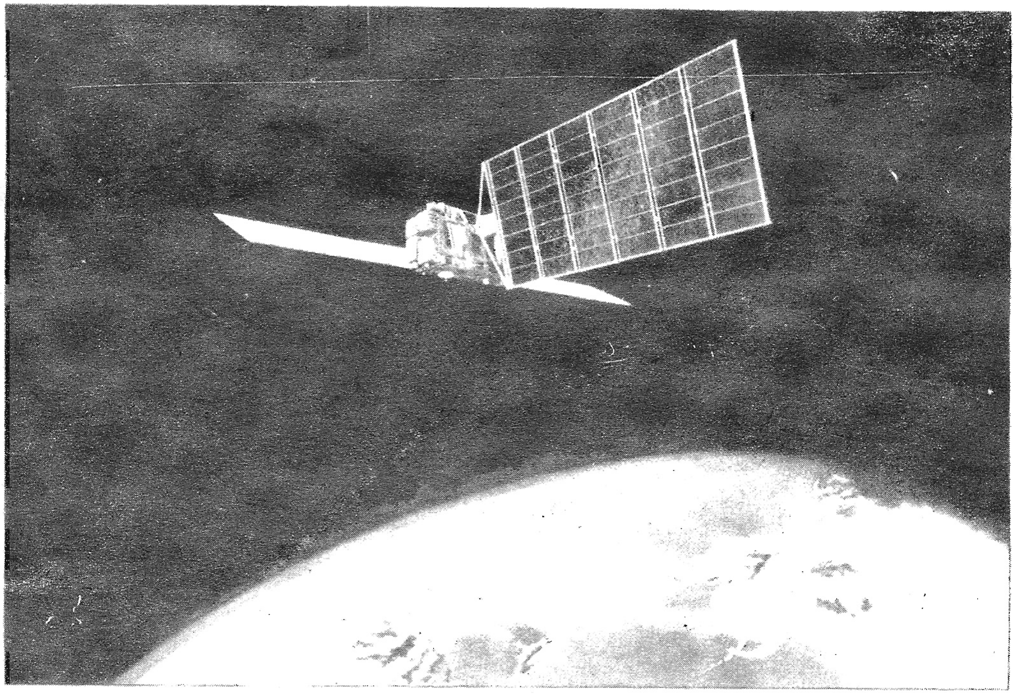

# METEOROLOGY AND HYDROLOGY FOR SUSTAINABLE DEVELOPMENT

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"OUR COMMON FUTURE", the report of the World Commission on Environment and Development, which was described as the most important document of the decade on the future of our planet, set in motion in virtually every country, a series of initiatives whose ultimate goal is the achievement of **sustainable development** - development that meets the need of the present without compromising the ability of future generations to meet their own needs.

This concept of sustainable development does imply limits - not absolute limits, but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the human activities. There have been many definitions of sustainable development before and after the release of Our Common Future in 1987. But all such definitions imply the need for forms of development that are sustainable in three senses. First, development must not damage or destroy the basic life support systems of planet Earth; the air, the water and the soil and biological systems. Nor should development serious degrade natural resources, such as water, soil and the vegetation on which human economic and social activities depend. The second aspect of the sustainability of development is economic, to provide for a continuous flow of goods and services derived from the Earth's natural resources. Much more careful and efficient use of these resources, our water, our soil, our forests is required than in past decades. The third implication of most definitions of sustainable development is the need for sustainable social systems, at international, national local and family levels, to ensure the equitable distribution of the benefits of the goods and services produced, and of sustained life support systems.

The last two aspects of sustainability, the need for economic and social systems, are human-centred, whereas the first aspect concerns all forms of life on the planet. It is for this first aspect of sustainable development, the sustaining of natural systems and resource, at weather, climate and hydrological services have a vital role to play. For many years these services have been routinely observing, recording, analyzing and forecasting weather and climate events and their repercussions. They have contributed to our understanding of the behaviour of the atmosphere, including the vagaries of its gaseous constituents, as well as of the movement and storage of the water on and below the land surface. It is this knowledge and the ability to acquire and update it which have assigned a primary responsibility to the sciences of meteorology and hydrology in the quest for sustainable development.

