

# WAITING FOR THE DELUGE!

Legends have it that many floods ravaged the Earth in the past. Some recent evidences show the levels of the world's seas to be gradually rising. P.K. DINESH KUMAR discusses the causes and effects of such a rise in sea level on the Earth

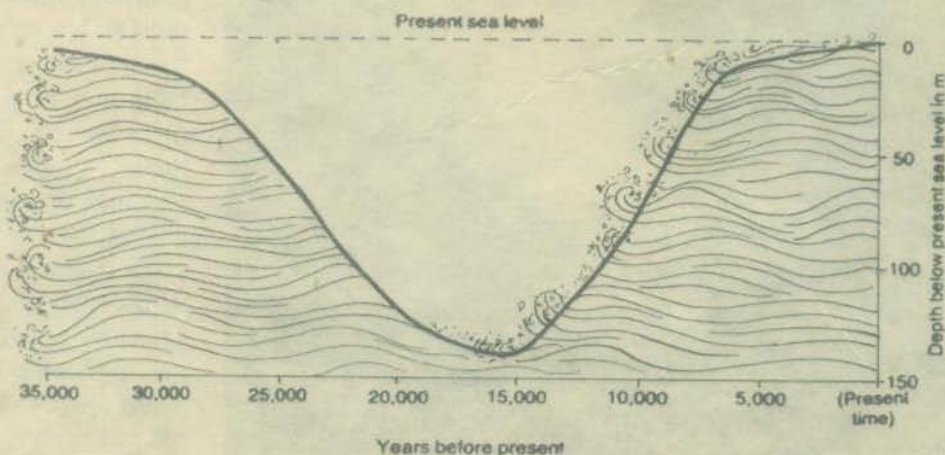
**M**ANY legends from the past tell of a great flood that swept the land. According to Hindu mythology, great havoc was wrought by a deluge that inundated the coasts and carried thousands to their deaths. The Greeks believed this great flood to be the work of Zeus, chief of the Olympian gods. A similar account is found in the Book of Genesis and many others are known from divergent sources. Most of these accounts are similar in many

aspects although they are told by people of varying cultures, from different parts of the world.

Science, however, tends to support

the flood legends rather than deny them. Both catastrophic and gradual inundations of the land by the sea are now known to have been common in the past

history of earth and it is therefore not unlikely that they have occurred in historic time to be recorded in tales by human cultures. The catastrophic variety, although devastating, rarely floods more than the very local margins of a land mass, whereas others may be of very large extent. Evidence suggests that sea level rose significantly about 6000 years ago, and



The record of past changes in the level of the world's seas



although some of the folklore tell of the subsidence of a great flood, the flood that science discovered did not subside. Infact it raised the sea level such that much of what was once dry land now lies submerged off the coasts of the islands and continents of the world.

Submergence of continental and subcontinental regions can be brought about by actual changes in the level of the sea. Sea level does change with time because of climatological factors, oceanographical factors, and due to the long period of astronomical tides. An example is found in the quaternary period.

The past 2 million years called the Quaternary period, was an interval of considerable climatic variation. Studies of glacial deposits, soil types, and sediments from the ocean have shown that there were several intervals of glaciation during the Quaternary. This period was also marked by glacial advances, with extensive areas covered by ice, snow and glaciers, followed by interglacial intervals similar to present-day conditions. During the most recent glaciation, which reached its peak about 15,000 years ago, glaciers extended to many large parts of the present continental shelves. The reasons for such major changes in climatic conditions have been the source of considerable speculation; indeed, some feel we may be entering a new glacial period because of the increasing carbon dioxide ( $\text{CO}_2$ ) content in the atmosphere.

**W**HATEVER the cause of an ice age, one of its principal effects is a change in sea level. The Quaternary glaciation was very significant for many features of the ocean. They lowered sea level by as much as 100m or more, and changed the temperature of the surface waters by several degrees.

