J. Natn.Sci.Foundation Sri Lanka 2005 ***33****(4): 233-237*

GENERAL ARTICLE

THE WARMING PLANET

CHARLES SANTIAPILLAI*
Department of Zoology, University of Peradeniya, Peradeniya.

Abstract: Gases such as carbon dioxide, methane and nitrous oxide are responsible for the greenhouse effect. Atmospheric carbon dioxide levels have increased from 270 ppm in 1780 to 380 ppm today. For a doubling of carbon dioxide levels, the global temperature is likely to rise by between 2.5°F and 8°F. When polar ice caps melt, sea levels will rise, leading to the pollution of inland aquifers with salt. Drastic and sudden change in climate may have triggered the collapse of some of the ancient civilizations. Reduction of global warming would need drastic change in how we live and consume the planet Earth's resources.

Key words: Global warming, greenhouse effect, permafrost.

Unlike oil, no one owns climate. Nevertheless, humans have disturbed it by clearing forests, burning coal, oil and gas, and introducing massive quantities of carbon dioxide and other heat-trapping gases into the atmosphere faster than plants and oceans can remove them. Therefore, as Elizabeth Kolbers[1] points out, "The world is now warmer than it has been at any point in the last two millennia". Although the implications of a warming planet were highlighted in the 1970's , it was the Irish Physicist named John Tyndall whose research on atmospheric physics at the Royal Institution (London) in 1859 first led to an understanding of the phenomenon. He examined the transmission of both radiant heat and light through various gases and found that while oxygen and nitrogen were transparent to both visible and infrared radiation, others such as carbon dioxide, methane and water vapour, were not. From his observations, Tyndall concluded that these imperfectly transparent atmospheric gases were responsible for determining the earth's climate.

As Martyn Bramwell[2] explains, Tyndall's discovery is referred to as the "natural greenhouse effect" which works as follows. The sun's radiation reaches the earth mostly in the form of visible light, which passes through greenhouse gases and warms up the earth. The earth then reflects some of this solar energy back into space in the form of infrared radiation. Gases such as carbon dioxide, methane and nitrous oxide absorb the infrared radiation and then re-emit a part of it into outer space and the rest back to the earth. These gases act like the glass of a greenhouse –trapping much of the heat inside-and thereby making the earth a pleasant place to live. Otherwise it would have been an inhospitably cold planet.

The greenhouse effect is not something new-it has been operating for millions of years. What is new is that human activities have disturbed the balance of the system, as a result of which, the earth is getting warmer. In the past, the combined processes of absorption and re-emission of infrared radiation provided just enough heat to keep the earth at a steady overall temperature at a mean value of 15 °C. Since the industrial revolution, this balance has been upset. Large amount of carbon dioxide are added to the atmosphere from factory emissions, burning of fossil fuels, and deforestation. Most of the methane present in the atmosphere comes from biological processes and from the soils in rice fields. Destruction of rain forests has led to increased levels of carbon dioxide, due to the loss of vegetation that use carbon dioxide from the air during photosynthesis. Deforestation accounts for 20% of the atmospheric carbon dioxide released into the atmosphere annually. In 2004 alone, some 26,000 km^2 of the Amazon rain forest (roughly a fifth of the total rainforest) were lost. Today, cattle ranching accounts for 80% of forest loss in Brazilian Amazons. Ironically, the World Bank plans to expand the logging industry in the Congo Basin –the second largest tract of tropical forest on earth! About 8,000 years ago, 50% of the planet Earth was forested. Today less than a third is under forest cover. In Sri Lanka, we have lost almost 80% of our forest.

* This article is based on a series of articles entitled ' The Climate of Man' published recently in The New Yorker.

Solar variations may also have affected one aspect of the climate, the rain-laden monsoonal winds that sweep in from the sea around our island. During our own lifetime, we have experienced an increase in average global temperature. Coastal cities have become hotter and more humid, while rainfall has decreased substantially in the hill country. Globally, there is ample evidence to show rising levels of carbon dioxide, permafrost thawing, glaciers melting, sea level rising, sea ice thinning, oceans becoming warmer and more acidic, the difference between daytime and nighttime temperatures diminishing, wildlife ranges shifting (towards the poles). birds nesting early, migration times of animals varying, droughts lingering, coral reefs bleaching, plants blooming early and diseases spreading. Already serious water shortages have become frequent in the tropics.

