CMFRI

Winter School on

Impact of Climate Change on Indian Marine Fisheries

Lecture Notes

Part 1

Compiled and Edited by

E. Vivekanandan and J. Jayasankar

Central Marine Fisheries Research Institute (CMFRI),
(*Indian Council of Agricultural Research*)
P.B. No. 1603, Cochin - 682 018, Kerala

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CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

CLIMATE AND CLIMATE CHANGE

E.Vivekanandan
Central Marine Fisheries Research Institute, Kochi 682018
(evivekanandan@hotmail.com)

Introduction

Weather is the fluctuating state of the atmosphere around us, characterized by temperature, wind, precipitation, clouds etc. Weather has only limited predictability. Beyond a week or two, individual weather system is unpredictable. Climate is the weather of a place averaged over a length of time. Weather and climate have profound influence on life on earth. They are part of the daily experience of human beings and are essential for health, food production and well-being.

Climate is determined by atmospheric circulation and by its interactions with the large-scale ocean currents and the land. To understand the climate of our planet and its variations, and to predict the changes of the climate brought by human activities, one cannot ignore these factors and components that determine the climate. Statistically significant variations of the mean state of the climate, typically persisting for decades or longer, are referred to as "climate change".

Climate changes with time and place

Climate varies in time; from season-to-season, year-to-year, and decade-to-decade. For example, a thousand years ago, northern latitudes were warmer than they are today. The warmer climate enabled early settlements in the southern coast of Greenland. But the colder climate that developed over the following centuries wiped out the settlements. About 18,000 years ago, a sheet of glacial ice up to 3,000 metres thick covered much of what is now Greenland, Canada and the northern United States. A warming trend gradually melted almost all the glaciers, except in Greenland. In Canada and the United States, the last large fields of ice disappeared by about 11,500 years ago. The warming trend ended after a mild period from 7,000 to 5,000 years ago, when the global average temperature was higher than it is today.

Within the past 1,200 years, the period between A.D. 950 and 1250 was mild. The years from A.D. 1400 to 1850 were cool. Since then, global average temperatures generally have risen.

Many natural processes influence a region's climate. Some of these processes, such as volcanic eruptions, are short-lived and cause short-term changes. Other processes, such as mountain building, occur over long periods and cause long-term changes in climate. The earth's climate varies from place-to-place, depending on latitude, distance to the sea, vegetation, presence or absence of mountains or other geographical factors, creating a variety of environments. Thus, in various parts of the earth, we find deserts; tropical rainforests; tundras (frozen, treeless plains); conifer forests (cone-bearing trees and bushes); prairies (grassland with tall grasses) and coverings of glacial ice.

Types of climates

The earth's surface is a patchwork of climate zones. Climatologists have organized similar types of climates into groups. A modified version of a classification system was introduced in 1918 by Wladimir Koppen, a German climatologist. Koppen based his system on a region's vegetation, average monthly and annual temperature, and average monthly and annual precipitation.

The modified version specifies 12 climate groups: (1) tropical wet, (2) tropical wet and dry, (3) semiarid, (4) desert, (5) subtropical dry summer, (6) humid subtropical, (7) humid oceanic, (8) humid continental, (9) subarctic, (10) tundra, (11) icecap, and (12) highland.

