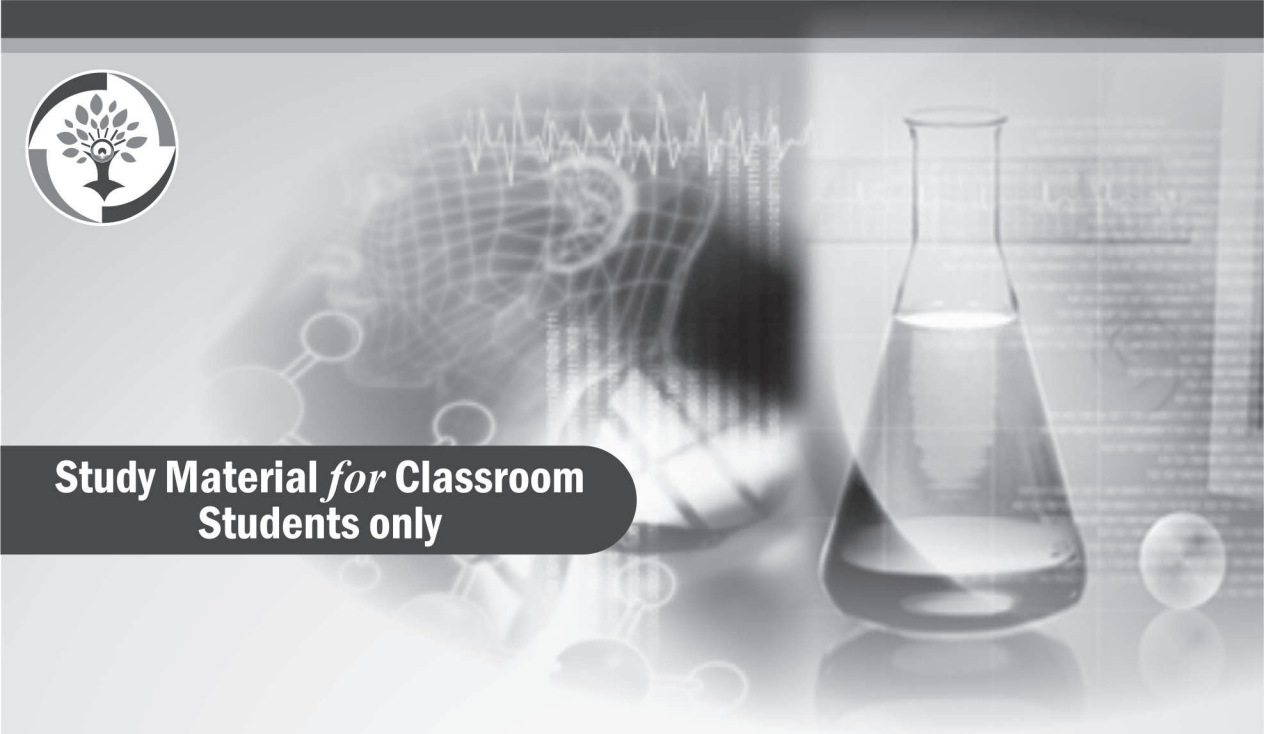

Study Material *for* Classroom Students only

GENERAL STUDIES

GENERAL SCIENCE

CLIMATE CHANGE

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CLIMATE CHANGE

Climate like any other physical phenomenon is not static but rather a fairly dynamic kind of thing. In greater or lesser degree it is ever changing. Till recently, the concept of climatic change was considered of academic importance. It was only during the past few decades that scientists began to recognize the inherent variability of climate on all time scales. Climate change is the long-term variability associated with the earth ocean climate system. In fact the growth and decline of past human civilizations and other species of plants and animals as well as the formulation of future public policy regarding all elements of human life depend on the climate and its change.

Instrumental records of climatic elements are available only for the last hundred years or so. Therefore, reconstruction of past climates is done through indirect evidences. These evidences are based on the findings of geology, geomorphology, botany, zoology, anthropology, glaciology, archaeology, geophysics, meteorology, oceanography, historical records and a host of other related disciplines.

- Fossilized remains of animal and plant life help to determine the duration and areal extent of climatic conditions obtained in distant geologic past. For e.g., fossilized pollen of Armeria sibirica unearthed from sedimentary rocks in Massachusetts suggest that the climatic conditions there must have been similar to those in the extreme north Canada at present.
- Study of ocean floor deposits and analysis of oxygen isotopes help in reconstruction of temperatures as they fluctuated in geologic past.

  Oxygen isotope analysis determines the periods of glacial activity by measuring the ratio between two isotopes of oxygen. ^{16}O (most common) and ^{18}O (heavier). Heavier precipitation leaves a greater concentration of the heavier isotope. It is so because the lighter isotope evaporates more readily from the sea-surface. Thus, the greater concentration of the heavier isotope in sea water indicates extensive glacial activity. Conversely, a marked drop in the concentration of ^{18}O is suggestive of warmer inter-glacial period.
- Another technique to reconstruct the past climates is the analysis of the annual growth of tree rings. This of course, reveals the history of local climate.
- Similarly the study of paleosols (buried soils) helps in exploring the past conditions of local climate.

Considerable help is also taken from the study of historical records which contains valuable information about draughts, floods, severe storms and other climatic extremes. Records of large-scale migration of peoples from one region to another and the nature of crops produced also give invaluable clues to past climatic conditions.

Before describing the Climate change it must be pointed out that the earth's geological history is divided into four main periods. Pre-Cambrian (Archaeozoic and Proterzoic) Paleozoic; Mesozoic; and Cenozoic (Tertiary and Quaternary).

Geologic Time Chart

System and Period	Series and Epoch	Distinctive Records of life	Duration (in Million Years/ 10,00,000 years) (m.y)
Pre-Cambrian Time			
Archeozoic Era Paleozoic Era		Origin of simplest life Age of invertebrate origins. Few fossils	3500 m.y to 4000 m.y
Proterzoic Era			
Cambrian		Marine invertebrates	550 m.y
Ordovician		First primitive fishes	400 m.y
Silurian		Earliest land plants and animals	350 m.y
Devonian		Amphibians appeared, fishes abundant	320 m.y
Carboniferous Lower (Mississippian)		Sharks abundant	250 m.y
Upper (Pennsylvanian)		First reptiles and coal forests	260 m.y
Permian		Reptiles developed, conifers abundant	235 m.y
		Mesozoic Era	
Triassic		Appearance of dinosaurs	200 m.y
Jurassic		Dinosaur's zenith, primitive birds, first small mammals	160 m.y
Cretaceous		Extinction of dinosaurs	130 m.y
Cenozoic Era			
Tertiary			70 m.y
	Paleocene	First placental mammals	
	Eocene	Rise of flowering plants	
	Oligocene	Large browsing mammals	
	Miocene	Whales, apes, grazing forms	
	Pliocene	Large carnivores. Transformation of ape like animals into man	
Quaternary	Pleistocene	Early man. Last great ice-age	2 m.y
	Recent	Modern man	11000 years

At intervals of many tens of millions of years, geological history has been punctuated by five or six glacial episodes, the oldest known being about 2500 million years ago. The last three occurred at the beinginning of the Cambrian (550 million year ago); during the late carboniferous and Permian period (250 m.y) and in Pleistocene or Quarternary Ice Age (the last 2 m.y).

