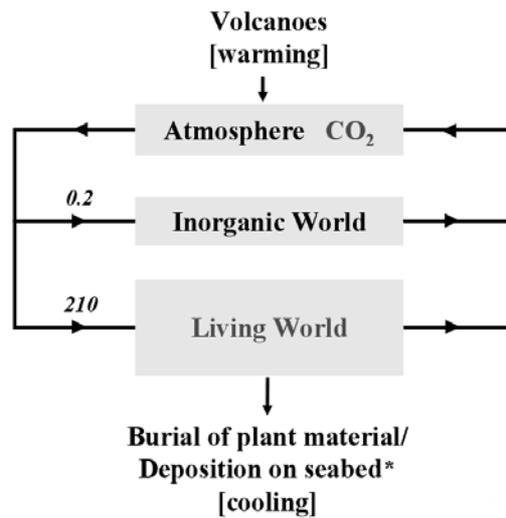


Figure 1. The grand air-conditioner of the Earth. The flux unit is PgC/year.

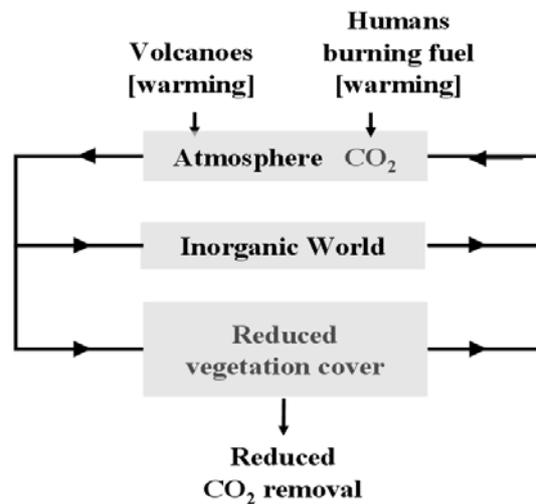


Figure 2. The impaired grand air-conditioner of the Earth.

5. The impaired air-conditioner

We are currently at the warm peak of a climate cycle when one would have expected more plants to appear on Earth, which with the help of microorganisms, should exert a braking effect on the rising carbon dioxide level through assimilation by photosynthesis and the burial of plant residuals after decomposition.

However, since agriculture emerged, Man has been cutting forests to form farmland. The carbon dioxide level rose slowly from 260 ppm to 280 ppm at the dawn of the Industrial Revolution. Then came the invention of the steam engine based on the burning of coal in the 18th century. The

subsequent Industrial Revolution brought about the modern form of life style in which combustion is the ultimate source of energy for practically all activities. An immense amount of fossil fuel, including coal, petroleum and natural gas, has been burnt in the building up of modern prosperity, and indeed increasingly more would be burnt as more countries transition into the “developed world”. The situation is exacerbated by the dramatic loss of vegetation cover on Earth in the last half century as human beings went through a population explosion driven by prosperity. Thus the grand air-conditioner of the Earth has been impaired at both ends (Figure 2).

6. The consequences

The carbon dioxide level has increased dramatically in the past two centuries and especially in the last half century (Figure 3). The carbon dioxide level has surged to some 380 ppm which is 100 ppm above the pre-Industrial Revolution level. It should also be noted that half of this increase occurred in the last three decades or so, reflecting the phenomenal rise of a wasteful life style driven by post-war consumerism and based on rapidly-rising energy consumption. In tandem with this rise in carbon dioxide level, there was a global warming of 0.6°C in the 20th century (Figure C3).