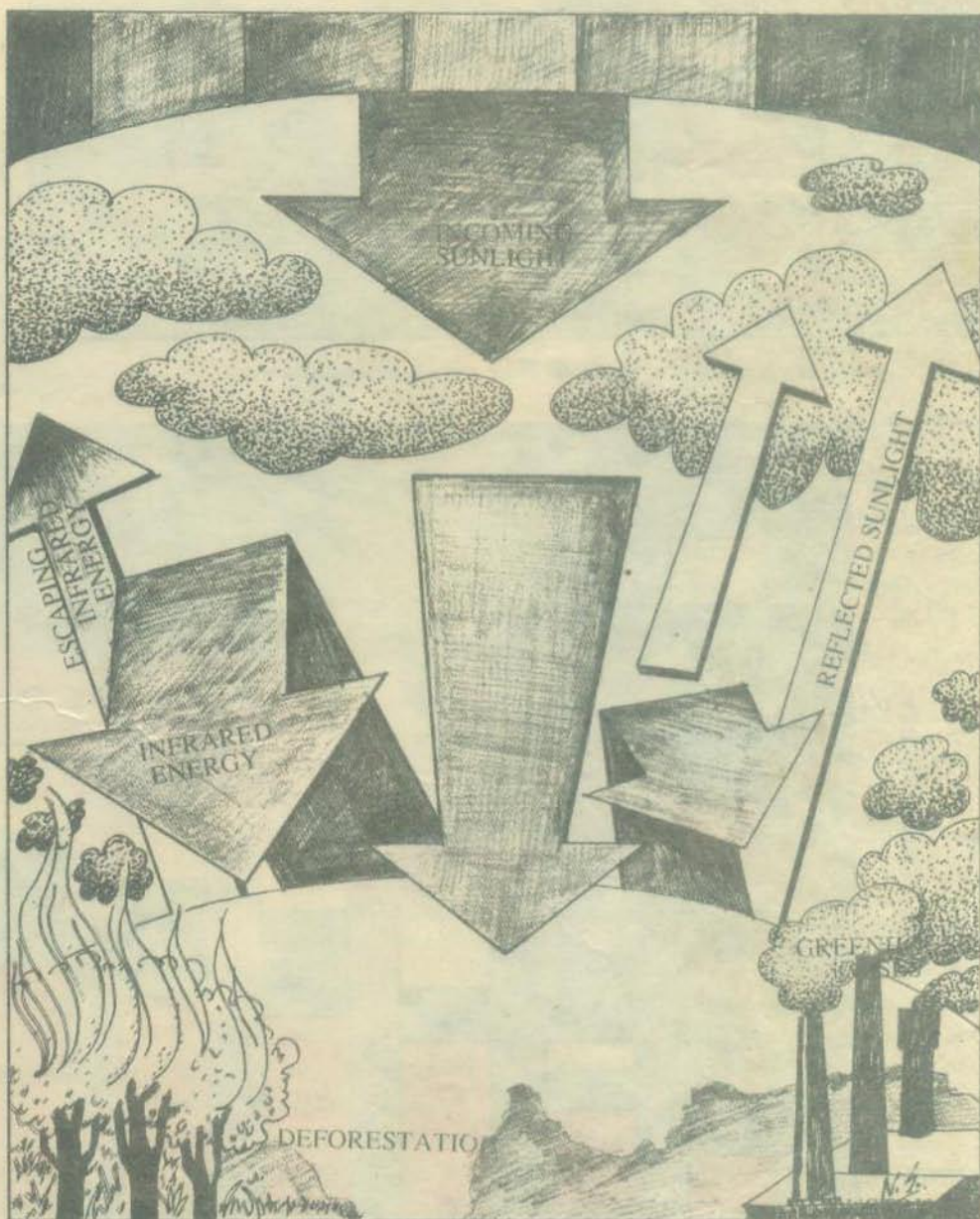
The amount by which the sea level was lowered during the most recent Wisconsin glaciation has been studied by obtaining carbon-14 dates of deposits that formed at or near sea level. The

deposits include peat and shells of animals that live in shallow water. Many of the deposits are now found underwater. By dating this material and noting the depth at which it was found, it is possible to reconstruct a curve of recent sea-land changes. The data show that about 15,000 years before present (B.P.), sea level was more than 100m lower than today. Geologically this means that the now-submerged continental shelf was exposed to the eroding forces of waves and currents as sea level rose

during the 15,000- year interval to its present position. Before the rise in sea level, rivers could cross the shelf and deposit much of their sediment directly into the deeper parts of the ocean. After 15,000 B.P. sea level rose relatively rapidly until about 7,000 B.P., when it reached a level of roughly 10m below present sea level. Since 7,000 B.P. sea level has risen slowly and irregularly.

