Proc. Indian Acad. Sci. (Earth Planet. Sci.), Vol. 102, No. 1, March 1993, pp. 27–34.

Climate and global change in relation to sustainable development: The challenge to science

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Abstract. In the light of the current worldwide concern on climate and global change and the outcome of the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil in 1992, the paper relates climate and global change to sustainable development. It emphasizes the importance of scientific research in the advancement of knowledge in the related areas. The role of science to socio-economic development is discussed in the context of the symbiotic relationship between science and society. In this connection, the four areas identified by the Rio Conference are discussed.

Keywords. Climate and global change; sustainable development; science and society.

1. Introduction

It is with a distinct honour and pleasure that I have accepted the invitation to contribute to this special issue of the Proceedings of the Indian Academy of Sciences (Earth and Planetary Sciences) devoted to the subject of "Climate and Global Warming". On behalf of the World Meteorological Organization (WMO), I take this opportunity to extend my warmest wishes for continuous success to the Academy, which is also to be congratulated for focussing on this very important theme with many significant implications for mankind and in which substantial contributions have been provided by Indian scientists.

In recent years, there has been a growing awareness of the important implications of various issues relating to climate and global change. This topic is one of the central areas of concern which is part of the current world-wide attention on the twin topic of environment and development.

2. Environment and development

The United Nations Conference on Environment and Development (UNCED) which took place in Rio de Janeiro in June 1992, discussed the linkage between environment and development issues. Among its output was the Rio Declaration, which stated universal principles that "must govern the economic and environmental behaviour of peoples and nations to ensure our common future." The Conference also resulted in "Agenda 21", a programme of action for the implementation of the principles enunciated in the Earth Summit.

Today, humanity is very much aware that it lives in a world that is poised on the threshold of a new epoch when the survival of human existence as well as those of other species in the planet is threatened and endangered, due to global changes. Nations have to cope with many issues like droughts, desertification, flooding, natural

disasters, depletion of the ozone layer, environmental degradation, and a possible climate change. There is increasingly disturbing evidence that man's activities are rapidly changing life-sustaining balances. We have gone beyond the point where sustainable use of the atmosphere as a highly mobile dump for man's waste is possible, without serious consequences. We are now more aware of possible implications of the stratospheric ozone layer depletion, a looming major change in climate and concomitant projected sea-level changes as well as other global changes. Furthermore, we are more conscious that failure to protect the environment can lead to the degradation of the natural resources base necessary for continuing development.

In an effort to maintain the quality of the environment and achieve environmentally sound and sustainable development in the light of global changes, UNCED addressed, among others, the protection of the atmosphere, land resources including forests, freshwater resources, oceans, seas and coastal areas, conservation of biological diversity, environmentally sound management of biotechnology and hazardous wastes, prevention of illegal traffic in toxic products and wastes, and the improvement in the quality of life and human health. Conventions on climate change and biological diversity were opened for signature at UNCED. It also called for the negotiations of a convention on desertification to be completed by June 1994. UNCED took these into account as environmental concerns which also have to be considered in relation to the socio-economic development efforts of many countries.

In this connection, basic changes will be needed if we are to move towards nationally and globally sustainable development. Among others, in the industrially developed countries, there will be a need to evolve economic systems that use resources more sparingly and efficiently, as well as minimizing waste discharge. In developing countries, it will be necessary to ensure socio-economic growth to meet the rising expectations of growing populations and that this takes place in a manner that will minimize resource depletion and environmental stress.

Indeed, issues relating to poverty, increasing world population, concerns for special groups like women, children and indigenous people, financial resources, and technology transfer are important considerations for environmentally sound and sustainable development. It is estimated that about 125 billion US dollars per year is the order of magnitude of the international financial resources assistance required for the full implementation of the Agenda 21 programmes proposed. It may be noted that this is 70 billion US dollars more than the annual official development assistance currently being made available by industrialized countries. Nonetheless, this is less than one percent of the Gross National Product of principal donor countries. Financial mechanisms, such as those similar to the Global Environment Facility, will have to be established to meet the requirements. These will also be necessary to facilitate technology transfer to developing countries in conditions favourable to these countries. In addition, suitable institutional structures should be in place to ensure the implementation of the necessary activities such as those relating to climate and global change.