Causes of climate change

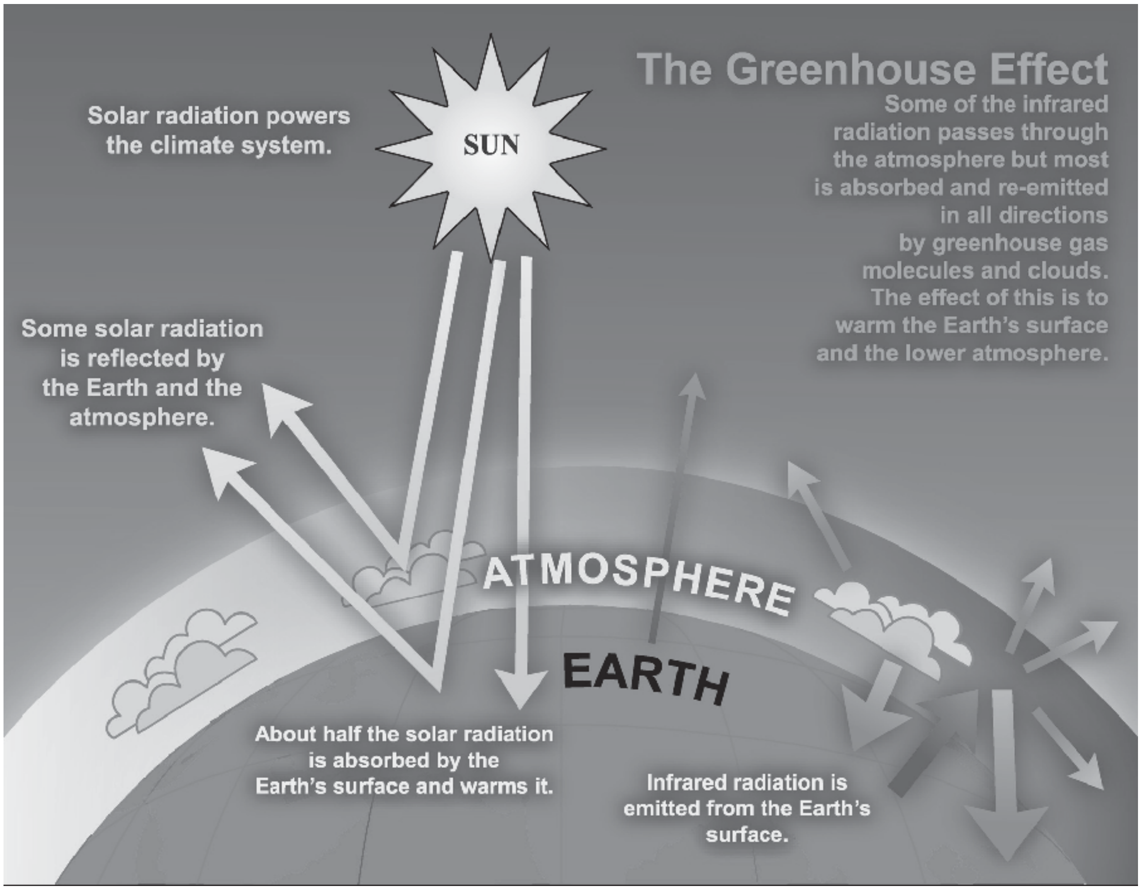
Changes in ocean circulation can alter the climate. For example, changes in ocean currents that occur during El Nino can affect the climate for a year or two. El Nino is a large-scale interaction between the tropical atmosphere and tropical oceans that happens about every two to seven years. Changes in the air pressure over the tropical Pacific Ocean cause the trade winds there to weaken or even reverse direction. This change enables the warm waters of the ocean surface to drift from the western tropical Pacific to the eastern tropical Pacific. This flow makes sea-surface temperatures lower than usual over the western tropical Pacific and higher than usual over the eastern tropical Pacific. The sea-surface temperature changes, in turn, alter the circulation of the atmosphere in tropical and middle latitudes. These alterations cause weather extremes in various parts of the world.

Activity on the sun's surface may affect the earth's climate for short periods. Sunspots are dark, relatively cool blotches that appear on the surface of the sun. Faculae are relatively bright, hot areas on the solar surface. The number of sunspots and faculae changes over a cycle of about 11 years. The average amount of energy given off by the sun is slightly higher during a sunspot maximum, *i.e*., when the number of sunspots is high. The average amount is slightly lower during a sunspot minimum *i.e*., when the number is low.