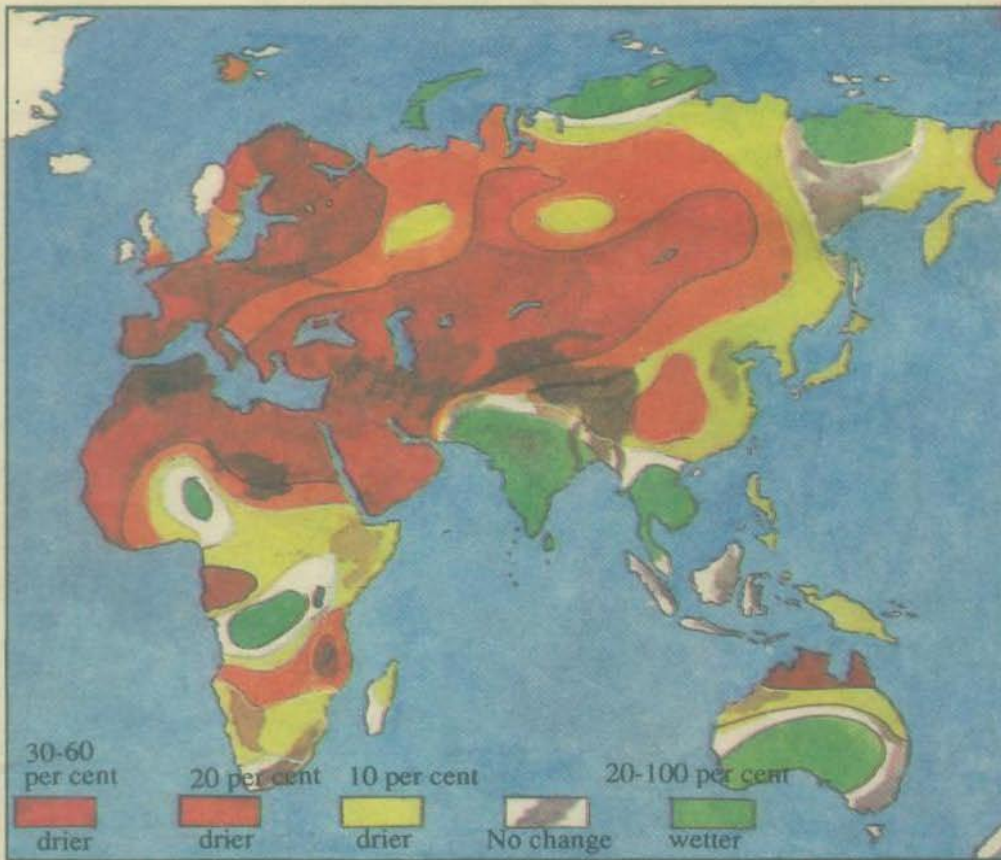
During the times of lowered sea level the continents of Asia and North

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Greenhouse effect—the  $\text{CO}_2$  and other gases produced by industry, deforestation and farming trap more infrared energy warming up the Earth's surface