3. Climate change

Climate and climate change will certainly have an effect on the future sustainable development of much of our planet's resources such as those relating to biodiversity, water, forests, land and oceans as well as in relation to various sectoral activities like agriculture and industry.

While climate changes have happened in the past, they did so at a much slower pace than what is now predicted to occur by the next century. In the earlier changes, the various forms of life usually had enough time to adapt. What is dramatic in the present situation is the unprecedented potential rapidity of the changes. Regular, meticulous scientific observations, carried out in a number of countries, provide ample evidence that the atmospheric concentrations of carbon dioxide, methane, nitrous oxide and various chlorofluorocarbons are continuously increasing at a very rapid rate. This is of great concern as it is known that these changes in the composition of the atmosphere will likely result in a warmer global climate. In turn, global warming may lead to a number of adverse consequences, such as sea-level change, major shifts of precipitation belts and increasing pressure on diminishing freshwater resources.

Much of our knowledge on climate comes from global scientific and technical programmes co-ordinated by WMO. The mandate of the WMO is to co-ordinate and facilitate world-wide co-operation in the making and exchange of standardized and quality-controlled meteorological, hydrological and other geophysical observations as well as in their analysis, understanding and interpretation. It actively promotes the application of the derived information for the benefit of humankind, especially in support of their socio-economic and cultural activities, protection of life and property, and safeguarding of the natural environment for future generations. The Organization is sensitive and responsive to the changing global needs for meteorological and hydrological support to an ever-widening spectrum of human activities.

WMO has inherited an interest and involvement in the study of climate and climate change from its predecessor, the International Meteorological Organization (IMO) which was created as early as 1873. In 1929, it already had an active technical Commission on Climatology. On the establishment of WMO in 1950, the new Organization took over the responsibilities of IMO and continued to intensify actions on the international co-ordination of measurements of atmospheric composition including ozone, carbon dioxide and other greenhouse gases. In 1979, WMO convened in Geneva the First World Climate Conference in collaboration with some other organizations of the United Nations System and the International Council of Scientific Unions (ICSU). During the same year, the World Climate Programme was established by the WMO Congress, recognizing among others 'that there is an immediate need for nations to utilize existing knowledge of climate and climate variations in the planning of social and economic development.'

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established jointly by the WMO and the United Nations Environment Programme (UNEP) to study all aspects of possible climatic changes including the socio-economic implications. A further major action was the convening of the Second World Climate Conference (SWCC) in Geneva from 29 October to 7 November 1990. Both the Conference Statement and the Ministerial Declaration resulting from the SWCC acknowledged and endorsed the activities carried out within WMO's World Climate Programme and IPCC. They also called for urgent action, including the international negotiation of a Framework Convention on Climate Change.

4. World Climate Research Programme (WCRP) and global change

Addressing the improved understanding of the climate and its relevant success is the concern of the World Climate Research Programme (WCRP), a programme which

I am aware is of particular interest to the Academy. It is the scientific component of the World Climate Programme. Its objectives are to determine to what extent climate can be predicted and the extent of man's influence on climate. To achieve these objectives it is necessary to improve the scientific knowledge of global and regional climates, their temporal variations and mechanisms, as well as to assess the evidence for significant trends in global and regional climates. There is also a need to further develop the physical-mathematical models capable of simulating and assessing the predictability of the climate system over all relevant space and time scales, to investigate the sensitivity of climate to possible natural and man-made forcings and to estimate the changes likely to result from specific disturbing influences. Achieving a quantitative prediction of the evolution of the physical climate system, constituted by the global atmosphere, the world ocean, the cryosphere and the land surface, is the ultimate goal of the Programme.