Flandrian Postglacial Changes: With the final retreat of the glaciers around 10,000 years ago (8000 B.C). the climate rapidly ameliorated in middle and higher latitudes. A thermal maximum some 2–3ºC warmer than now was reached between 5000 and 3000 B.C

The period 1550 to 1800 has been called '**the Little Ice Age'**, because in it the glaciers of the mountains of Europe reached their most advanced positions since the beginning of the postglacial epoch. This advance has left well marked terminal moraines, known collectively **as the neoglacial maximum limit.**

Pluvial periods: During the glacial periods the precipitation is estimated to be greater than during the inter-glacial periods in tropical and subtropical regions. The pluvial periods were separated by inter-pluvial periods when most of the lakes dried up.

On the basis of instrumental records and weather diaries it may be concluded that during the past 100-200 years there have been many changes in temperature, precipitation and other climatic elements. The most significant aspect of these changes has been the world-wide climatic amelioration from the 1830s to the 1930s. This is the first climatic change that can be measured and plotted on maps. The present climatic phase resembles the warmer periods in the Middle Ages. Investigations have shown that the intensification of the general circulation has continued from about 1800 to the 1920s in the northern and the southern hemispheres. This has led to the most rapid shrinkage of the Arctic ice. The pronounced effect of the intensified atmospheric circulation has been that the extent of the oceanic influence has increased, particularly during the winter months. Very low surface temperatures over the continents became rare. Thus, in winter the gradients of surface temperature showed a declining trend. On the contrary, the temperature gradient in summer increased. After 1850, winters, according to meteorological records, became progressively warmer in all polar and temperate regions. However, a reversal of this tendency is indicated by the colder winters beginning from the middle of the twentieth century.

REGIONAL AND GLOBAL VARIATIONS

To gain some insight into the cause of climate variation, it is worth nothing at the outset that some changes appear to occur on a global scale, but many others, particularly those of a short-term nature, are regional —that is, they are climatic changes characterized by an excess of heat of precipitation in one region, but often matched by a corresponding deficiency in another, without mean global values being affected. As long as the *amount of radiation from the sun*, **the solar constant**, really does remain constant, then the mean global values of temperature, evaporation and total precipitation should remain unchanged, unless the composition of the atmosphere (e.g. ozone, carbon dioxide content) is altered in some way. However, one of the most significant discoveries of the last decade is that these global values are not constant. This may seem minor, but is substantial considering the volume of water involved, and has had the side-effect of slightly raising sea-level.

THE LINK WITH GENERAL CIRCULATION

There seems little doubt that the immediate cause of recent climate fluctuations is linked to the strength of the general circulation, particularly in the northern hemisphere westerlies and in the trade winds. The effect of an intensified atmospheric circulation is to increase the extent of oceanic influence, especially in winter, thereby raising mean temperatures. **H. H. Lamb** has made a particular study of this thesis. He has shown that the beginnings of climatic amelioration in Europe in the 1820s were linked to a pronounced increase in the vigour of the westerlies over the North Atlantic. This was accompanied by a northward shift in depression tracks, which reached

their most northerly mean positions in the 1920s and 1930s. At the same time, the mean pressure of the Icelandic low deepened, whereas that of the Azores high and the winter Siberian high increased, resulting in increased pressure gradients over the North Atlantic and Europe. It has been suggested that increased precipitation in Antarctica may relate to the higher incidence of storm in this century.

WHAT CAUSES CLIMATES TO CHANGE?

There is little doubt that changes in Earth-Sun relationships may be a basic cause of long-term climatic change. In conjunction with other factors the human activity is now a major factor influencing climate change.

There is a close relationship between the irradiance of the sun and the climate of earth. A decline of 2 percent irradiance of the sun for 50 years would be enough to cause renewed glaciations. A drop of 5 per cent should be adequate to bring about a major glaciations of the Earth. For the time associated with human civilization which has historical records, diaries, planting records, clothing and use of building material, the Global climate has undergone more or less cyclic variations. Every one million years there had been alternating glacial and inter-glacial episodes.

Solar Cycles: If we take the argument one stage further and look for the key to these circulation changes, we inevitably return to the fundamental factors of the Earth's energy budget. The link between the distribution of energy and the circulation has been stressed several times in the book. Climatologist have searched repeatedly for period trends in the record of climatic fluctuations, and have particularly explored the possibility of a link with the well-known solar cycles.

Changes in Atmospheric Composition: Another possible cause of interference in the Earth's atmospheric budget are changes in the composition of the atmosphere.

Independent of any solar activity, the amount of carbon dioxide seems to bear a relationship with temperatures.

Attempts have been made to relate climatic change to variations in the Earth's attitude as a planet. This connection has been invoked in a number of theories explaining the glacial/interglacial fluctuations within the Pleistocene Ice Age. The earth revolves around the sun in a elliptical orbit, and at the same time rotates itself every 24 hours on an axis inclined at 23½^{o} to the plane of the orbit. At the present time, summer occurs in the northern hemisphere when the Earth is farthest away from the sun **(aphelion),** and the southern summer when it is nearest **(perihelion).** It is known that over long periods of time the shape of the **elliptical orbit changes** because of different arrangements of planets in the solar system: the angle of tilt can vary from **21½ to 24½**; and that the seasons will gradually swop over. The latter effect is known as **the precession of the equinoxes**.

These astronomical oscillations have been called **'the pacemakers of ice ages'**, for although they may not cause ice ages, many scientists agree that they do control the succession of glacial and interglacial stages within them.

Continental drifting: Another suggestion is that glaciations is linked to **continental drifting**. The **Ewing-Donn theory** proposes that Pleistocene glaciations was initiated when, relatively speaking, the North Pole reached its present position in the middle of the Arctic ocean, and Antarctica became coincident with the south polar region.

These theories are based on the presumption that some 300 million years ago all the continents were joined together to form the super-continent '**Pangaea**'. It was located at high latitudes far to the south of their present positions. Although Pangaea was centered on the equator, its southern-most part included the South Pole. There was a rift in the Pangaea, and gradually it broke up into the separate continents that we know at present. These continents drifted apart to occupy their present position.

According to the **plate tectonic theory**, all these regions having glacial features were joined together to make one universal continent called Pangaea. This super continent was situated farther from the

present positions of its component parts. Later on this super continent broke apart. Each piece drifted towards its present position moving on a different plate. This revolutionary theory emerging from geology thus explains how large fragments of glaciated terrain reached their scattered subtropical locations.

Since the plates move at a very slow rate of only a few centimeters per year, significant changes in the positions of continents occur over large scales of geological time. Therefore large-scale climatic changes also happen in millions of years.

Radiation and Relief : Some tentative progress has been made in recent years in linking short-time regional climatic changes with changes in the general circulation of the globe. However, there is no general agreement as the causes of long-term climatic change. It may be that a combination of causes is the answer **R.F. Flint** has suggested **a solar topographic model,** which puts forward the idea that radiation and relief factors combined are necessary to cause an ice age.