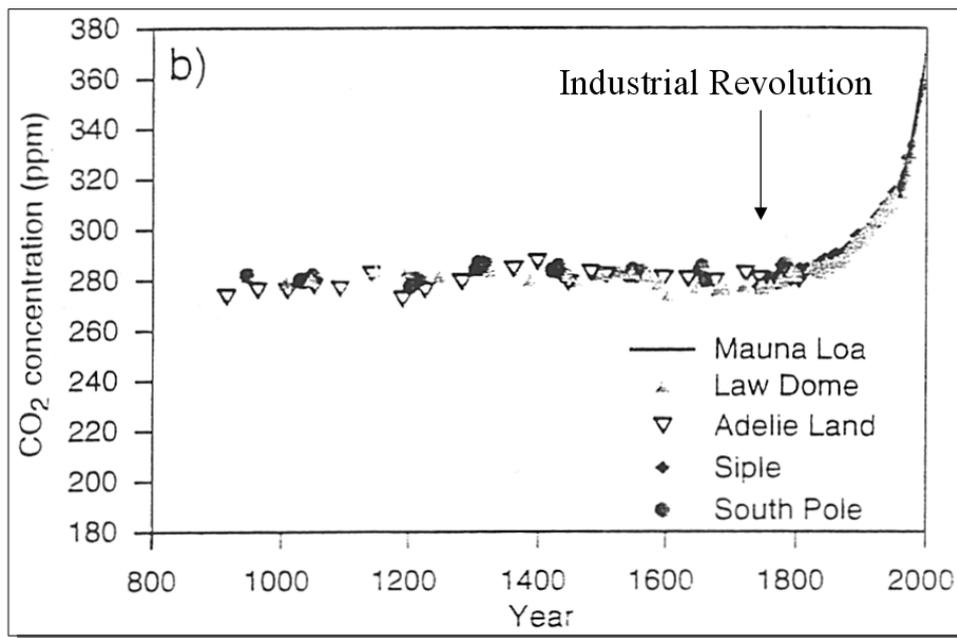


Figure 3. Surge in carbon dioxide level after the Industrial Revolution and the prevalence of combustion-based life style (after IPCC 2001).

Estimates of the future trends of carbon dioxide level and global temperature have been made based on extensive modeling work. The results depend on assumed scenarios of economic and technological developments. By the end of the 21st century, the upper-bound estimates are that

carbon dioxide may reach 1000 ppm and global temperature could go up a further 5-6 degrees (IPCC 2001).

In Hong Kong, the Hong Kong Observatory has conducted work in climate projections to the last decade of the 21st century relative to the old “climatological normals” based on the statistics of 1961-1990 (Leung et al. 2004). The number of hot days (daily maximum temperature 33 degrees or above) will increase from 11 to 24. The number of hot nights (daily minimum temperature 28 degrees or above) will increase from 8 to 30. The number of cold day (daily minimum temperature 12 degrees or below) will decrease from 21 to an amazing 0.8, that is, less than one day per year on average.

Warming *per se* is not a serious problem. Some people may even welcome it. The trouble is that past equilibria among weather systems have been disrupted, leading to a rapidly rising number of people affected by more frequent severe weather events in an unstable atmosphere. According to the statistics of the International Federation of Red Cross and Red Crescent Societies (2004), the number of people reported affected by disasters climbed by 59% from an average of 163 million per year (1984-1993) to 258 million per year (1994-2004). Furthermore, the people in the less developed countries and the underprivileged communities of developed countries will be impacted much more owing to their inability to cope with the impact of weather extremes becoming more frequent. This is the recipe for increasing social instability.

Disruptions in the biological world have also been inferred and indeed observed (Parmesan et al. 2003). Natural habitats are in a state of stress, with manifestations in terms of loss of an increasing number of species. The change in the biological world, especially in the micro-organisms, is increasingly being seen as a threat through consequential reduction in food production, geographical expansion of diseases and potential emergence of new diseases. The spread of dengue fever and Rift Valley fever is now firmly related to climate change. One has to ponder the dire consequences of bacteria and viruses evolving quickly to adjust to the new climate while the human species adjusting much more slowly by having a new generation once in 20-30 years. This is particularly relevant as we prepare ourselves for the alleged onslaught of avian flu becoming human flu.

7. Engineers to the rescue

Engineers will have to come to the rescue of mankind, by fixing the impaired grand air-conditioner of the Earth. We have to find ways to reduce carbon dioxide in the atmosphere. Can we capture it and hide it somewhere? Can we at least stop the emission of additional carbon dioxide into the atmosphere? Can we help biologists find some way to increase the vegetation cover on Earth or increase the efficiency of burying dead plant material? We also have to devise means to help people in underprivileged communities cope with the physical and biological consequences of climate change, like high winds, heavy rain, drought, storm surge and diseases. This is a long list but unfortunately, climate is concerned with the physical, chemical and biological aspects of the Earth.

Engineers in a way has a special responsibility to help put things right, because they invented the steam engine and the numerous gadgets for modern living afterwards. As the Chinese proverb says, “Whoever tied the bell to the cattle will have to un-tie it.”