During the last ice age, much of the world's northern hemisphere was under permafrost. It was at the end of more than a million year epoch, the Pleistocene, that colossal ice sheets began advancing and retreating, thereby ploughing up much of Northern Europe and America. Ice-core records show that in the 1780s, the carbon dioxide levels stood at about 270 parts per million (ppm). But with the industrial revolution, levels began to rise. It took more than 150 years for carbon dioxide levels to reach 315 ppm in the mid-1930s, about 40 years to reach 330 ppm in mid 1970s; 20 years to reach 360 ppm in the mid-1990s and just 10 years to reach 380 ppm at present. During the same time-interval, concentrations of methane doubled from 0.78 to 1.76 ppm. Over 64% of the extra carbon dioxide comes from industry, and over 35% from the burning of forests. Thus since James Watt perfected his steam engine in 1765, the average temperature of the earth has been increasing gradually but steadily.

An anthropogenic cause for global warming was predicted by the Swedish chemist, Svante Arrhenus in 1895 who studied the consequences for the earth's surface temperature, should carbon dioxide levels double. It is feared that atmospheric carbon dioxide levels may reach 500 ppm by 2050 if the current trend continues. For every added increment of carbon dioxide, the earth will experience an increase in surface temperature. According to Elizabeth Kolbert[1], modern scientific evidence suggests that for a doubling of carbon dioxide from pre-industrial levels, global temperature is likely to rise by between 2.5 ^{0}F and 8 ^{0}F. Already the planet earth is warmer than it has been at any point since the birth of Christ. The 1990s was the hottest decade, and 1998 was the warmest year. While carbon dioxide levels can be increased through levelling forests and burning fossil fuels, its removal from the atmosphere is not easy. It is a persistent gas that may last a century. Green plants, however consume one seventh of the atmospheric carbon dioxide. As Kolbert[3] points out, for all practical purposes, the recent "carbonation" of the atmosphere is irreversible. The US is by far, the largest emitter of carbon dioxide, responsible for more than 30% of the global emissions (estimated at 7 billion metric tons per year). An average American produces as much greenhouse gases as 18 Indians or 99 Bangladeshis. Texas' emissions alone far exceed those of France. Regrettably, America unilaterally withdrew from the Kyoto Protocol designed to cut down greenhouse gas emissions.

While the continent of Antarctica rests on land, the Arctic is ice suspended in a frozen ocean- the permafrost. Because of the heat that emanates from the centre of the earth, the permafrost gets warmer the further one goes down. A straight line graph is obtained if permafrost temperatures are plotted against depth. As Kolbert[1] points out, the graph is more sickle-shaped today, since permaforest instead of being coldest at the top, is coldest somewhere in the middle. Permafrost is also a repository of billions of metric tons of carbon accumulated by trees which died millions of years ago. One of the problems with global warming is that this organic material could break down, giving up carbon dioxide and methane back into the atmosphere. In the Arctic, such a reverse process is already going on and the polar ice cap is melting.

The covering of ice in the Poles, reflects much of the solar radiation back into space without transforming it into heat. The ratio of reflected light to incident light, as measured by a spectrophotometer, is known as albedo (from the Latin for "whiteness") , which is a fundamental parameter of global energy balance. The normal albedo of snow, for example, is nearly 1, whereas that of charcoal is about 0.04. Snow looks white because it reflects back much of the sun's rays. In the absence of clouds, the moon has an albedo of 0.12, while Venus which is covered by dense clouds has an albedo of 0.76. The most recent value obtained for earth is approximately 0.29. This means that only about a third of sunlight that strikes the earth gets reflected back. According to Wielicki *et al.*[4], "the average incident solar radiative flux is 341 watts/m^2 so that a change in albedo of 0.01 represents a global energy balance change of 3.4 watts/m^2, similar in magnitude to the impact of doubling carbon dioxide in the atmosphere". Kolbert[1] quotes Donald Perovich of the Cold Regions Research and Engineering Laboratory (CRREL), according to whom, as more and more polar ice melts and retreats, "we are replacing the best reflector with the worst reflector". Much of the energy of the sun goes into heating the ocean. Carbon dioxide levels drop during glaciations when ice sheets advance, and rise when ice sheets retreat. According to George Monbiot[5], "the latest studies show unequivocally that most of the world's glaciers are retreating". Antarctic ice cores also show that carbon dioxide levels are much higher today than at anytime during the past 420,000 years, thereby implying that perhaps we are living in a warm period after an ice age.