The WCRP co-operates in many scientific activities, particularly the International Geosphere-Biosphere Programme (IGBP) initiated by ICSU in 1986 to study the changes in the earth's geo-biochemical cycles and global ecosystems. WCRP remains the focus of the investigations of dynamical and physical aspects of the earth system, while IGBP is the focus of the studies of bio-geochemical and biological aspects. Together, these two programmes constitute the international framework in the quest for scientific understanding of global change.

The WCRP has instituted three major projects to investigate the climate change mechanism. These are: the study of the Tropical Ocean and Global Atmosphere (TOGA) interactions; the Global Energy and Water Cycle Experiment (GEWEX) and the World Ocean Circulation Experiment (WOCE).

The ten-year TOGA programme, started in 1985, aims to predict seasonal and interannual variability linked to dynamic and thermodynamic interactions between the atmosphere and the tropical oceans. The most far-reaching development was the progress made in launching the GEWEX programme, to observe and model the global hydrological cycle and energy fluxes in the atmosphere and the earth's surface, and to improve our knowledge of the thermodynamics of the "fast climate system" which controls the overall sensitivity of the earth's climate to changes in greenhouse gases or similar forcings.

Field operations began in 1990 to implement the WOCE, a worldwide oceanographic programme to determine oceanic circulation at all depths and over the global domain within the seven-year period, 1990–1997. The data collected are essential for developing global ocean models as required for time-dependent prediction of climate change resulting from ongoing changes in the composition of the atmosphere.

Good progress has been also made in the implementation of the Global Precipitation Climatology Project, the International Satellite Cloud Climatology Project, the WCRP/NASA Earth Radiation Budget Experiment, as well as in the development of comprehensive models of the climate system, all of which contribute to the overall goals of WCRP. The improved understanding certainly is called for if we are to fully address the full range of sustainable development objectives.

5. Role of science

The issues relating to environment and development are very much linked to science and technology. The current issues relating to environment and development can be

seen as requiring responses to questions which are within the domain of science and technology. For instance, the increased consciousness on the subject of global environmental changes has been brought about through the painstaking efforts of many men and women of science, including those in India.

Humanity has now reached the stage, both in terms of the magnitude of the earth's population and the sheer weight of its activities, where it makes its impact felt on the planetary scale. Demonstrating the existence of such global environmental impacts, such as depletion of the ozone layer or increase in the global greenhouse effect of the atmosphere, and showing their connections to specific human activities, is a major achievement of environmental sciences in the last decades. Due to the work of the world's meteorologists, hydrologists, oceanographers, and ecologists, a new awareness has been created of the role of man and the influence of human actions on a finite planet; one whose limited resources is being subjected to escalating demands from an increasing population. New scientific insight, on a broader scale than ever before, has given humanity a new perception of the limits of the resources of our planet, a recognition of the interdependence of all men on the planet and the need to achieve a sustainable balance between man's needs and nature's resources.

Through a better understanding of the Earth system, there is an improved estimate of the carrying capacity of the planet and its resilience under the many stresses placed upon it by human activities. While much more still needs to be done, nonetheless science has provided some understanding through the use of improved networks of ground observations and through the application of modern effective and efficient tools such as remote sensing instruments, modelling capabilities and high-speed computers. Science has helped to show the link of the basic significance of this Earth system as a life support with appropriate strategies for development that ensures the Earth's sustainability or continued functioning.

Indeed, global change is upon us. The momentum of human economic development and population pressure on natural resources is such that we must expect significant alterations of the hitherto relatively stable global environment. Science and technology can provide effective warning of a number of future events, consisting of information on the magnitude of expected variations, the timing of these variations, and the geographical patterns of change. In a nutshell: how much, when and where?