Human beings, like other living organisms, have always influenced their environment. It is only since the beginning of the Industrial Revolution in the mid18th century, that the impact of human activities has begun to extend to a much larger scale. Human activities, in particular those involving the combustion of fossil fuels for industrial or domestic usage, and biomass burning produce greenhouse gases (water vapour, carbon dioxide, methane, nitrous oxide, ozone and fluorocarbons) and aerosols (suspended solid particles and liquid droplets in air) which affect the composition of atmosphere.

The following human activities may be changing the global climate: (i) Burning of fossil fuels, *i.e*., coal, oil and natural gas to power motor vehicles, heat buildings, generate electric energy, and perform various industrial tasks is increasing the amount of carbon dioxide released into the atmosphere. Fossil fuels contain carbon, and burning those produces carbon dioxide. Since the mid1800's, the level of atmospheric carbon dioxide has risen by about 25 per cent. Trees and other green plants remove carbon dioxide from the air during photosynthesis. The clearing of forests also contributes to the buildup of atmospheric carbon dioxide by reducing the rate at which the gas is removed from the air. This gas slows the escape of heat released by the earth into space. This gas absorbs heat that radiates from the earth's surface and radiates heat back to the surface. Thus, an increase in atmospheric carbon dioxide may cause global warming, *i.e*., a rise in the temperature of the air just above the earth's surface. Changes in carbon dioxide concentration in the atmosphere may cause short-term and long-term variations in the climate. Many scientists estimate that by about 2050, the amount of carbon dioxide in the atmosphere will have doubled from the preindustrial level. If this increase were to add to the natural greenhouse effect, the earth's surface temperature might rise between 1.5 and 4.5 °C by 2100. Even a warming of 0.5^{o}C in a century would be several times faster than the typical natural rate.

(ii) Livestock and paddy farming, land use and wetland changes, pipeline losses and covered vented landfill emissions lead to higher methane atmospheric concentrations. (iii) Many of the new, fully-vented septic systems that enhance the fermentation process, are major sources of atmospheric methane. Since the mid-1800's, methane concentration has risen by about 150 per cent. (iv) The emission of chlorofluorocarbons (CFCs) and other chlorine and bromine compounds from refrigeration systems, fire suppression system and manufacturing process has not only an impact on radiative forcing, but has lead to the depletion of ozone layer. CFCs and other halogen compounds have long atmospheric lifetimes and therefore become well mixed with the atmosphere. (v) Agricultural activities, including the use of fertilizers, lead to higher nitrous oxide concentrations.



(source: IPCC First Report, 1994)

(vi) Human, industrial, energy related, and land use activities increase the amount of aerosol in the atmosphere, in the form of mineral dust, sulphates and nitrate and soot. Soot absorbs solar radiation directly, leading to local heating of the atmosphere, or absorb and emit infrared radiation, adding to the greenhouse effect. Aerosols may also affect the number, density and size of cloud droplets. This may change the amount and properties of clouds. It may have an impact on the formation of precipitation.

