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FUNDAMENTALS OF PHYSICAL GEOGRAPHY - XI

NCERT GIST

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Unit - I THE EARTH

1 The Origin and Evolution of the Earth

Early Theories

- **Nebular Hypothesis** - by German philosopher Immanuel Kant. Mathematician Laplace revised it in 1796.
  - i. The hypothesis considered that the planets were formed out of a cloud of material associated with a youthful sun, which was slowly rotating. Later in 1900, Chamberlain and Moulton considered that a wandering star approached the sun.
  - ii. As a result, a cigar-shaped extension of material was separated from the solar surface.
  - iii. As the passing star moved away, the material separated from the solar surface continued to revolve around the sun and it slowly condensed into planets.
    - Binary theories- the arguments considered of a companion to the sun to have been coexisting.
    - Revised Nebular Hypothesis- By Otto Schmidt in Russia and Carl Weizascar in Germany.
      - i. They considered that the sun was surrounded by solar nebula containing mostly the hydrogen and helium along with what may be termed as dust.
      - ii. The friction and collision of particles led to formation of a disk-shaped cloud and the planets were formed through the process of accretion.

Modern Theories

A. Origin of the Universe: -

- **Big Bang Theory** - also called expanding universe hypothesis.
  1. In the beginning, all matter forming the universe existed in one place in the form of a "tiny ball" (singular atom) with an unimaginably small volume, infinite temperature and infinite density.
  2. At the Big Bang the "tiny ball" exploded violently. This led to a huge expansion. It is now generally accepted that the event of big bang took place 13.7 billion years before the present. The expansion continues even to the present day. As it grew, some energy was converted into matter. There was particularly rapid expansion within fractions of a second after the bang
  3. Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event, the first atom began to form
  4. Within 300,000 years from the Big Bang, temperature dropped to 4,500 K (Kelvin) and gave rise to atomic matter. The universe became transparent.
  5. The expansion of universe means increase in space between the galaxies.
  6. An alternative to this was Hoyle's concept of steady state. It considered the universe to be roughly the same at any point of time. However, with greater evidence becoming available about the expanding universe, scientific community at present favours argument of expanding universe

B. The Star Formation

- **Formation of Planets:** The following are considered to be the stages in the development of planets
  1. The stars are localised lumps of gas within a nebula. The gravitational force within the lumps leads to the formation of a core to the gas cloud and a huge rotating disc of gas and dust develops around the gas core.
  2. The gas cloud starts getting condensed and the matter around the core develops into small- rounded objects like other celestial into what is called planetesimals these large number of small planetesimals accrete to form a fewer large bodies in the form of planets. These small-rounded objects by the process of cohesion develop in the same period sometime about 4.6 billion years ago.
  3. Planetesimals are a large number of smaller bodies.
  4. Till recently (August 2006), Pluto was also considered a planet. However, in a meeting of the International Astronomical Union, a decision was taken that Pluto Is dwarf planet.

Our Solar System

Our Solar system consists of eight planets.

- The nebula, from which our Solar system is supposed to have been formed, started its collapse and core formation some time 5-5.6 billion years ago and the planets were formed about 4.6 billion years ago. Our solar system consists of the sun (the star), 8 planets, 63 moons, millions of smaller bodies like asteroids and comets and huge quantity of dust-grains and gases. Out of the eight planets, Mercury, Venus, Earth and Mars are called as the inner planets as they lie between the sun and the belt of asteroids the other four planets are called the outer planets.
- Alternatively, the first four are called Terrestrial, meaning earth-like as they are made up of rock and metals, and have relatively high densities.
- The rest four are called Jovian or Gas Giant planets. Jovian means Jupiter-like. Most of them are much larger than the terrestrial planets and have thick atmosphere, mostly of helium and hydrogen.

The difference between terrestrial and Jovian planets can be attributed to the following conditions:

- The terrestrial planets were formed in the close vicinity of the parent star where it was too warm for gases to condense to solid particles. Jovian planets were formed at quite a distant location.
- The solar wind was most intense nearer the sun; so, it blew off lots of gas and dust from the terrestrial planets. The solar winds were not all that intense to cause similar removal of gases from the Jovian planets.
- The terrestrial planets are smaller and their lower gravity could not hold the escaping gases
- The Moon only natural satellite of the earth.

Early theory of evolution of Moon: -

- In 1838, Sir George Darwin suggested that initially, the earth and the moon formed a single rapidly rotating body.
- The whole mass became a dumb-bell-shaped body and eventually it broke.
- It was also suggested that the material forming the moon was separated from what we have at present the depression occupied by the Pacific Ocean.
- Giant impact' "the big splat Theory
- A body of the size of one to three times that of mars collided into the earth sometime shortly after the earth was formed. It blasted a large part of the earth into space.

- This portion of blasted material then continued to orbit the earth and eventually formed into the present moon about 4.44 billion years ago.