Atmospheric C-14: Variation in the emission of solar radiation determines the concentration of **atmospheric C-14.** It has been argued that the major intervals of high atmospheric C-14 activity coincides with periods of neo-glacial expansion while the intervals of relatively low C-14 activity coincide with intervals of glacier contraction.

THEORIES ON CLIMATE CHANGE

1. The sunspot theory, 2. variation in atmospheric dust theory 3. Human induced greenhouse-gases theory, 4. Earth orbital eccentricity theory, 5. Extraterrestrial impact theory and the passage of earth through an interstellar dust theory.

1. THE SUNSPOT THEORY

Sunspots are the most conspicuous features on the solar surface which appear as dark spots. The sunspots are simply the huge magnetic storms that occur on the sun's surface. There is a close relationship between the solar activity and the number of sunspots. The number of sunspots increases and decreases in a cyclic manner. It may be pointed out that sunspots are a sign of increased solar activity.

Many attempts have been made to link the well-known sunspot cycle of 11.2 years with meteorological events, but results have been conflicting. Another possibility is that a significant double cycle of 22 years exists within the pattern of the general circulation, and involves, among other things, the frequency of blocking anticyclones over Europe.

Changes in the upper atmosphere may be crucial. A recent hypothesis suggest that ozone becomes more abundant at a certain time in the sunspot cycle. The effect of the increase is to warm the stratosphere and weaken the sub-tropical high pressure belt and in turn the westerlies circulation, causing a period of lower rainfall.

2. VARIATION IN ATMOSPHERIC DUST THEORY

Volcanic dust, because of the size of its particles, deflects light of short wavelengths coming from the sun. But long wave terrestrial radiation can easily pass through volcanic dust without any loss. It is, therefore, natural that large-scale volcanic dust may lower down the earth's temperature to a certain extent. The large amount of volcanic dust present in the atmosphere is possibly one of the causes of the 'Little Ice Age'. According to this theory, the ice ages are supposed to be initiated during epochs of frequent volcanic eruptions.

3. HUMAN INDUCED GREENHOUSE GASES THEORY

Anthropogenic causes of climate change

Human activities are considered largely responsible in enhancing the greenhouse effect.

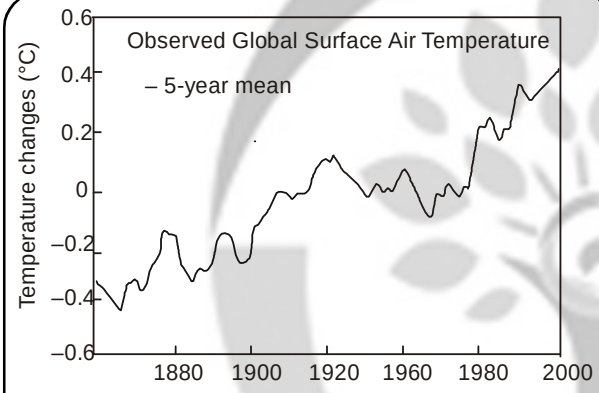
A. Increase in Air temperature

The air temperature are temperature are the highest since recordings were begun in earnest more than 100 years ago. This is the result of emission of carbon dioxide and greenhouse gases from human activity including industrial processes, fossil fuel combustion, deforestation and change, in the land use patterns.

The world is warming, Climatic zones are shifting, Glaciers are melting, Sea-level rising and we expect them to accelerate over the next years as the amounts of carbon dioxide, methane, and other trace gases accumulated in the atmosphere through human activities increase.

It may be observed from fig. 1 that the increase in the air temperature in the 20th Century has been about 0.5-ºC. In fact, the last five decades of the 20th Century and first decade of the 21st Century (1950 — 2010) have been the warmest year since the systematic recording of temperature began in 1878.

It may also be seen from fig. 2 that the earth temperature was about 14ºC in 1950 which rose to about 15ºC in 2000.



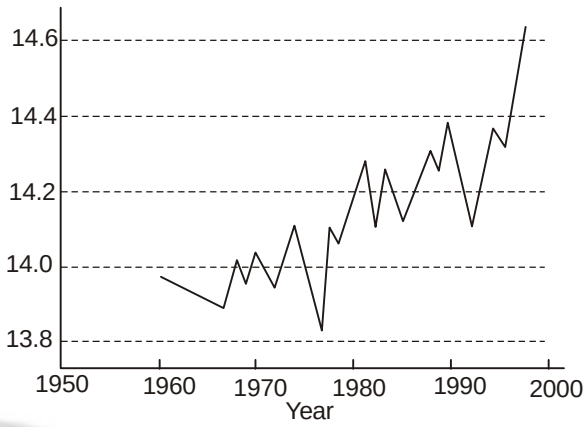
Trend of change in surface temperature since 1880 (source: H. Wilson and J. Hansen)

Fig. 1

B. Green house gases

The gases which absorb and re-emit infrared radiation are known as greenhouse gases. They are added to the atmosphere either by the natural or by anthropogenic process The carbon dioxide (CO_2), methane, chlorofluoro-carbon, etc. are the main gases responsible for the global warming.

(i) Carbon-Dioxide: Carbon dioxide and water vapour are the most important greenhouse gases. They stop long-wave radiation from escaping. The traped heat, raising Earth's temperature.



The rise in atmosphere carbond dioxide since 1700 A.D.

Fig. 2

The industrial Revolution in Europe in the mid-17th Centaury, burning of fossils fuels, destruction and inadequate replacement rate of forest, is causing atmospheric CO_2 levels to increase about 8 billion metric tons to 10 billion metric tons per year . They construct 60 per cent of the global warming. The CO_2 concentration 20 parts per million in 1800 A.D is expected to increase to 600 parts per million by the end of 21st Century. The presence of carbon dioxide and water vapour allows the Earth to maintain an average temperature of approximately 15º C. Without them surface temperature of the earth would be about -19ºC, Earth could not support if, But because of rapid growth of population and consumerism. The global temperatures are increasing fast and it will lead to catastrophic global warming, which would melt the polar caps, resulting into sea-level rise, stormy weather, droughts and floods, which may be catastrophic to agriculture and other primary, secondary tertiary activities

Year	CO_2 concentration (%)	Parts per million
1800	0.020	200
1950	0.028	280
2000	0.037	370
2050 (estimated)	0.060	600

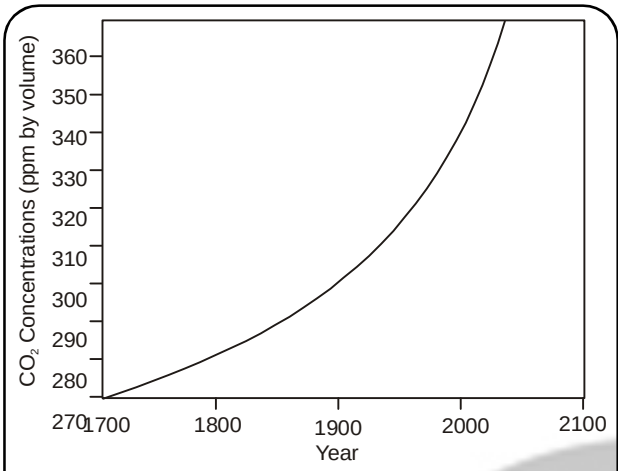


Fig. 3: The rise in atmosphere carbon dioxide since 1700 AD

Since the beginning of the Industrial Revolution in Britain and Europe (1779), apart from the atmospheric concentration of carbon dioxide, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15 per cent. The enhancement in temperature as, consequently, increased the temperature trapping capability of the Earth's atmosphere

(ii) **Methane:** Another radioactive active gas contributing to the overall greenhouse effect is methane (CH4), which is increasing in concentration at about 1 per cent per year. Methane is generated by organic processes, such as digestion and rotting in the absence of oxygen (anaerobic processes).About 50 per cent of the excess methane being produced comes from bacterial action in the intestinal tracts of livestock and from under- water bacteria in rice fields. Methane is now believed responsible for at least 12 per cent of the total atmospheric warming, complementing the warming caused by the build-up of CO2 and equaling about one-half the contribution of CFCs.