Scientific knowledge could and should be applied to support the goals of sustainable development through scientific assessment of current conditions and future possibilities. Science should be seen as an essential component in the search for viable sustainable development pathways. For instance, science is playing an increasing role in improving the efficiency of utilization of renewable and non-renewable resources. Hence, developing countries need not follow the high energy consumption path previously taken by industrialized countries, as they seek an improvement in their socio-economic standing.

In the context of the present discussion, it can therefore be said that a primary role of science is to enable better formulation and selection of environment and development policies in the decision-making process.

6. Science and society

The increasing concern relating to environment and development provides an opportunity to recall the mutual and synergistic relationship between science and society. On the one hand, science (and technology) contributes to the development

of society. In turn, society must nurture the development of science if it is to contribute to society's advancement.

J. D. Bernal, a famous crystallographer, wrote extensively on the relationship between science and society. In his treatise on "The Social Foundations of Science", Bernal perceived "science as an integral part of both the material and economic life of our time and of the ideas which guide and inspire it." He also spoke of science in terms of "its application both to the satisfaction of human needs and to the processes of productive industry through which in modern society those needs can be satisfied." Furthermore, he considered science to be "the chief agent of economic and social change, and latterly, as a sure, concise and direct motive of social change itself." The analysis of the social transformation which had taken place in history led him to the view that we are witnessing, in the twentieth century, a renewed "scientific transformation of society." This can be seen through achievements such as in the fields of energy, industry, communication, medical science and agriculture, which are just part of what we now understand as representing some of the most essential changes of our time. Indeed, the particular example of the development of and ever-expanding use of computers and satellites demonstrate clearly the pervasiveness of science and technology's contribution to human activities. A number of those human activities are closely linked to the issues of environment and development.

7. Support for science

Given the symbiotic relationship between science and society, there is a need for society, in turn, to provide the necessary support to enable science to play its role with respect to the challenges of environmental and developmental issues. In this connection, UNCED considered four areas which should be addressed. These are:

- Strengthening the scientific basis for sustainable development;
- Enhancing scientific understanding;
- Improving long-term scientific assessment; and
- Building up scientific capacity.

The four areas were identified following the International Conference on an Agenda of Science for Environment and Development into the 21st Century (ASCEND 21), which was held in Vienna in November 1991 and organized by the International Council of Scientific Unions (ICSU) in co-operation with the Third World Academy of Sciences (TWAS).

Allow me to expand a bit on each of these four areas. Strengthening the scientific basis for sustainable development will imply, among others, the need to strengthen the capabilities for monitoring the biosphere to enable the countries, especially developing ones, to have mastery of their environment. The Global Climate Observing System (GCOS) together with the Global Atmospheric Watch (GAW) will contribute in this respect. The national Meteorological and Hydrological Services would also need to be better strengthened. As agriculture is the primary economic activity of many countries and since much of the agricultural production is rainfed, the role of these Services is crucial for taking advantage of climate as a resource. Furthermore, there will be a need to develop the capacity for installation, calibration and maintenance of necessary equipment as well as gathering, processing and exchange

of the acquired data. Such data will serve multisectorial purposes including agriculture, water resources, land use, forestry, conservation, and management of ecosystem.

The second area, enhancing scientific understanding, will imply the need to make full use of data and information by undertaking appropriate researches, especially those directed towards applications for improved and sustained productivity. Numerous research areas could be identified, but each country, depending on its policies and needs, resources and development plan, should be able to identify a set of priority research areas that it could address. In the agricultural sector, for instance, there will be a need to strengthen the link between research and the small farmer. In that sector, it is estimated that widespread application of scientific results and known technologies could expand productivity by over 50 per cent.

Additionally, collaborative effort among various institutions within each country should be encouraged. This should also be the case among countries within the region as well as with those elsewhere. The concept of associated agricultural research centres being supported by the World Bank is a case in view [Consultative Group on International Agricultural Research (CGIAR)].

Moreover, impacts of research will be felt even more if the use of modern technology is also taken into consideration. For purposes of illustration, the significance of the use of satellites and computers will suffice.