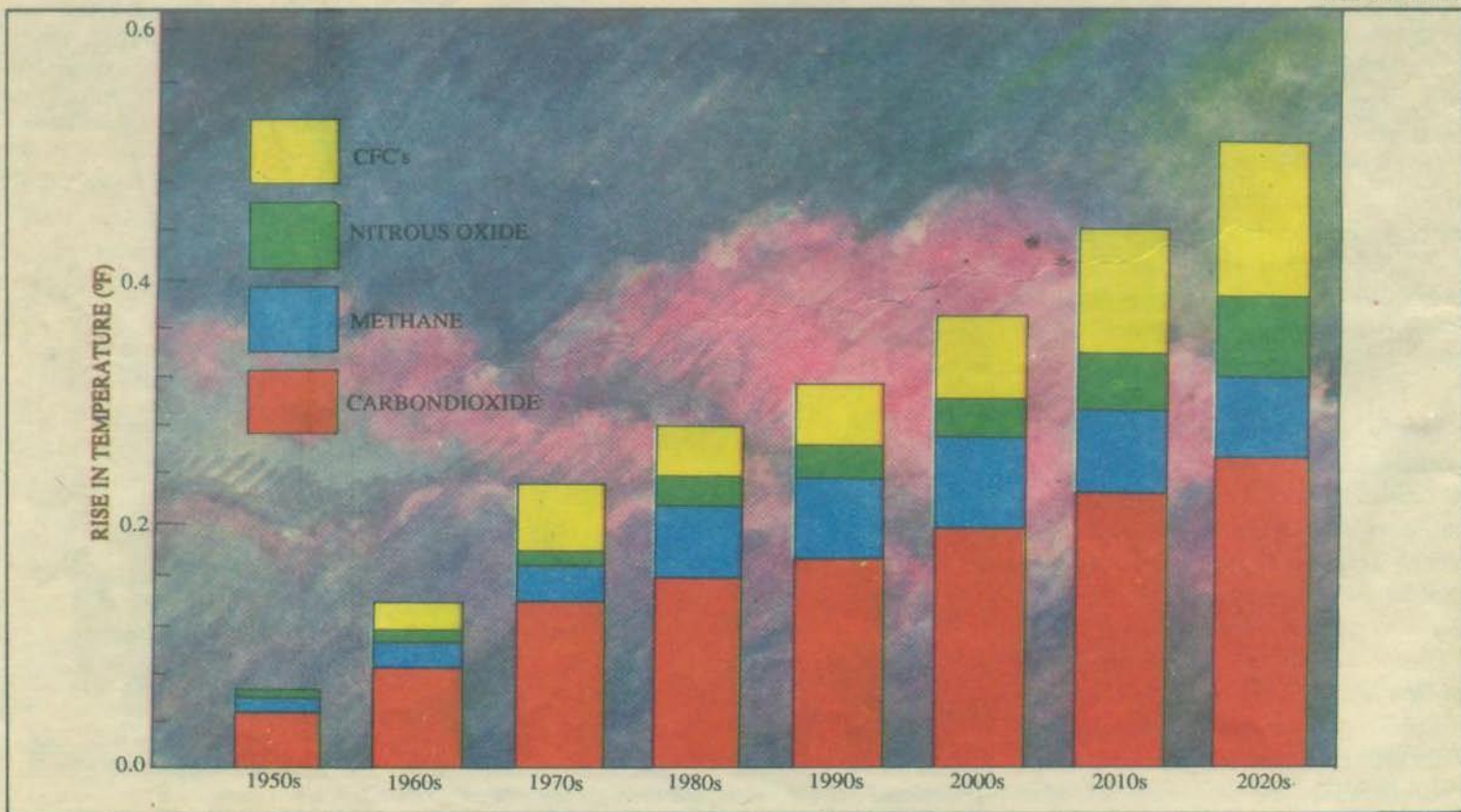




The CO<sub>2</sub> doubling can turn parts of the globe drier and some parts of it wetter

America were connected by a 'land bridge'. This bridge is now covered by a shallow Bering and Chukchi Seas. But when the sea level was low in the Pleistocene, early people and animals could have migrated from Asia to North America and South America. Glaciation also modified conditions in the ocean, e.g, the freezing of large quantities of water in surface layers of the ocean. Deep-sea geochemical and micropaleontological (the study of the microscopic fossils) work had detected some of these changes. The amount of various isotopes in the water and in living organisms or in those that once lived in the water is a function of the water's temperature; therefore a study of these isotopes can reveal past oceanographic conditions. Some planktonic animals, such as Foraminifera, also undergo changes in their shell characteristics, apparently in response to temperature changes. When the shells of these organisms, obtained in deep-sea cores,

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The biggest problem-gas is carbon dioxide. But CFCs, methane and nitrous oxide will also cause as much warming by the next decade



are studied it is often possible to identify temperature adoptions.

These well-documented changes show that, geologically, oceanographic conditions of today are not completely representative of those of the past. The glacial influences on the chemical, biological and physical properties of the sea are generally more subtle than the dramatic geologic changes.