(iii) **Chlorofluorocarbon (CFCs):** Chlorofluorocarbon gases are produced large manufactured molecules (polymers) containing chlorine, fluorine, and carbon. These gases possess remarkable heat properties. After slow transport to the stratosphere ozone layer CFCs react with ultraviolet radiation freeing chlorine atoms that act as a catalyst to produce reactions that destroy ozone. Chlorofluorocarbon (CFCs) are thought to contribute about 25. per cent of the global warming. As stated above, CFCs absorb infrared-in wavelength missed by carbon dioxide and water vapour in the lower troposphere. As relatively active gases, CFCs enhance the greenhouse effect, and also play negative role in stratospheric ozone depletion.

C. Black Carbon on Climate Change

Black Carbon influences the climate in the following two ways given below:

(i) When suspended in air, Black Carbon absorbs sunlight and generates heat in the atmosphere, which warm the air and can affect regional cloud formation and precipitation patterns.

(ii) When deposited on snow and ice, it absorbs sunlight, again generating heat, which warms both the air above and the snow and ice below, this accelerating melting.

Because the black carbon remains in the atmosphere for only one to four weeks, its climate effects are strongly regional. Its short lifetime also means that its climate effects would dissipate quickly if black carbon emission were reduced, thus benefitting most directly the countries of communities that invest in policies to reduce black carbon emission.

According to experts, the black carbon may be responsible for more than 30 per cent of recent warming in the Arctic contributing to the acceleration of Arctic Ocean's ice melting. Loss of ice of the Arctic Ocean would lead to more rapid warming and possibly irreversible climate change. Black Carbon may also be driving some of the observed reduction of the snowpack in the Pacific Northwest of North America.

Different types of soot has different amounts of black carbon-generally the blacker the soot, the more warming agent it is. Fossil fuel and bio-fuel soot are blacker than soot from biomass burning, which is generally more of a brownish colour. Thus, controlling emissions of soot from fuel sources is an effective way of reducing atmospheric temperatures in-the short term. Based on current information, most of the black carbon emissions come from the developed

countries in which the share of United States of America is over 6 per cent. China and India together account for some 25 to 35 per cent of the total black carbon emissions of the world.

D. Cryogenic/Cryergic Processes

The processes of permafrost, glaciations, defrosting and de-glaciations are known as **cryogenic process.** Nearly 20 per cent of the Earth's land surface currently experiences cryogenic peri-glacial conditions

The cryogenic processes are also the very important factors of global warming and consequent, climatic change. The period of widespread glaciations is called the ***great ice age*** which comprises several glacial and interglacial periods. The glacial period denotes onset of cold climate while interglacial periods indicate relatively warmer period when ice sheets retreat and the valley glaciers shrink.

The most pervasive effect of climatic change may be observed in the melting of glaciers and ice-sheets. This will directly affect the area under pastures and agriculture, especially in the higher latitudinal regions of Eurasia and, and Canada. The recent evidences have shown that the ice sheets of Antarctica, Greenland, Baffin Island, etc. are breaking, thinning and melting. Moreover, the valley glaciers of folded mountains are also shrinking. According to the experts of glaciology, the Gaumukh Glacier (source of Bhagirathi-Ganga), and Satopanth Glacier (source of Alaknanda) are shrinking at a faster pace. Same is the case with the glaciers of Karakoram, Hindukush, Andes, Rockies, Alps, Carpathian, and Altai, etc. Altai etc. The reduction in the size of glaciers is a clear and conclusive evidence which proves beyond doubt the phenomena of global warming and climate change. .

CO_2 can Crack Ice

Atomic level simulation studies by material science of Massachusetts Institute of Technology (MIT) suggest that increased concentrations of carbon dioxide (C02)in the atmosphere can cause ice to become more brittle, not unlike the breaking up or cracking of materials due to corrosion. Thus CO2 can play the role of corroding agent and lead to destabilization of the structure.

4. EARTH ORBITAL ECCENTRICITY THEORY

Although the effect of solar distance is of little significance in current seasonal temperature fluctuations, it plays an important role in producing large scale climatic changes (secular climatic variations). In perihelion the sun is nearest to the earth, while in aphelion it is farthest from the earth. The difference in distance is not more than 3 percent. This difference means that there is a variation of 6% of solar radiation received by the earth. But this is not always so.

The earth's orbit undergoes a change of shape during a cycle of 90,000 and 100,000 years. Sometimes the orbit forms a longer ellipse, and then it returns to a more circular shape. At the time of the greater eccentricity of the earth's orbit, the amount of solar radiation received at the earth's surface at perihelion may be 20 to 30 percent greater than at aphelion.

As a result of the variation in the angle between the earth's axis and the ecliptic, the Tropics and Polar Circles are displaced. At present, the earth's axis is inclined by 23.5 degrees. But according to scientists, this angle undergoes a change. The inclination of the axis varies from 22.1 degrees to 24.5 degrees during a cycle of about 41,000 years. Smaller changes in the inclination of the angle bring about smaller temperature differences between winter and summer. If the temperature difference between the two seasons is reduced, the ice sheets get an opportunity to grow in thickness and extent. Warmer winters cause more snow to fall, since higher temperatures mean increased capacity of air to hold moisture. On the other hand, cooler summer temperatures do not allow much snow to melt. This would lead to the growth of ice sheets.

All three effects have been combined in the **Milankovitch curve** to plot the results of these changes over long periods of time.

Like a spinning top, the earth rotating on its axis wobbles. At present, the axis of the earth points towards the North Star, but by the year 14,000 A.D. the axis will be pointing towards the star Vegas which will then be called the North Star. Since the period of precession is roughly about 26,000 years, Polaris will once again be the North Star by the year 27,000.

Due to this cyclic wobbling of the axis, climatic change of great magnitude takes place. As a result of the tilt of the axis towards Vega in about 12,000 years, the northern hemisphere will experience winter when the sun is farthest from the earth (aphelion) and summer will occur when the earth is nearest to the sun (perihelion). In this way, summers will be warmer and winters colder than at present.