Acknowledgments

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COLOUR PLATE

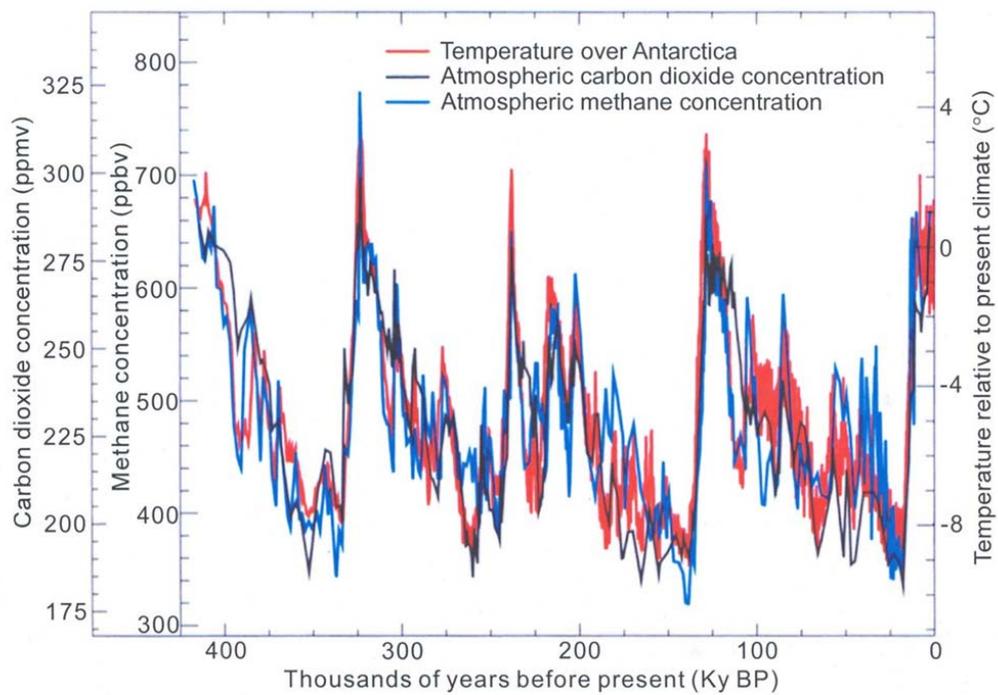


Figure C2. Stable oscillations of air temperature and levels of carbon dioxide and methane in the last 0.4 million years (after IPCC, 2001).

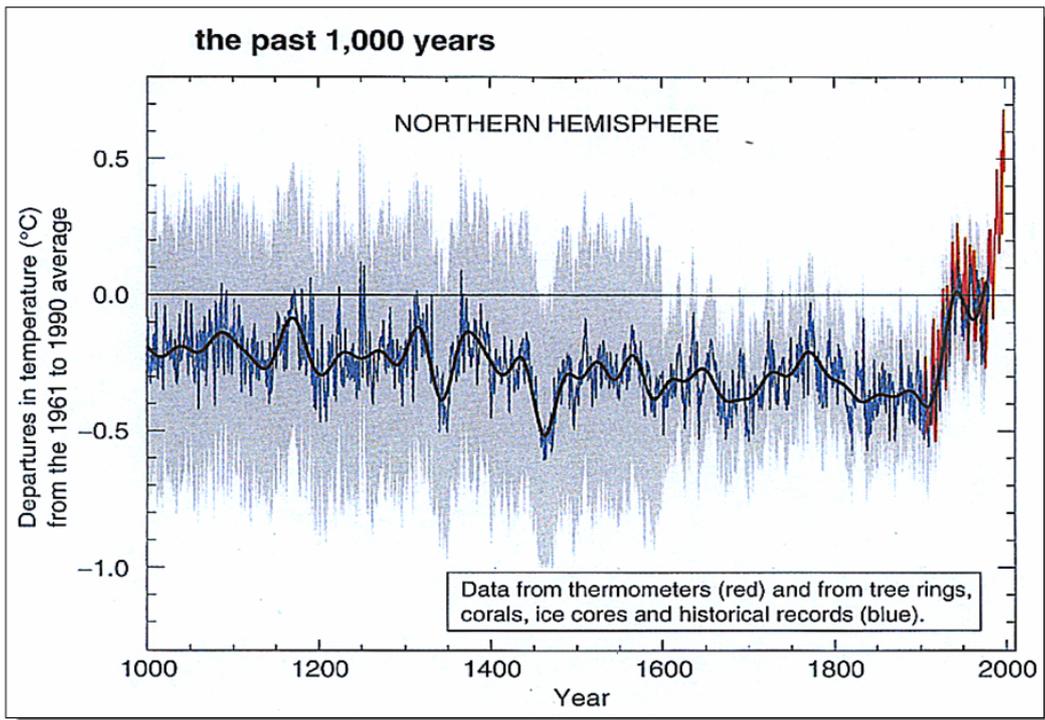


Figure C3. The Earth's surface air temperature in the last 1000 years. It started rising after the Industrial Revolution had taken hold (after IPCC 2001).