The atmosphere of our planet is an essential environment and resource. It has developed in harmony with the biosphere of Earth, and is essential for life of all creatures. It produces the climates which determine the natural endowments of regions and the way we live. For development to be truly sustainable, the character of the atmosphere must not be significantly degraded or altered.

**One of the earliest signs of adverse large-scale impacts of humans on the atmosphere was acid rain. A particular problem for North America and Europe, it is the result of the discharge of gaseous sulphur and nitrogen oxides into the atmosphere from the burning of coal and oil, during the operation of electricity generating and smelting industries and from transportation. In the atmosphere, these gases combine with water vapour to form acids. Falling as rain or snow these lead to acidification and degradation of sensitive lake and river systems and damage to forests and to metal and limestone structures.**

Until the latter half of this century it was generally considered that the envelope of air around us was so vast, and the energy involved in the restless weather systems so enormous, that human activities would have but temporary and local impacts. But measurements and documentation of global contamination of the atmosphere which disprove this idea are now only too well known. Such documentation includes the increasing acidity of the rain over extensive regions, the startling reductions in the stratospheric ozone over Antarctica during the southern hemisphere spring, the rapid rate of increase of the greenhouse gases throughout the global atmosphere giving rise to projections of global climate warming, and the inter continental transport by sea and air ofoxic chemicals from the Arctic to the Antactic in detectable, even dangerous amounts, and far away from industrial and agricultural sources.

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**If human uses of water are to be on a renewable, sustainable, basis they should be at a rate that does not exceed the minimum flows of the accessible rivers and in the case of ground water, the rate at which it is recharged through precipitation. In many locations these sustainable rates are being exceeded. In addition, pollution of water bodies by human activities is effectively reducing even more the available safe supply, especially for domestic use. It is estimated that human water use has grown 35 times in the past three centuries, and is now growing at between 4 to 8% per year due to rapid increases in both per capita use and the total population. It is clear that such rated of growth would not be sustainable for long in many parts of the world.**

Perhaps the most serious threat to sustainable use of the Earth's renewable natural resources lies in the rapidly increasing contamination of the atmosphere by the greenhouse gases, and the changes in the climate expected as a result. It is a pervasive issue which provides the most obvious reasons as to why more sustainable development practices must be adopted.

The energy that drives and shapes the constantly changing atmosphere-ocean-biological system, comes from the Sun. About on-half of the incoming solar energy is absorbed and reflected by the atmosphere with its clouds and dust, and other half absorbed and reflected by the surface of the Earth. The incoming energy is balanced by the outgoing radiation at longer, infra-red wavelengths from the Earth and the atmosphere. A number of gases occurring naturally in the atmosphere, especially water vapour, carbon dioxide and methane radiate much of this long wave radiation energy back to Earth, warming the air masses near the Earth's surface.

Without this natural "greenhouse effect" the global climate would be some $33^0C$ colder, an uninhabitable environment for most present life forms. However since the beginning of the Industrial Revolution, human economic activities have emitted pollutants to the atmosphere that have increased the natural greenhouse effect, mostly by adding to the existing concentration of carbon dioxide, methane, nitrous oxide and low level ozone, but also by the introduction of the wholly artificial greenhouse gases, especially chlorofluorocarbon ($CFC_5$).

Scientists are not yet able to predict with confidence what changes will take place in regional and local climates or what the impacts of those changes on society and the environment will be. However, In spite of the present uncertainties a number of impacts of a warmer Earth can be reasonably predicted. First, sea level is projected to rise from 30 cm to 100 cm by the end of the next century. Heavily populated low-lying coastal zones would be inundated or seriously affected by increasingly damaging storm surges, by salt water intrusion into coastal aquifers, and changes in shorelines. A sea level rise of the order of one metre would threaten the very existence of some of the smaller islands.