5. EXTRATERRESTRIAL IMPACT THEORY AND THE PASSAGE OF EARTH THROUGH AN INTERSTELLAR DUST THEORY

One possible cause of variability in receipt of insolation over the Earth's surface is the presence of clouds of **fine interstellar matter (nebulae)** through which the earth might pass from time to time or which might interpose themselves between the Sun and the Earth. In encircling the Galaxy the Earth passes through one of the rotating spiral arms of the Galaxy about once every 300 m.y. Passage through this and the adjacent dust lane might cause climatic effects as interstellar dust affects the radiative transmittancy of interplanetary space or as infalling interstellar material affects the solar luminousity. The earth path around the Galaxy is elliptical and its passage nearest to the Galaxy's centre every 270 to 400 m.y might give rise to cyclic changes in climate on the 100 m.y time scale on a more local scale there is some suggestion of correlation between the indirect climate record and reversals of the earth's magnetic field but there is no obvious physical mechanism to account for the link.

EVIDENCE OF GLOBAL WARMING

Important proofs are as follows:

1. In Antarctica the ice sheets are breaking up. Icebergs and ice shelves of the size of more than 11,000 sq. km (300 km long X 37 km wide) have been reported from the Antarctica. The population of Adele- Penguins on Antarctica declined by 40 per cent.
2. The edge of West Antarctic ice-sheet is shrinking at the rate of about 125 metres each year. The Garhwal Himalayan (Uttarakhand-India) glaciers are rapidly retreating at the rate of about 10 metres per year.
3. The average elevation of glaciers in the Southern Alps of New Zealand moved upward about 100 meters in the 20th century.
4. The glaciation in the Tien Shan Mountains of China, Cuacasus Mountains of Georgia and Russia shrank nearly 25 per cent in the past 50 years.
5. The Bering Glacier in Alaska is retreating, and the area of Bering sea shrunk by about 5 per cent in the last 50 years.
6. The largest glacier of Mount Kenya almost completely melted away in the 20th century.
7. Glaciers of Alps Mountains of Europe shrank by about 50 per cent in the last century.
8. The temperature of global oceans are rising.
9. Vegetation (mosses and lichen) appearing on the slopes of the mountains of Antarctica.
10. The tree-line in mountain ranges is moving upward.
11. Many tropical diseases (malaria, cholera, yellow-fever, dengue-fever, plague and hantavirus) are spreading towards the higher latitudes and the polar regions.
12. Snowfall was recorded in the desert of Dubai and Abu-Dhabi (Ras-al-Khaima) for the first time in the recorded history in January/February, 2005.
13. The 20th Century was the warmest century of the millennium and the year 1998 was the warmest year of the 20th Century. Seven out of ten warmest years were recorded in the last decade of the 20th Century.
14. Extreme events such as heat-waves, cold-waves, droughts, tornadoes and western disturbances are becoming more frequent.
15. The frequency of El-Nino and La-Nina are increasing.
16. The corals are dying at an unprecedented rate. The epidemics in the colonies of corals in the form of bleaching is attributed to the rise in temperature of the oceans.

17. Cloudbursts and flesh floods like that of the 16th June, 2013 in Uttarakhand are becoming more frequent.
18. Untimely heavy snowfall in Kashmir, Himachal Pradesh, Badrinath valley (Uttarakhand) and Nepal on 16th October 2014

CONSEQUENCES OF CLIMATIC CHANGE

The consequences of global warming are complex and effect the characteristics of temperature, precipitation, soil moisture, and air-masses both at the regional and global level. Though it is difficult to forecast how the change of climate will affect the environment, ecology and society, it is sure to have far-reaching consequences.

MAJOR CONSEQUENCES OF CLIMATE CHANGE

1. **Rise in sea level:** The experts of Oceanography opine that significant changes are taking place in the sea level. In fact, the measurements of sea level exhibit cyclical changes in sea level. The main cause of sea level rise is the melting of ice-sheets and glaciers. It is observed that about 18 thousand years before present, the sea level was about 82 metres below the present sea level. Since then, it is continuously rising. The more significant rise in the sea level occurred about 6000 years before present. The sea level rise gradually inundates coastal areas which affect the occurrence and frequency of tropical cyclones, patterns of precipitation, causing droughts and floods and ultimately affecting the vegetation, animals Soil humidity and human society.
2. Change in pressure belts and atmospheric circulation. The Inter-Tropical Convergence Zone (ITCZ) may mover northward in the Northern Hemisphere.
3. Change in the direction of permanent and periodic winds.
4. Change in the directions of warm and cold water currents.
5. Increase in the frequency of tropical and temperate cyclones, cloud cover, tornadoes and storms.
6. Change in the intensity and patterns of precipitation altering natural vegetation, cropping patterns, crop combination, agricultural productivity and soil belts. National parks, sanctuaries and biosphere reserves may be altered.
7. Change in hydrological cycle and water supply will bring changes in the soil-moisture and humus content of the soils.
8. The marine life will be adversely affected. Warming of temperature of the oceans may endanger the corals worldwide.
9. Agricultural fields in the deltaic regions may submerge. This would effect the food supply and international trade of grains.
10. Countries like Maldives, and greater parts of Netherlands, etc. may submerge under water.
11. Expansion of deserts due to desertification.
12. The land-based animals will have to adapt to changing patterns of climatic belts.
13. Change in the international trade pacts and geo-politics of world.
14. Climatic change will effect the nutrious value of the food crops. The rising carbon dioxide emissions will lead to deficiencies in iron and zinc.

CLIMATE CHANGE IN INDIAN CONTEXT: CONSEQUENCES

The scientists of the Indian Institute of Tropical Meteorology (IITM), New Delhi found that temperature would increase by about 5°C in several parts of India, especially in Gujarat (Rann of Kachchh) and Rajasthan, and 3°C to 4°C in Peninsular India by the end of the 21st Century. In addition to this, the incidence of violent and stormy weather and the frequency of tropical cyclones may it increase by about 50 per cent. This may lead to heat waves, more torrential rainfall and more prolonged dry spells in the less rainfall recording areas. The rising temperature may affect every aspect of ecology and society.

Following are the consequences of global warming and climate change in India:

1. The hydrological cycle will be adversely affected. The discharge of water even in the perennial

rivers may decrease by about 20 per cent by 2050 resulting in decrease in fresh water availability.

2. In several areas, rainfall will increase, while in others there will be decrease .
3. With Increased temperatures the rate of evaporation will increase resulting in more of rainfall and most of it would be in the oceans.
4. Decrease in soil moisture in the northern plains of India and the consequent increase in saline affected areas would effect the Agricultural production by about 15 per cent . The unseasonality of hot and cold spells will not be conducive for good agricultural productivity. Such conditions would have a lasting influence on cropping patterns too.
5. The forest cover will change in nature and the vegetation belts will shift which will effect the areas of Biosphere Reserves and National parks.
6. With increasing temperatures effecting the Himalayan glaciers, the proneness to floods in the plains of Indus, Satluj, Ganga and Brahmaputra will increase in the initial years
7. The deltas along coast of Tamil Nadu, Andhra Pradesh, Odisha, and West Bengal may submerge under water. This would result in submergence of islands in front of Sundarban Delta and the Lakshadweep.
8. With lowered productivity and production, India may be forced to depend on importing food grains to feed its teeming millions.
9. There will be increased inter-regional and international migration of people in search of jobs and better quality of life.