As Kolbert[1] points out, there are two types of sea ice in the Arctic, the seasonal ice which forms in winter and melts in summer, and the perennial ice which remains throughout the year, Furthermore, while new ice tastes salty, multiyear ice is so fresh that one can drink it melted. Warm water expands. Melting ice also causes a rise in sea level. However, as Kolbert[1] argues, when sea ice melts, it does not affect sea level since the floating ice has already displaced an equivalent volume of water. But when the polar ice caps melt sea levels will rise. Estimates of sea level rise by the UN's Intergovernmental Panel on Climate Change (IPCC) range from approximately 10-90 cm by the year 2100. Within the next few decades, it is feared that rising sea levels will pollute inland aquifers with salt. Already salt water has penetrated 5 km beneath Manila in the Phillippines. Globally, over 2 billion people depend on underground water.

Wind moves surface water in oceans in horizontal current, parallel to the earth's surface. Such wind-driven currents often take circular routes (gyres) and are influenced by the earth's rotation. On the other hand, thermohaline ('thermo' for heat, 'haline' for salt) circulation involves vertical movements of water-from the surface to the sea floor. At the Polar Regions, as sea water freezes, the salt is drained out and the salty water being heavy sinks to the sea floor, where it spreads horizontally forcing the water already on the bottom, upward. Warm water is drawn from the tropics, and as it moves towards the poles, it gets denser through evaporation and heat loss. The coldness and high salinity together makes the water denser, and it sinks to the bottom of the sea, thereby establishing a kind of conveyor-belt movement. It is these circulations that moderate earth's climate by redistributing heat through the ocean. As Arnold Gordon[6] explains, these circulations help transfer heat from the equator to the poles. The circulation also affects the storage of carbon within the deep ocean given that the remains of dead marine organisms on the ocean floor represent the main 'storehouses' of carbon in the ocean, taking up almost a third of human-generated carbon dioxide. Slight variations in the density-driven thermohaline circulation can alter the ocean's ability to store heat and carbon. Koibert[1] quotes Wallace Broecker, a professor of Geochemistry at Columbia University's Lamont Doherty Earth Observatory who refers to it as the "Achilles' heel of the climate system".

As Kolbert[7] explains, climate change models consider the impact of "forcings" measured in terms of watts/m^2. A natural forcing is any ongoing process or event, such as a volcanic eruption, that alters the energy of the system. Anthropogenic forcing, on the other hand, refers to any man made process, such as increasing the carbon dioxide levels in the atmosphere by burning fossil fuels. The size of the greenhouse forcing is estimated to be 2.5 watts/m^2. At the current rate of greenhouse emission, carbon dioxide levels are expected to reach 500 ppm by 2050, by which time the forcing associated with the greenhouse gases too would have increased to 4 watts/m^2. Kolbert[7] cautions us to bear in mind that the total forcing that ended the last ice age- a forcing sufficient to melt the mile-thick ice sheets and raise sea levels by 400 ft is estimated to have been just 6.5 watts/m^2.