With respect to the third area, on improving long-term scientific assessment, it is clear that the knowledge acquired through data gathering, analysis and research must be used to provide scientific assessments. Such scientific assessments and projections are required at the global, regional and local levels. The scientific assessments pertinent to the global warming issue which are provided by the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) are examples of how scientific assessments can provide a basis for policy formulation and decision-making. It is recognized that much more still needs to be done, particularly to reduce the uncertainties in the timing, magnitude and regional patterns of climate change. It is important that assessments should be able to provide a basis for mapping out manageable development pathways within the environmental and socio-economic carrying capacity of each region.

On the fourth area, on building scientific capacity, it is clear that this is especially important for developing countries. Activities in support of this area should provide for education, training and facilities for local research and development, as well as improving access to relevant information for scientists and decision-makers.

The scientific activities required can only be successfully pursued if the required human resources, suitably trained and well motivated, are available. Any development programme should ensure that manpower development is an identified priority. High priority must therefore be placed on investments in people as both the means to and an end of long-term sustainable development. The quality of scientific and technical staff development programmes needs to be improved and the resources input for these should be increased.

8. Concluding remarks

It is clear that the environmental and developmental issues before us are complex and interconnected. These interlinkages between the various issues have to be seriously

considered. A major task then is to understand the complex interacting processes. Such understanding will serve as a basis in the better formulation and selection of appropriate policies, decisions and actions.

In view of the interdisciplinary nature of the challenges relating to environment and development, it will be necessary to have an integrated, interdisciplinary and systems approach to these challenges. Individual branches of science cannot treat the problems in isolation from other branches, as was done classically. For instance, atmospheric concerns cannot be dealt with only in terms of physics, chemistry and mathematics but will also need to consider biological processes, among others. Moreover, the atmosphere has to be studied also in the light of its interaction with the hydrosphere, cryosphere, biosphere, and geosphere.

Hence, I believe that there should be an increasing emphasis on interdisciplinary undertakings at national, regional and international levels.

I am aware that global investigations are not without difficulties. They require the development and use of sophisticated observing systems and techniques (for example, satellites) as well as information management and system simulation capabilities using powerful computers. These are in addition to worldwide implementation of more conventional operational observing networks. As industrialized countries have, more readily, the resources and technical capabilities to undertake the monitoring of the planetary environment, they should take the lead and provide support so that the necessary information and benefit can be provided to all.

At the same time, it is important to increasingly enhance the capability of developing countries so that they can more fully participate in, and benefit from the relevant scientific and technical programmes. I therefore wish to stress the importance of evolving a network of regional specialized centres in the developing world. Countries with similar interests and requirements can come together to jointly address these areas of concern. Such centres can serve to trigger the growth of expertise that is essential to our efforts to meet the challenges of environmental and developmental issues. Certainly, the provision of financial and other resources will be needed to realize these centres.

In addition, it is also important that the broad masses of people are aware and informed of these challenges we now face together. It is necessary to ensure that there is widespread dissemination of the relevant scientific information. Scientists must not limit themselves to their journals but must work with non-scientists such as those in the media, to promote the dissemination of information, analyses and assessments at the grassroot level. Non-governmental organizations (NGOs) have increasingly been active in this respect. Special groups, such as women and children, should be particularly targeted.

I believe that these are part of what should be included in the considerations of appropriate science policies and programmes. For my part, and on behalf of the World Meteorological Organization, I can only reaffirm our commitment to ensure that the scientific disciplines, in which the WMO is engaged, continue to be in the service of humankind as it faces the challenge of climate and global change.

Indeed many challenges lie ahead. But with great resolve and armed with the tools that science and technology can provide, we can turn these challenges into opportunities for advancement toward a better quality of life for all of us on Earth. In this context, I feel certain that the Indian Academy of Sciences will be found among those who contribute substantially to the relevant efforts.