**I**t is questionable whether we are completely out of the interglacial period. Tide-gauge records from different parts of the world indicate that sea level is still rising slowly; however, the reasons for the rise are not clear. It could be due to faulting and sea-floor spreading movements, climatic changes that have melted additional glacial ice or warmed the ocean, or other reasons. If all the remaining ice on the earth were to melt, sea level would rise by an additional 60m. The effects of such a rise could be catastrophic, since a large portion of the world's population lives at or near sea level. Alternatively, we could enter into another period of glaciation,

which would result in a general decrease in temperature and a drop in sea level. These prospects are receiving serious consideration due to the awareness of the increasing content of carbon dioxide and other 'greenhouse gases'.

The earth and its atmosphere absorb solar radiation and emit their own ra-

diation to the surrounding space. Averaged over a long period of time, the rates of absorption and emission are more or less the same. In other words, the system consisting of the earth and the atmosphere is in approximate radiative equilibrium with the sun. A num-

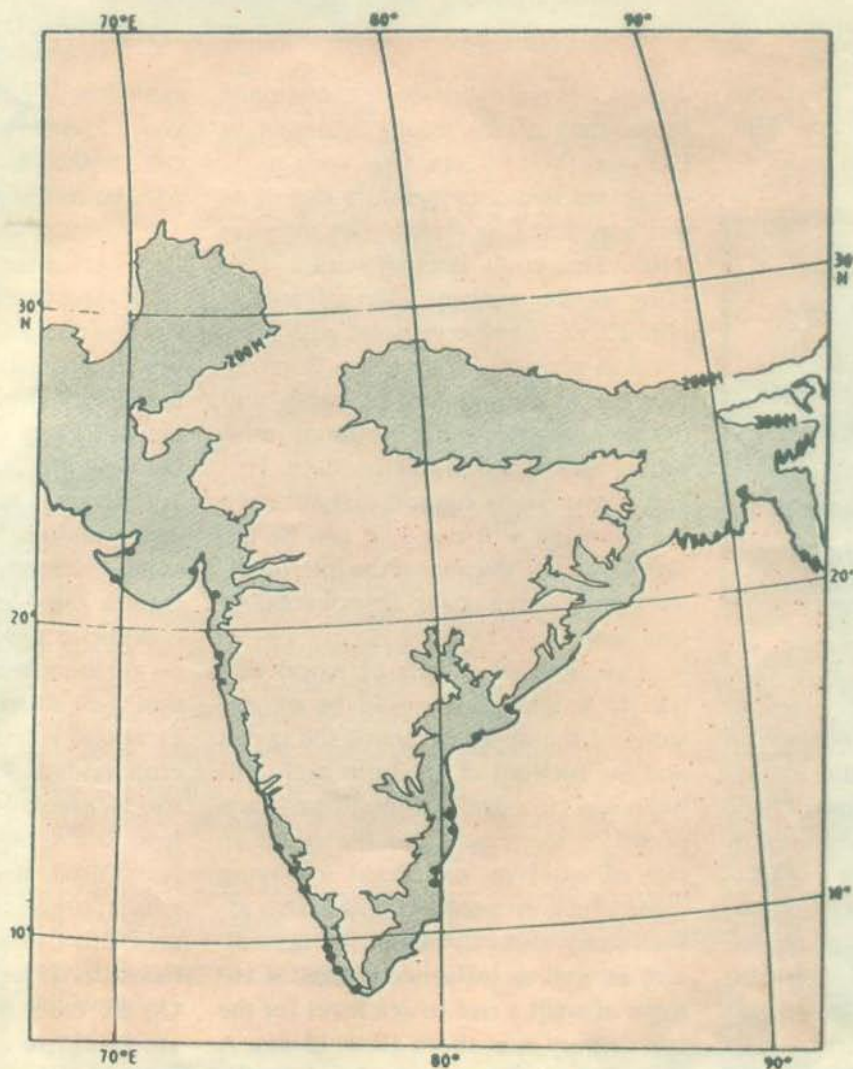
The present atmosphere is roughly 76% nitrogen and 23% oxygen by mass. Other gases in the atmosphere include argon, water vapour, carbon dioxide, etc.