On a visit to Columbia University's Lamont-Doherty Earth Observatory in 1998, I was able to see its vast collections of ocean sediment cores. At that titme, Rusty Lotti, a paleoclimatologist explained how past climate data could be extracted from studying the remains of dead microscopic animals such as foraminifera in sediments on the sea floor, Foraminifera are abundant and widespread in modern seas and their fossil occurrences are extensive, indicating the extent of the past seas. According to Virginia Morell[8], various species of foraminifera thrive at different temperatures, and their fossilized shells contain a chemical signature of water temperature, which enables researchers to trace climate back for millions of years. Until about 6,000 years ago, the Sahel region in North Africa was forested. Today it is largely a desert. Changes in the earth's orbit around the sun may have been responsible for the sudden shift from wet to dry conditions. According to Morell[8] such changes in the orbit and orientation of the earth are known to determine the timing of ice ages by affecting the distribution of sunlight over the earth's surface. Prolonged drought and the subsequent shortage of food and water may have been the principal cause for the collapse of many past civilizations. Kolbert[7] provides a number of examples. The Akadian Empire that flourished between the Tigris and Euphrates Rivers in what is known today as Iraq collapsed about 2200 B.C. About the same time, the Old Kingdom of Egypt too disintegrated. The Mayan civilization collapsed about 800 A.D. while at its peak.The major pre-Columbian Tiwanaku civilization that flourished near the southern shore of Lake Titicaca in Bolivia vanished by 1200 A.D. In the Indus Valley, the Harappan civilization suffered a decline following changes in the monsoon patterns. Drastic and sudden changes in climate might have triggered the collapse of these civilizations, which predated the industrial revolution by hundreds or even thousands of years.

If nothing is done to reverse the current trend of greenhouse gas emissions, the scenario is refereed to as "business as ususal" (B.A.U.). As Kolbert[3] points out, according to B.A.U. carbon emissions will reach 10.5 billion metric tons a year by 2029, and 14 billion tons a year by 2054. During the year 2004, carbon emissions reached 7 billion metric tons. Therefore, if carbon emission needs to be kept constant at today's levels, then ways must be found to ensure that 7 billion metric tons of carbon are not released into the atmosphere in 50 year's time. How can carbon dioxide emissions be stabilized? Robert Socolow, a professor of Engineering at Princeton University and his colleague Stephen Pacala (as explained by Kolbert[3]), tackle the problem in a novel way by breaking it into a number of manageable blocks called "stabilization wedges", which deal with (a) energy demand.(b) energy supply and (c) capture and storage of carbon dioxide somewhere other than the atmosphere. Kolbert[3] defines a stabilization wedge as a step that would be sufficient to prevent a billion metric tons of carbon per year from being emitted by 2054". According to her, examples of stabilization wedges include (1) the solar-power wedge, which produces clean energy with no pollution of emissions. However it would need millions of acres of space to accommodate the required number of photovoltaic cells to produce energy equivalent to that of a coal-fired power plant; (2) wind electricity: given the standard output of a wind turbine being 2 megawatts, it would require at least a million turbines; (3) nuclear power: although nuclear power produces no carbon dioxide, yet its radioactive wastes are difficult to dispose off. To be effective, the number of nuclear power plants currently functioning in the world need to be doubled. This is not only risky, but it can also lead to the rapid depletion of world's uranium ores as well, (4) automobile wedges; either every car in the world must be driven half as much as it is today, or it be twice as efficient.

Many people who worry over climate change are trying to find a way to avoid the perils of a warming planet without changing the way they live and consume the Earth's resources. These options are not easy, and they would require tough measures and strong government interventions. Responsible governments should realize that there are many ways to tackle climate change; ignoring it is not one of them. As one climatologist cautioned Kolbert, " the time is already five past midnight".

References

1. Kolbert E. (2005a). The Climate of Man- I. *The New Yorker*. April 25, 2005: 56-71.

2. Bramwell M. (1992). *Book of Planet Earth*. Simon & Schuster, New York.

3. Kolbert E. (2005c). The Climate of Man – III. *The New Yorker*. May 9, 2005: pp. 52-63.

4. Wielicki B.A., Wong T., Loeb N., Minnis A., Priestley K. & Randall R. (2005). Changes in earth's Albedo measured by satellite. *Science* **305**:825.

5. Monbiot G. (2005).Junk Science. *The Guardian Weekly*. **172** (22): 17.

6. Gordon A.L. (1992). Currents and Climate. In: *1992 Science Year*. The World Book Annual Science Supplement. 191-203. World Book, Inc. Chicago.

7. Kolbert E. (2005b). The Climate of Man-II. *The New Yorker*. May 2, 2005: 64-73.

8. Morell V. (2004). Time Sings. What causes climate change? *National Geographic*. **206**(3): 56-75.

9. Walsh N.P. (2005). Shrinking lakes blamed on global warming . *The Guardian Weekly*. **172**(26): 8.