A second major impact of the global warming is that Arctic and sub-Arctic areas would be 6-12$^0$C warmer in winter than at present, which would mean that the surface layers of permafrost would melt, the stability of buildings, roads and other structures in those areas would be threatened, and Arctic sea ice would be reduced. In the snow melt season, greater floods due to both a more rapid melt and greater accumulation of snow would occur.

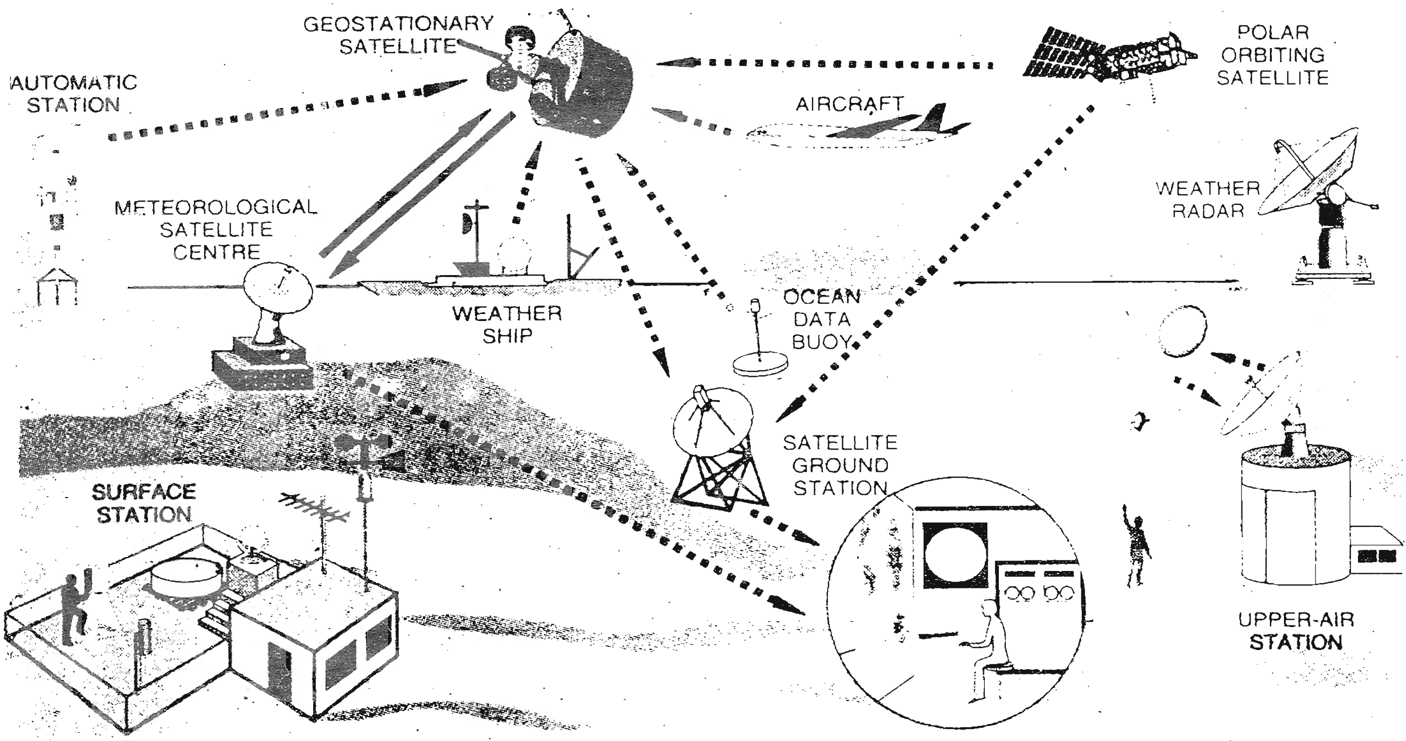
Changes in agricultural production are less predictable because of uncertainties as to the distribution of rainfall. However, most models suggest a drying of the southern portions of the great grain-growing areas of North America and Eurasia that would seriously reduce world cereal production and change the balance of agricultural exports and imports for a number of countries. There would, as well, where adequate water is available. be direct stimulation of plant growth rates because of the increased concentrations of carbon dioxide in the atmosphere.