The amount of carbon dioxide ( $\text{CO}_2$ ) in the atmosphere is important since it is opaque like water vapour, to infrared radiation emitted from the earth, but essentially transparent to visible incoming solar radiation. This leads to a 'greenhouse effect' causing higher temperatures on the earth's surface. The more  $\text{CO}_2$  in the atmosphere the more heat is absorbed. It is a well-accepted fact that the concentration of carbon dioxide has increased in the atmosphere over the last three decades; many scientists feel this may be causing a rise in global temperature. The increase in carbon dioxide concentration in the atmosphere is not surprising when one realizes that about 18 billion tonnes of carbon dioxide are added to the atmosphere each year from the burning of fossil fuel.

There are other reasons as well for the rise in carbon dioxide level such as the reduction of land biomass by urbani-

zation and burning of firewood; the exact contribution of each is a subject of controversy, but many experts feel they are generally small compared with burning of fossil fuels.

The effects of the increase of carbon dioxide in the atmosphere may be one of the more important environmental



The present Indian coastline and the future one if the sea-level rises

der of processes active within the atmosphere-earth system play a role in maintaining this equilibrium and consequentially in determining the thermal structure of the atmosphere, one of the important processes amongst these is absorption and emission of radiation by molecules making up the atmosphere.



problems facing this planet. It should be appreciated that other than stopping the burning of fossil fuels, little can be done to reduce any potential effects.

The problem is further complicated by having to distinguish which changes are due to increasing carbon dioxide content and which are due to other, sometimes unknown, factors.

**C**ARBON DIOXIDE, however, is not the only greenhouse gas present in the atmosphere. There are others contributing substantially. This includes chlorofluorocarbons (CFCs),

**If all the ice on the Earth were to melt, the sea level would rise by 60m, the effect of which could be catastrophic since large portion of the world's population lives near the sea**

nitrous oxide and methane. It is estimated that CFCs, which are used to make plastic foam and as coolant in refrigerators and air conditioners account for about 15% of the greenhouse effect. Nitrous oxide is released in automobile exhausts and power-plant smokestacks. Methane is a primary component of natural gas which is generated in underground oil deposits. It is also generated by bacteria living in the guts of cattle, and by degradation of litter from mangroves and coastal wetlands. On the whole, production of greenhouse gases today comes from so many sources, that it is unrealistic to expect to stop the rise in their concentration in the atmosphere. One can only hope that it will be slowed down.

How will the concentration of greenhouse gases and the atmospheric temperature change the future? There are considerable uncertainties in the pre-

**Table 1. Estimated Sea Level Rise, 2000-2100 AD (in cm)**

Year	Conservative	Mid-Range Moderate	High Scenario	Historical Extrapolation
2000	4.8	8.8	17.1	2-3
2025	13.0	26.2	54.9	4.5-8.25
2050	23.8	52.3	116.7	7-12
2075	38.0	91.2	212.7	9.5-15.5
2100	56.2	144.4	345.0	12-18

Source : J. Hoffman, D. Keyes and J. Titus, 1983

diction. Several major studies have made projections of the future increases in CO<sub>2</sub> and their effects. One such study suggested that a temperature rise of as much as 5.5° C is possible by the year 2100. This could happen with a doubling of the concentration of atmospheric CO<sub>2</sub> (a rate consistent with present and projected increases). Such an increase in temperature probably will cause geographic shifts in climate, rainfall, evaporation and soil moisture. This and other reports suggest that although the warming will occur, it can be delayed by a few decades if the intermediate waters of the ocean absorb some of this heat.

Two obvious effects of worldwide rise in temperature would be expansions of the upper layers of the ocean and the melting of ice from high altitudes and latitudes. The melting of parts of major ice sheets and the resulting rise of sea level can flood low-lying areas. Such an increase could also affect many areas available for agriculture as well as influence rainfall. Estimate of such a rise in sea level for the last century was about 10 to 15 cm. A rise of about 5 cm in sea level can be linked to thermal expansion because of the global warming. The remaining 5-10 cm rise has been attributed to deglaciation. Because little is known about the rates of deglaciation due to global warming, it has generally been assumed that its contribution to the sea level rise in anything between half of the rise to nothing in comparison to thermal expansion. With such approximations the

estimates of global sea level rise for the year 2050 vary from 23.8 cm to 116.7 cm; for the year 2100, from 56.2 cm to 345.0 cm (Table 1).