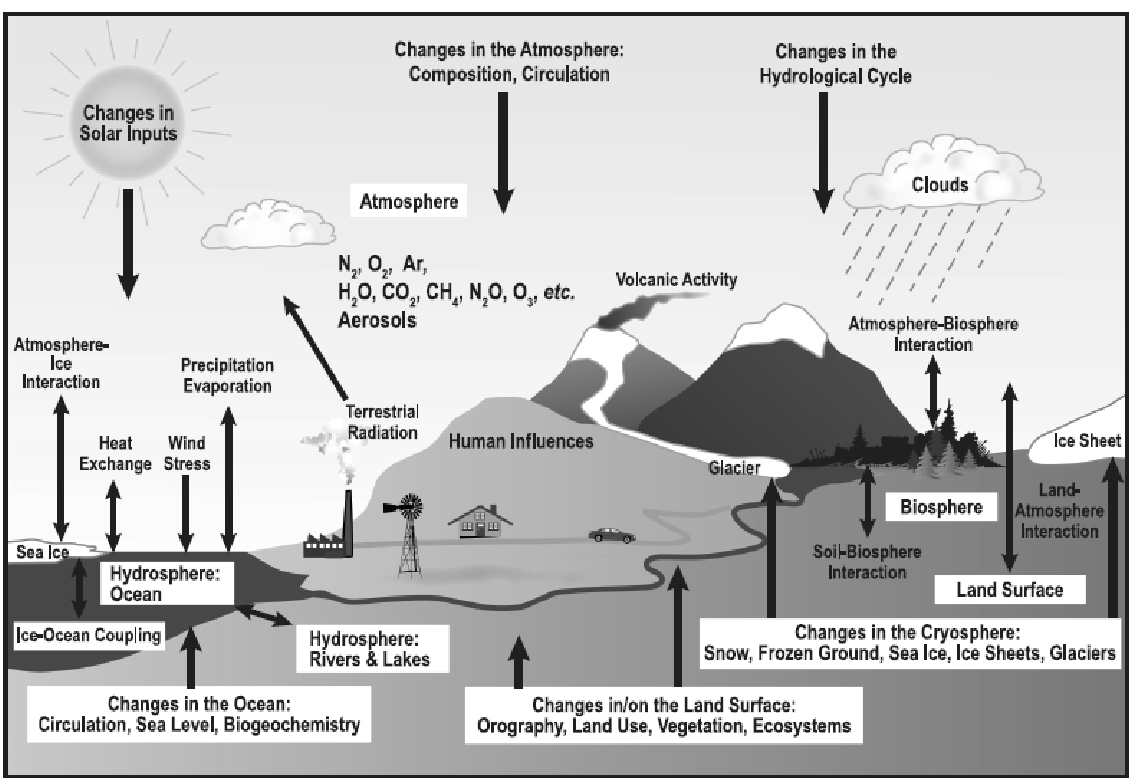
(vii) Water vapour is a naturally occurring greenhouse gas and accounts for the largest percentage of greenhouse effect between 36% and 70%. Increase in atmospheric temperature caused by the greenhouse effect due to anthropogenic gases will in turn lead to an increase in water vapour. The increased water vapour in turn leads to an increase in greenhouse effect and thus a further increase in temperature. The increase in temperature leads to further increase in water vapour; and the feedback cycle continues.

(viii) Land-use change, due to urbanization and human forestry and agricultural practices, affect the physical and biological properties of the Earth's surface. Such effects change the radiative forcing and have a potential impact on regional and global climate. The construction of cities creates areas that are warmer and drier than the surrounding countryside. Cities are warmer for several reasons. The use of storm drainage systems means that less solar radiation is used to evaporate water and more is used to heat the city surfaces and air. The brick, asphalt, and concrete surfaces readily radiate the heat they absorb and so raise urban air temperatures even more. In addition, cities themselves generate heat from a number of sources, including motor vehicles and heating and air conditioning systems.

Few scientists argue that the increase in greenhouse gases has not made a measurable difference in the climate. These scientists say that the warming trend is a normal change in the climate system. They argue that natural processes, such as increases in the energy given off by the sun, could have caused global warming (increase in surface temperature). But the greater weight of evidence suggests that an unusual climate change has occurred and that human activities are responsible to a major part of it.

Effects of climate change

Global warming affects many aspects of the environment, including sea levels, coastlines, agriculture, forestry and wildlife. Continued global warming could have a beneficial impact in some areas and a harmful impact in many others. For example, people could begin to farm in regions where it is currently too cold. At the same time, global warming could cause sea levels to rise and thereby increase the threat of flooding in low-lying coastal areas, many of which are densely populated. Global warming could alter the ecology of many parts of the earth. For example, global warming could change rainfall patterns, melt enough polar ice to raise the sea level, increase the severity of tropical storms, and lead to shifts in plant and animal populations. Ocean currents and wind patterns could change, making some areas cooler than they are now. One remote possibility is that a warming of northern regions will result in more winter snowfall, causing some ice sheets to advance. A rapid and large-scale climate change could severely harm the earth's ecosystems (the living organisms and physical environment in particular areas). For example, such a change could make it difficult for many species to survive in the regions they now inhabit. Some could be forced to migrate, while others could become extinct.