Another impact, not often emphasized is the possibility of the spread of tropical diseases. In many cases the agents that transmit the diseases, mosquitoes, anails, bacteria, are markedly limited in their range by the water and air temperatures-they cannot thrive at temperatures lower than certain thresholds-often about 26$^0$C. With gradual warming the areas would expand in which favourable conditions for these agents persist, resulting in a spread poleward of these tropical diseases.

The world's surface water resources are already under great stress. Only two percent of the 1.41 billion cubic kilometres of water of Earth is fresh water of which eighty-seven per cent is estimated to lie in ice caps and glaciers and the rest in deep ground water. Only about 2,000 Km$^3$ is at any instant readily available in lakes, rivers and shallow ground water for numerous human uses.

If human uses of water are to be on a renewable, sustainable, basis they should be at a rate that does not exceed the minimum flows of the accessible rivers and in the case of ground water, the rate at which it is recharged through precipitation. In many locations these sustainable rates are being exceeded. In addition, pollution of water bodies by human activities is effectively reducing even more the available safe supply, especially for domestic use. It is estimated that human water use has grown 35 times in the past three centuries, and is now growing at between 4 to 8% per year due to rapid increases in both per capita use and the total population. It is clear that such rated of growth would not be sustainable for long in many parts of the world.

In no other economic activity are the dilemmas of sustainable development so clearly evident as in the production and distribution of energy. Energy use has increased eighty fold since the middle of the 19th century, with profound effects on carbon, sulphur and nitrogen flows on the planet. The wealthy industrial economies of the world have developed on the basis of abundant cheap energy mainly through the burning of fossil fuels, i.e coal, oil and natural gas. These are non-renewable resources, dug from the earth. It is estimated that each year's current consumption of fossil fuels represents a million years of accumulated fossil deposits. Known oil reserves will be exhausted over the next century with, at current consumption rates, the most readily accessible and cheapest reserves being depleted in 30 to 40 years. Natural gas reserves and coal will last longer but will be consumed over the next centuries at present rates of use. In short, burning of fossil fuels is inherently a non-sustainable activity-fossil fuel resources are being exhausted, and their burning is rapidly changing the composition of the atmosphere. On the other hand, renewable energy sources, solar, wind, wave, tidal power and biomass energy represent a small proportion of the current global energy mix. Hydro-Electricity is the only renewable energy source with a significant share (6.6%) of global commercial power production. Nuclear power occupies an im-




portant niche in some developed countries, but represents only five per cent of the commercial energy production.

The knowledge so far acquired on environmental issues is based largely on the data collected through meteorology, hydrological oceanographic services. Through the assessment and evaluation of these data, information can be derived on changes in atmospheric composition radiation budget, water balance and concentrations of dissolved and suspended materials ; future scenarios can also be predicted. These can then be considered by governments so that environmental management policies may be adjusted to changing situations. In this manner meteorology and hydrology can be used to test whether or not existing development is sustainable and what future development may be most propitious in the context of sustainability. Well-established meteorological, climatological, and hydrological services provide the essential assurance that the environment is managed to the advantage of all.

Recent development in environmental and resource issues related to the global atmosphere and to fresh water, have clearly demonstrated the urgent need for better measurements and understanding of these components of our Earthly inheritance. To preserve this inheritance for future generations and to use it for the benefit of all people, will require an unprecedented level of understanding of the atmosphere and of water systems, and wise use of that understanding in public policies.