**B**UT there are some scientists who feel that the increase in CO<sub>2</sub> and the greenhouse effect will have a completely opposite effect and may even be beneficial. They suggest that the warmer air will carry more moisture and will increase the snowfall in places like Antarctica. The ice sheet will then increase and sea level may even fall. Still some scientists feel that the increased carbon dioxide, mixed with other atmospheric gases, would have little or no greenhouse effect. They further note that agriculture experiments under the increased levels of CO<sub>2</sub> show increased crop production and a decrease in water loss by the plants. This effectively could lead to a doubling in yield per litre of water used. If such information is correct it suggests that the predicted increase in CO<sub>2</sub> in the atmosphere might have less of an impact than anticipated. On the other hand if the prediction of sea-level rise and global cooling is the more likely result, the future will not be so promising.

Anyway, there is evidence to believe that concentration of greenhouse gases in the atmosphere, the global surface temperature and the mean sea level are all rising, and are expected to continue to do so in the near future. Although the evidence seems to favour the more pessimistic viewpoints, the hard fact is that we just do not know



enough.

The total length of the Indian coastline (inclusive of major indentations and shores of islands) is approximately 9000 km. Of these about 55% has beaches, and 25% has prograding shore, including deltas.

The vulnerability of the Indian coastal region to damage from sea level rise due to greenhouse effect has been examined by S.R. Shetye, A.D. Gouveia and M.C. Pathak of the National Institute of Oceanography, Goa. One indicator of the vulnerability of a coastal region to inundation is the topographic slope (increase in altitude for a given distance perpendicular to the coast). The slope is generally the largest in the central west coast. The west coast slopes are smaller than those on the east coast. From the point of view of shore line retreat, the stretch of west coast of India between approximately 120 and 18 is the safest. The east coast is more vulnerable to inundation, because the frequency of occurrence of cyclones is more on the east coast than the west coast. Some studies suggest that as greenhouse effect sets in, the cyclones will get both more frequent and destructive. Hence, the vulnerability of the east coast to storm surge damage is more than the west coast.

WITH the greenhouse effect, it is expected that changes will occur also in the global precipitation pattern. This in turn will alter the rate or recharge of groundwater aquifers. But, if this rate does not change for the better, then with the increased sea level salt-water will penetrate the freshwater aquifers thus bringing coastal water supply under pressure. At present the coastal drought-prone areas include Kutch and parts of Saurashtra, southern region of Tamil Nadu, central coastal Andhra Pradesh and south western West Bengal. Moreover groundwater availability in Kerala and Goa is low, less than one million hectare metres per year.

The Lakshadweep Archipelago off the southwest coast of India consists of 27 separate coral reefs and islands with a total area of 32 sq. km. Ten of the islands are inhabited. The Lakshadweep islands are low-lying with the highest point on the islands generally not higher than a few metres above the sea level. The Andamans consist of 204 islands and islets. The Nicobar have 12 inhabited and 7 uninhabited islands.

The vulnerability of the low-lying Lakshadweep islands to the sea-level rise can be appreciated from the estimations that a rise of even 1 m in the mean sea level will severely restrict human activity on the island and a rise of 2m will vir-

tually stop it. However the topography of Andamans and Nicobars has steeper slopes, the maximum altitude on the islands often exceeding 100m. Hence the danger from inundation due to sea level rise in this archipelago is lesser in comparison to that in the Lakshadweep.

Earth scientists in 1990 have a recurring nightmare. They visualise the sort of diary people might be writing in 80 years if the greenhouse effect is allowed to take hold. "The 21st century has 30 years to run, but few believe we will survive far into the next. Last year was the hottest ever; a global average of 25°C, eight degrees up since 2000 AD. Scientists say it might all have been different if there was more foresight, but now it hardly matters whether we stop industrial pollution or not, nature has taken over."

So might our planet look in the year 2070, unless an international treaty limiting the emission of greenhouse gases is urgently negotiated and agreed. If current industrial, agricultural, energy and transport policies proceed with the same pace, the possibility exists that the real disaster might look that way, or even worse.

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