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GUEST EDITORIAL

Hottest decade: Early warning or false alarm?

The global mean temperature in 2005 was 14.5°C. This was the second warmest year in the last 125 years. During the last decade, 9 out of the 10 years were the warmest during the past 125 years. Hence the impact of global warming may become the most important environmental issue in the 21st century. The general public has become aware of this issue after the publication of the book *State of Fear* by the celebrated author Michael Crichton and the release of the movie *The day after tomorrow*. The book and the movie represent opposite views on the issue of future climate. In the book, Crichton tries to convince the readers that global warming is a hoax perpetuated by climate scientists for personal gain. The film *The day after tomorrow* is a typical 'disaster' movie (with a lot of special effects) that shows that global warming can trigger abrupt climate change. Both views are simplistic and misleading. Can global warming lead to unpredictable climate change? This issue cannot be answered easily because the mean climate of the earth is determined by a delicate balance in exchange of energy and gas among the atmosphere, the ocean and the biosphere. The optimists will argue that the earth's climate is so complex that small perturbations introduced by human beings cannot alter the earth's climate dramatically. The pessimists will argue that the climate system is nonlinear and hence small perturbations by human beings can cause large changes in global climate. Geologists who have peered into past climate will be sympathetic to the latter view because the earth has experienced many ice ages in the past. These ice ages were triggered by small changes in the sun-earth geometry (caused by changes in the eccentricity of the earth's orbit around the sun and the inclination of the earth's rotational axis).

The earth's climate is modulated by a large number of factors and hence we need sophisticated climate models to predict how the earth's climate will evolve in the future. These climate models incorporate the laws of dynamics and thermodynamics and need large computational resources for the simulation of future climate. Can we trust the predictions made by such models? The predictions made by these models are reliable for parameters such as global mean temperature. James Hansen, Director of Goddard Institute of Space Studies in USA used the predic-

tions from climate models in a testimony before the US Senate in 1988. In this testimony he discussed the 'most plausible' scenario for the evolution of global mean temperature in the next 50 years. In 1988 James Hansen predicted that global mean temperature in 2005 will be 14.45°C, while the observed value was 14.50°C. This means that we can trust the prediction made by global models about the increase in global temperature during the next 20 years. How will the global mean temperature evolve after 2025? The evolution of global mean temperature beyond 2025 will depend upon the rate of fossil fuel consumption. This will depend upon how the global population increases and the efficiency of energy use. These quantities cannot be forecasted accurately and hence there will be a large uncertainty about what the global mean temperature will be beyond 2025.

The surface air temperature in most parts of India has increased by half a degree centigrade during the second half of the 20th century. The surface air temperature in the Himalayas has, however, increased by one degree centigrade during the same period. This has led to the rapid melting of the glaciers in the Himalayas. The rapid melting of the glaciers has resulted in the large increase in the volumes of glacial lakes. Some of these lakes are dammed by thin walls of ice or debris. Hence these lakes can cause glacial lake outburst floods in Nepal, Bhutan and North India that can discharge millions of cubic metres of water in a few days. After the melting of all the Himalayan glaciers there will be a major water crisis in most of North India. This water crisis can be upon us in just a few decades if the rate of global warming is as fast as what we have witnessed in the last 20 years.

Will global warming have an adverse or beneficial impact on the Indian monsoon? The complex climate models have not been able to provide an accurate simulation of the spatial or temporal variation of the monsoon in the 20th century. Hence the predictions made by these models about the monsoons in the 21st century cannot be trusted. One of the reasons for the poor simulation of monsoons by climate models is the crude representation of clouds in these models. In order to simulate monsoons accurately, climate models need to accurately capture phenomenon

whose spatial scales range from a few kilometres to few thousand kilometres. This has not been possible so far even though high performance computing has shown remarkable progress in recent years.

The fossil fuel industry is worried that the concern about global warming might lead to regulation that will stifle the growth of their industry. They have adopted the approach followed by the tobacco industry in the 1960s. One of the tobacco companies issued a memo in 1960s which observed: 'Doubt is our product since it is the best means of competing with the "body of fact" that exists in the mind of the general public. It is also the means of establishing a controversy'. During the past 15 years the Intergovernmental Panel on Climate Change (IPCC) has produced many reports that document the scientific evidence for global warming. These reports have been written by scientists around the world which have been reviewed critically by the scientific community. These reports have been attacked by the fossil-fuel industry in order to create seeds of doubt among the general public. The novel *State of Fear* creates doubts in the readers' mind about whether global warming is really occurring or not. Naomi Oreskes of the University of California, San Diego, examined 928 peer-reviewed papers on climate change published between 1993 and 2003 and found that all the authors believed that global warming is real (*Science*, 2004, **306**, 1686). She has stated that 'Politicians, economists, journalists and others may have the impression of confusion, disagreement or discord among climate scientists, but that impression is incorrect'.

Many economists have been opposed to constraints on fossil fuel consumption since it may lead to reduction in economic growth. They argue that the cost that is imposed in the present by curtailing the consumption of fossil fuels may be more than the benefits that may accrue in the future. This argument is futile because there are large uncertainties in the estimate of economic loss imposed by curtailing fossil fuel consumption or the economic gain that may accrue by preventing global warming. Crichton believes that 'the people in 2100 will be richer than we are, consume more energy, have smaller global population

and enjoy more wilderness than we have today'. Most politicians will be happy to believe in such an optimistic prediction because it will absolve them of the responsibility of taking any action today with regard to population, energy consumption or wildlife! Rich people and rich nations will have the resources to tackle the consequences of global warming. There have been many occasions in the past where large-scale human migration occurred in response to adverse climate change. In the 21st century, most human beings will not be able to exercise this option on account of the existence of national boundaries

In the book *Is the Temperature Rising? The Uncertain Science of Global Warming*, George Philander (Princeton University Press) provides a balanced view of this controversial topic. He highlights the dilemma faced by human beings with the following allegory: 'Suppose we are in a raft, drifting toward a waterfall. To avoid a calamity, we must address two questions: How far is the waterfall? And when should we get out of the water? We deal with these questions in radically different ways. The first can be answered with the methods of science. The second (a matter of policy) is far more difficult. It has a multitude of possible answers, none entirely satisfactory to everyone, and it requires compromises among the different values of different people (some timid, some foolhardy). The difference between the science and policy aspects of environmental problems is sharp in this allegory, but the distinction can easily become blurred when the scientific results possess uncertainties'.

One's viewpoint about the impact of global warming thus depends upon one's attitude towards the natural world and the legacy that one would like to leave for future generations. If one considers the natural world to be a resource to be exploited for the immediate benefit of human beings then there will be no need to be concerned about the future. On the other hand, if the complex natural world is held in reverence, as most ancient civilizations did, then one would be concerned about the irreversible changes that may be brought about by human beings.

J. Srinivasan