ADAPTIVE STRATEGIES FOR CLIMATE CHANGE MITIGATION

The United Nations Framework Convention on Climate Change: The world community recognized that there is a problem and need to be addressed at the earliest.

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change, as a framework for international cooperation to combat climate change by limiting average global temperature increases and the resulting climate change, and coping with impacts that were, by then, inevitable.

Convention sets an ultimate objective of stabilizing greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." And such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner".

The "base year" for tabulating greenhouse gas emissions has been set as 1990.

Kyoto Protocol: By 1995, countries launched negotiations to strengthen the global response to climate change, and, two years later in 1997, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed country Parties to emission reduction targets. The Protocol's first commitment period started in 2008 and ended in 2012. The second commitment period began on 1 January 2013 and will end in 2020.

There are now 196 Parties to the Convention and 192 Parties to the Kyoto Protocol.

Kyoto Protocol-what it means : Its an International and legally binding agreement to reduce greenhouse gas emission worldwide, entered into force on 16 February 2005.

The convention place the heaviest burden for fighting climate change on industrialized nations, since they are the source of most past and current greenhouse gas emissions. These developed nations, called **"Annex** I" countries listed under annex I belong to the **organization for Economic Cooperation and Development (OECD)**. These advanced nations, as well as 12 **"economies in transition"** (countries in Central and Eastern Europe, including some states formerly belonging to the Soviet Union) were expected by the year 2000 to reduce emission to 1990 levels and they succeeded.

Industrial nations agree under the convention to support climate-change activities in developing countries by providing financial support to these countries. A system of grants and loans has been

set up through the convention which was managed by the Global environment Facility. Industrialized countries also agree to share technology with less-advanced nations. Because economic development is vital for the world's poorer countries and because such progress is difficult to achieve even without the complications added by climate change the convention accepts that the share of greenhouse gas emissions produced by developing nations will grow in the coming years. It nonetheless seeks to help such countries limit emissions in ways that will not hinder their economic progress.

Paris Agreement: The 2015 Paris Agreement, adopted in Paris on 12 December 2015, marks the latest step in the evolution of the UN climate change regime and builds on the work undertaken under the Convention.

The Paris Agreement seeks to accelerate and intensify the actions and investment needed for a sustainable low carbon future. Its central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The Agreement also aims to strengthen the ability of countries to deal with the impacts of climate change.

UN's United Nations Environment Programme gathers temperature, weather, and climatic information to assist climate modelers and policy makers.

U.N's Climate Science Panel said that the world would have to reduce greenhouse gas emissions by 40-70% below 2010 levels by 2050 in order to have a fair chance to keep the rise in the global temperature below 2 degree Celsius and CO2 down to 430-480 parts per million (ppm) equivalent 2100.

Steps to Reduce Emission of Greenhouse Gases

(i) **Alternative sources of energy: There is a need to increase the use of alternate sources of energy.** The renewable and non-conventional energy sources like solar , wind, tidal energy provides only about 18 per cent of the total electricity generated in the world and there should be serious efforts to reduce the use of thermal power.

(ii) **Generation of Nuclear Power: Measures to increase the production of nuclear power as it** accounts for about 14 per cent of the world's electricity produced and consumed.

(iii) **Afforestation:** Planting instead of felling more trees

(iv) **Urban Planning:** encroachment of agricultural land for non-agricultural purposes should be avoided. The urban areas should implement environmentally protective measures like multiple transport choices, green areas and 'green belts.

(v) **Building designing:** To use the solar heat and light resources in the construction design and also to use insulation and high efficiency appliances.

(vi) **Controlled burning of biomass:** Promoting biomass fuelled power plants to reduce the emission of greenhouse gases.

(vii) **Reduction in the growth of population:** Framing of measures and policies to control population growth.

(viii) **Reduction in consumerism:** With consumerism, the judicious use of goods has come down resulting in more and more of wastage of resources.

(xi) **Mass education about ecology and environment:** Proactive use of media, holding workshops, conferences and seminars can train and tune the general public into cultivating habits to Conserve resources and protect the environment.

(x) Developing appropriate technologies so as to adapt and mitigate the adverse impact of the emissions of greenhouse gases like The diesel vehicles should be fitted with filters to capture black carbon and Replacement of inefficient cook stoves with cleaner alternatives.

HEAT BUDGET

This flow of incoming and outgoing energy is Earth's energy budget. For Earth's temperature to be stable over long periods of time, incoming energy and outgoing energy have to be equal. In other words, the energy budget at the top of the atmosphere must balance. If incoming energy is not balanced with the outgoing energy the earth would get warmer or cooler progressively with each passing year. This state of balance is called **radiative equilibrium.**

Input is received in the form of short-wave solar energy. This is called **insolation.**

Insolation is **solar radiation** received in the Earth's atmosphere or at its surface.

Reflected heat, is in the form of long-wave radiation. This reflection is called the **albedo**. The albedo of an object is the extent to which it diffusely reflects light from the Sun.This reflected heat is trapped in our atmosphere and keeps our planet warm. This is known as the natural greenhouse effect.

Temperature doesn't infinitely rise, however, because atoms and molecules on Earth are not just absorbing sunlight, they are also radiating thermal infrared energy (heat). *The amount of heat a surface radiates is proportional to the fourth power of its temperature. If temperature doubles, radiated energy increases by a factor of 16 (2 to the 4th power).* If the temperature of the Earth rises, the planet rapidly emits an increasing amount of heat to space. This large increase in heat loss in response to a relatively smaller increase in temperature—referred to as **radiative cooling**—is the primary mechanism that prevents runaway heating on Earth.

- About 29 percent of the solar energy that arrives at the top of the atmosphere is reflected back to space by clouds, atmospheric particles, or bright ground surfaces like sea ice and snow. This energy plays no role in Earth's climate system. About 23 percent of incoming solar energy is absorbed in the atmosphere by water vapor, dust, and ozone, and 48 percent passes through the atmosphere and is absorbed by the surface.
- The atmosphere and the surface of the Earth together absorb 71 percent of incoming solar radiation, so together, they must radiate that much energy back to space for the planet's average temperature to remain stable. However, the relative contribution of the atmosphere and the surface to each process (absorbing sunlight versus radiating heat) is asymmetric. The atmosphere absorbs 23 percent of incoming sunlight while the surface absorbs 48. The atmosphere radiates heat equivalent to 59 percent of incoming sunlight; the surface radiates only 12 percent. In other words, most solar heating happens at the surface, while most radiative cooling happens in the atmosphere.
- For the energy budget at Earth's surface to balance, processes on the ground must get rid of the 48 percent of incoming solar energy that the ocean and land surfaces absorb. Energy leaves the surface through three processes: **evaporation, convection,** and **emission of thermal infrared energy.**
- About 25 percent of incoming solar energy leaves the surface through evaporation. Liquid water molecules absorb incoming solar energy, and they change phase from liquid to gas. The heat energy that it took to evaporate the water is latent in the random motions of the water vapor molecules as they spread through the atmosphere. When the water vapor molecules condense back into rain, the latent heat is released to the surrounding atmosphere. Evaporation from tropical oceans and the subsequent release of latent heat are the primary drivers of the atmospheric heat engine.
- An additional 5 percent of incoming solar energy leaves the surface through convection. Air in direct contact with the sun-warmed ground becomes warm and buoyant. In general, the atmosphere is warmer near the surface and colder at higher altitudes, and under these conditions, warm air rises, shuttling heat away from the surface.
- Finally, a **net** of about 17 percent of incoming solar energy leaves the surface as thermal infrared energy (heat) radiated by atoms and molecules on the surface.