Schematic view of the components of the climate system, their processes and interactions (source: IPCC First Report, 1994)

Determining past climates

Scientists study the climate record to learn about climate and its changes. The most reliable portion of the record is based on standardized measurements by weather instruments. The reliable instrument-based record dates back only about 125 years and is too short to reveal all possible variations in climate. Climatologists have lengthened the record by studying historical documents, tree growth rings, fossil plants and animals, deposits of pollen, and cores drilled out of glacial ice and seafloor sediments.

Historical documents that contain information about climate include logs maintained by ships' captains and lighthouse keepers, diaries kept by farmers, and records of harvests. Another source is a record of the duration of ice cover in a harbour.

Growth rings: A tree adds a growth ring each year. The thickness of those rings depends to some extent on seasonal weather conditions. By analyzing growth rings from living and dead trees, scientists can distinguish years of relatively favourable weather from years of stressful weather. In the southwestern part of the United States, tree growth rings provide information about the climate record dating back almost 8,000 years. Recently, the climate during the last few decades has been determined by reading growth rings in the otoliths of a few long-lived fishes.

Fossils are the remains or imprints of plants and animals that lived in the past. Based on an understanding of the environmental conditions required by these organisms, scientists can reconstruct climatic conditions of the places where the fossils are found. Knowing the age of fossils, scientists can identify major shifts in climate.

Pollen consists of tiny grains that play an essential role in the reproduction of flowering and cone-bearing plants. Pollen is released by the plants and carried by the wind. Some pollen falls into lakes and settles to the bottom along with tiny bits of clay and other particles to form sediment. Scientists can drill into a lake bottom and extract a sediment core, a sample of many layers of sediment. The core contains a record of changes in pollen, which reflects changes in a region's vegetation. Because climate largely determines the type of vegetation in a region, climatologists can use the pollen record to reconstruct an area's climate record. For example, climatologists have used pollen records to determine that the average July temperature in Western Europe was 2 degrees Celsius warmer 6,000 years ago. In parts of the midwestern United States, climatologists have reconstructed changes in climate from the pollen record as far back as 12,000 years ago.

The tiny shell and skeletal remains of organisms settle out on ocean water and accumulate with other sediments on the sea floor. A core extracted from sea-floor sediment provides a record of marine life through time. Scientists use chemical analysis of shells and skeletons removed from the sediment core to determine seawater temperatures. Analysis of deep-sea sediments revealed much of what is known about the climatic variations of the Pleistocene Epoch.

Glaciers are composed of layers of ice created by the compression of winter snows. Each layer corresponds to one winter's snowfall. Through the chemical analysis of ice layers, scientists can determine winter temperatures. Tiny air bubbles trapped in the ice also provide clues about the chemical composition of the atmosphere when the snow fell. Scientists have obtained lengthy ice cores from ice sheets in Antarctica and Greenland. Cores extracted in Greenland in the early 1990's covered a period of almost 200,000 years.

Predicting the climate

Climatologists rely on computerized climate models to predict the earth's climate. A climatologist programmes a computer with a numerical model of the climate. The model consists of a set of mathematical equations that describe how various factors influence climate. By altering one or more factors, the climatologist can use the model to predict changes in climate. One common application of climate models is to predict the impact of rising levels of atmospheric carbon dioxide.

Suggested Reading

http://www.grida.no/climate/ipcc_tar/wg1/039.htm

http://www.grida.no/climate/ipcc_tar/wg1/044.htm

Wikipedia, the free encyclopedia

http://en.wikipedia.org/wiki/Greenhouse_gas

Historical Overview of Climate Change Science

World book 1999

Encarta encyclopedia 2000