- Clouds, aerosols, water vapor, and ozone directly absorb 23 percent of incoming solar energy. Evaporation and convection transfer 25 and 5 percent of incoming solar energy from the surface to the atmosphere. These three processes transfer the equivalent of 53 percent of the incoming solar energy to the atmosphere. If total inflow of energy must match the outgoing thermal infrared observed at the top of the atmosphere, where does the remaining fraction (about 5-6 percent) come from? The remaining energy comes from the Earth's surface.
- Just as the major atmospheric gases (oxygen and nitrogen) are transparent to incoming sunlight, they are also transparent to outgoing thermal infrared. However, water vapor, carbon dioxide, methane, and other trace gases are opaque to many wavelengths of thermal infrared energy. Remember that the surface radiates the net equivalent of 17 percent of incoming solar energy as thermal infrared. However, the amount that directly escapes to space is only about 12 percent of incoming solar energy. The remaining fraction—a net 5-6 percent of incoming solar energy—is transferred to the atmosphere when greenhouse gas molecules absorb thermal infrared energy radiated by the surface.

TOTAL INCOMING

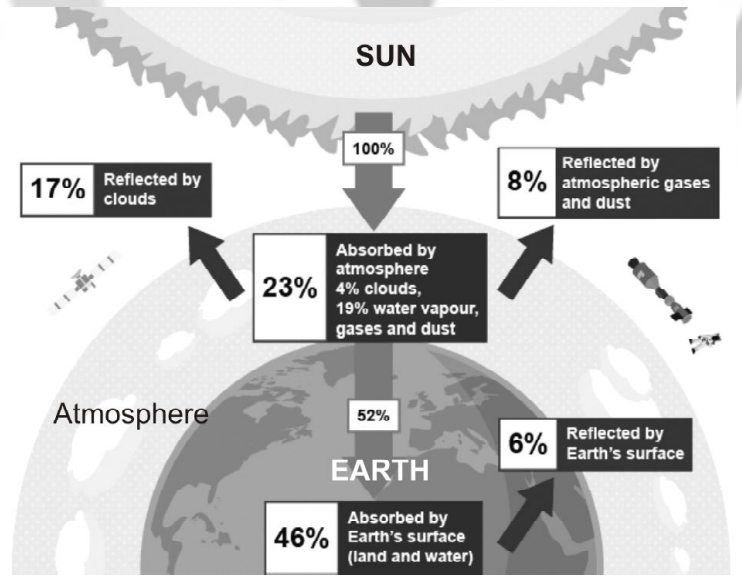
29% (reflected from the outer atmosphere) + 23% (Absorbed in the atmosphere) + 48% (Absorbed by the Earth) = 100 (Radiated by the Sun).

23% (Absorbed in the atmosphere) + 48% (Absorbed by the Earth) = 71% (Absorption by Earth)

TOTAL OUTGOING

Earth radiates directly 17% out of which 12% escapes the earth and 5% is absorbed by various greenhouse gases in the atmosphere.

25% (Evaporation) + 5% (Convection) + 5-6% (Greenhouse gases) + 12% (Long wave radiation) + 23% (Atmospheric absorption) = 71% (Radiated from the earth



Heat Budget

Objective Questions

1. The following statements about greenhouse gas methane are correct.

(i) Landfills produce methane

(ii) Termites produce methane.

(iii) Cattle produce methane.

(iv) Methane is produced from Paddy fields.

(a) i, ii and iii only (b) ii, iii and iv only

(c) i, iii and iv only (d) All are correct

2. Indirect greenhouse effect is caused by

(a) CO (b) Ozone

(c) Chlorofluorocarbons (CFCs)

(d) Methane

3. Regarding Hydro fluorocarbons (HFCs), find out the correct statements?

(i) They are one group of the greenhouse gases.

(ii) HFCs are replacing CFCs.

(iii) HFCs have shorter atmospheric liferime than CFCs.

(a) i, ii and iv only (b) ii, iii and iv only

(c) i, ii and iii only (d) All are correct

4. Match List-I (Environmental Degradation) with List-II (Constituent Causing Degradation) and select the correct answer using codes given below :

List-I	**List-II**
A. Acid rain	(i) Nitrogen
B. Automobile Smoke	(ii) Carbon dioxide
C. Ozone Depletion	(iii) Nitrogen oxide
D. Global Warming	(iv) Oxide of sulphur
	(v) Clorofluro-carbon

Code :

	A	**B**	**C**	**D**
(a)	iv	ii	v	iii
(b)	v	iii	i	ii
(c)	iv	iii	v	ii
(d)	v	ii	i	iii

5. Green Climate Fund was set up in which conference?

(a) Doha (b) Durban

(c) Cancun (d) Lima

6. Consider the following agricultural practice : (UPSC-2014)

(i) Contour bunding (ii) Relay cropping

(iii) Zero tillage

In the context of global climate change, which of the above help/help in carbon sequestration/ storage in the soil?

(a) i and ii only (b) iii only

(c) i, ii and iii (d) None of them

7. Which of the following is most significant factor in coral bleaching? (UPPSC-2015)

(a) Mining of coral rocks

(b) Outbreak of coral disease

(c) Siltation of seawater

(d) Global warming

8. Ozone protects biosphere from (UPPSC-2014)

(a) Infrared rays (b) Ultravioler rays

(c) X-rays (d) Gamma rays

9. The main gas responsible for ozone depletion is (Maharastra PCS-2014)

(a) carbon dioxide (b) nitrogen dioxide

(c) methane (d) chlorofluoro carbon

10. Which of the following group of gases contribute to the "Green House Effect"? (UPPSC-2013)

(a) Ammonia and ozone

(b) Carbon monoxide and sulphur dioxide

(c) Carbon tetrafluoride and nitrous oxide

(d) Carbon dioxide and methane

11. Which of the following is the correct definition of "Agenda-21"? (UPPSC-2013)

(a) It is an action plan of UNO for protecting human rights.

(b) It is a book of 21 chapters on nuclear disarmament.

(c) It is an action plan for conservation of global environment in 21st century

(d) It is agenda for the election of the president in the next meeting of SAARC.

12. Climate change is caused by (UPPSC-2013)

(a) Green house gases

(b) Depletion of ozone layer

(c) Pollution

(d) All the above

13. Which one among the following substances does NOT contribute to global warming? (UPPSC-2013)

(a) Oxides of sulphur and nitrogen

(b) Methane

(c) Carbon dioxide

(d) Water vapour

14. Which of the following is not a Greenhouse gas? (UPPSC-201)

(a) Carbon dioxide (b) Methane

(c) Nitrous oxide (d) Nitrogen

15. Which one of the following is the most effective factor of coral bleaching? (UPSC-2012)

(a) Marine pollution

(b) Increase of salinity of seas

(c) Rise in normal temperature of sea water

(d) Outbreak of diseases and epidemics

16. Which of the following is responsible for global warming?

(a) Methane (b) Carbon dioxide

(c) Water vapour (d) All of the above

17. Which one of the following is a major constituent of biogas?

(a) Carbon dioxide (b) Methane

(c) Hydrogen (d) Nitrogen dioxide

18. Which colour of heat radation represents the highest temperature?

(a) Blood red (b) Dark cherry

(c) Salmon (d) White

19. Which of the following gases is released from rice fields in the most prominent quantities?

(a) Carbon dioxide (b) Methane

(c) Carbon (d) Sulphur dioxde

20. What does water gas comprise of?

(a) Carbon monoxide and hydrogen

(b) Carbon dioxide and hydrogen

(c) Carbon monoxide and methane

(d) Carbon dioxide and methane

21. The increasing abundance of greenhouse gases in the atmosphere has led to the following effects except

(a) global warming

(b) depletion of Ozone layer in the stratosphere

(c) oxygen fertilization effect

(d) carbon dioxide fertilization effect

22. Match list **I (Green house Gases)** with **list II (Major Sources)** and select the correct answer using the codes given below the lists.

List I	**List II**
A. Carbon dioxide	1. Enteric fermentation in cattle
B. Methane	2. Burning of fossil
C. Chlorofluoro carbons	3. Mercury compounds in waste water
D. Nitrous oxide	4. Nylon production
	5. Air-conditioner and refrigeration units

Codes:

	A	**B**	**C**	**D**
(a)	2	1	5	4
(b)	3	4	2	1
(c)	3	2	4	1
(d)	1	2	3	5

23. **Assertion :** Presently the global atmosphere is warming up.

Reason : The depletion of stratospheric ozone layer has resulted in increase in ultravoilet radiations reaching earth.

24. Which one of the following is mismatched?

(a) Fossil fuel burning — Release of CO_2
(b) Nuclear power — Radioactive wastes
(c) Solar energy — Green house effect
(d) Biomass burning — Release of CO_2

25. **Assertion :** UV radiation causes photo-dissociation of ozone into O_2 and O thus causing damage to stratospheric ozone layer.

Reason : Ozone hole is resulting in global warming and climatic change.

26. Which one of the following is an environment related disorder with correct main cause

(a) Black lung disease is found mainly in workers of stone quarries and crushers
(b) Blue-baby disease is due to heavy use of nitrogenous fertilizers
(c) Non-Hodgkin's lymphoma is found mainly in workers involved in manufacture of neem-based pesticides
(d) Skin cancer occurs mainly in people exposed to benzene and methane.

27. Process by which incesticides like DDT reach man is

(a) Bioaccumulation (b) Biomagnification
(c) Bioremediation (d) Eutrophication

28. Match the columns

	Column—I		**Column—II**
a.	Nitrous oxide	1.	Secondary pollutant from car exhausts
b.	Chlorofluorocarbons	2.	Combustion of fossil fuels
c.	Methane	3.	Denitrification
d.	Ozone	4.	Refrigerators aerosols, sprays
e.	Carbon dioxide	5.	Cattle, rice fields, toilets

(a) a — 3, b — 4, c — 5, d — 1, e — 2
(b) a — 5, b — 1, c — 3, d — 4, e — 2
(c) a — 1, b — 3, c — 4, d — 5, e — 2
(d) a — 2, b — 4, c — 5, d — 1, e — 3

29. Air pollution is not reduced by

(a) Using precipitators (b) Reusing wastes
(c) Cleaning air (d) All the above

ANSWERS

1. (d)	**6.** (c)	**11.** (c)	**16.** (d)	**21.** (c)	**26.** (b)
2. (a)	**7.** (d)	**12.** (d)	**17.** (b)	**22.** (a)	**27.** (b)
3. (c)	**8.** (b)	**13.** (a)	**18.** (d)	**23.** (b)	**28.** (a)
4. (c)	**9.** (d)	**14.** (d)	**19.** (b)	**24.** (c)	**29.** (b)
5. (c)	**10.** (d)	**15.** (c)	**20.** (a)	**25.** (d)	

HINTS

3. (c) The HFCs are broken down in troposphere.

6. (c) Any method that helps the soil to retain more organic matter, so that it may work as an effective carbon sink would be helpful in carbon sequestrian or storage.

Contour Bunding : Contour bunding is one of the extensively used soil and water conservation technique in several rain-fed areas. Contour bunding is a mechanical measure that minimizes the soil erosion. Contour bunding involves the construction of small bunds across the slope of the land along a contour so that the long slope is reduced to a series of small ones. The contour bund acts as a barrier to flow of water down a slope and thus the benefit is that it increases the time so that water concentrates in an area and by this more water is absorbed. Contour bunding increases the water holding capacity while minimizing the surface evaporation. Then soil erosion is minimized, and surface residues favour the nutrient recycling and result in higher carbon storage in the soil.

Relay Cropping : Relay cropping means that new a crop is planted or sown before the previous one is harvested. This can provide advantages for both crops as one of them may provide nitrogen, shade, support or may discourage pests. The obvious benefit of relay cropping is soil conservation. Then, relay cropping helps in better yield and also helps in solid conservation. It does help in carbon sequestrian.

Zero Tillage : Zero tillage is also based upon the premise of soil conservation, basic premise is to minimize the disturbances to the soil leading to an increase in retention of water, nutrients and topsoil itself. No-till has carbon sequestration potential through storage of soil organic matter in the soil of crop fields.

8. (b) The ozone layer or ozone shield refers to a region of Earth's stratosphere that absorbs most of the Sun's Ultraviolet (UV) radiation.

9. (d) Ozone depleting substance

(i) CFC and HCFCs — Mostly used in refrigeration, air conditioning and heat pump systems. Only HCFCs can continue to be used for a limited period of time.

(ii) Halons — Used historically as fire suppression agents and firefighting, but now only allowed in very limited situations.

(iii) Carbon tetrachloride (tetrachloromethane) — Limited solvent use in laboratories and chemical and pharmaceutical industry.

(iv) 1, 1, 1, -trichloroethane — Limited solvent use in laboratories and chemical and pharmaceutical industry.

(v) Methyl bromide — Historically used in fumigation, soil treatment, pest control, quarantine, market gardening. Methyl bromide is no longer registered for use in Ireland.

(vi) Hydrobromofluorocarbons - Historically used in fire suppression systems and fire fighting, (vii) Bromochloromethane — Llistoncally used in the manufacture of biocides.

10. (d) The primary greenhouse gases in the Earth's atmosphere are water vapour, carbon dioxide; methane, nitrous oxide and ozone.

11. (c) Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, governments, and major groups in every area in which human impacts on the environment.

Agenda 21, the Rio Declaration on Environment and Development, and the Statement of principles for the Sustainable Management of Forests were adopted by more than 18 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janerio, Brazil, June 3-14, 1992.