Evolution of Atmosphere and Hydrosphere: -

- **The present composition of earth's atmosphere is chiefly contributed by nitrogen and oxygen.** There are three stages in the evolution of the present atmosphere.
    1. The first stage is marked by the loss of primordial atmosphere.
    2. In the second stage, the hot interior of the earth contributed to the evolution of the atmosphere.
    3. Finally, the composition of the atmosphere was modified by the living world through the process of photosynthesis.
- The early atmosphere, with hydrogen and helium, is supposed to have been stripped off as a result of the solar winds.
- During the cooling of the earth, gases and water vapour were released from the interior solid earth. This started the evolution of the present atmosphere.
- **The early atmosphere largely contained water vapour, nitrogen, carbon dioxide, methane, ammonia and very little of free oxygen.**
- **The process through which the gases were outpoured from the interior is called degassing.**
- Continuous volcanic eruptions contributed water vapour and gases to the atmosphere.
- As the earth cooled, the water vapour released started getting condensed.
- The carbon dioxide in the atmosphere got dissolved in rainwater and the temperature further decreased causing more condensation and more rains.
- The rainwater falling onto the surface got collected in the depressions to give rise to oceans.
- Oceans began to have the contribution of oxygen through the process of photosynthesis.
- Eventually, oceans were saturated with oxygen, and 2,000 million years ago, oxygen began to flood the atmosphere.

2 Interior of the Earth

Sources of Information about the Interior

- The configuration of the surface of the earth is largely a product of the processes operating in the interior of the Earth. **Endogenic** as well as **Exogenic** process are constantly shaping the landscape.
- Two type of source of information: -
  i. Indirect
  ii. Direct

Direct Sources:

1. Surface rock or the rocks we get from mining areas.
   - Example- Gold mines in South Africa are as deep as 3 - 4 km.
2. 2Scientists have taken up a number of projects to penetrate deeper depths to explore the conditions in the crustal portions.
   - Example- Scientists world over are working on two major projects such as **"Deep Ocean Drilling Project" and "Integrated Ocean Drilling Project".**
   - The deepest drill at Kola, in Arctic Ocean, has so far reached a depth of 12 km.
3. **Volcanic eruption** forms another source of obtaining direct information.
   - As and when the molten material (magma) is thrown onto the surface of the earth, during volcanic eruption it becomes available for laboratory analysis.

Indirect Sources:

1. The **mining activity** gives information that temperature and pressure increase with the increasing distance from the surface towards the interior in deeper depths.
   - It is also known that the density of the material also increases with depth. It is possible to find the rate of change of these characteristics.
2. Another source of information are the meteors that at times reach the earth.
   - The material and the structure observed in the **meteors** are similar to that of the earth. They are solid bodies developed out of materials same as, or similar to, our planet.
3. The other indirect sources include **gravitation, magnetic field, and seismic activity.**
   - The gravitation force (g) is not the same at different latitudes on the surface. It is greater near the poles and less at the equator. This is because of the distance from the centre at the equator being greater than that at the poles. The gravity values also differ according to the mass of material.
   - The reading of the gravity at different places is influenced by many factors and these readings differ from the expected values. Such a difference is called **gravity anomaly.**
   - Gravity anomalies give us information about the distribution of mass of the material in the crust of the earth.

- Magnetic surveys also provide information about the distribution of magnetic materials in the crustal portion, and thus, provide about the distribution of materials in this part.
- Seismic activity is one of the most important sources of information about the interior of the earth.

Earthquake

- The study of seismic waves provides a complete picture of the layered interior.
- An earthquake, a natural event caused due to release of energy, which generates waves that travel in all directions.
- The release of energy occurs along a fault and the energy waves travel in all directions.
- The point where the energy is released is called the focus of an earthquake. It is also called the hypocentre. (inside the earth)
- The point on the surface, nearest to the focus, is called epicentre. It is the first one to experience the waves. It is a point directly above the focus on the surface of the Earth.

Earthquake Waves

- All-natural earthquakes take place in the lithosphere. Lithosphere refers to the depth up to 200 km from the surface of the earth.
- Two types of waves - body waves and surface waves.
  1. **Body waves** are generated due to the release of energy at the focus and move in all directions travelling through the body of the earth. Hence, the name body waves.
  2. The body waves interact with the surface rocks and generate new set of waves called **surface waves.** These waves move along the surface. The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities.

Body Waves and its Propagation: They are called P and S-waves.

P-waves:

i. These are also called primary waves. The P-waves are similar to sound waves.
ii. They move faster and are the first to arrive at the surface.
iii. They travel through gaseous, liquid and solid materials. (as sound)
iv. P-waves vibrate parallel to the direction of the wave. (P for parallel)
v. This exerts pressure on the material in the direction of the propagation. As a result, it creates density differences in the material leading to stretching and squeezing of the material.

S-waves:

i. These are called secondary waves. It arrives at the surface with some time lag. An important fact about S-waves is that they can travel only through solid materials.
ii. It has helped scientists to understand the structure of the interior of the earth.
iii. These waves are more destructive. They cause displacement of rocks, and hence, the collapse of structures occurs.
iv. The direction of vibrations of S-waves is perpendicular to the wave direction in the vertical plane. Hence, they create troughs and crests in the material through which they pass.

Emergence of Shadow Zone

- Earthquake waves get recorded in seismographs located at far off locations. However, there exist some specific areas where the waves are not reported. Such a zone is called the 'shadow zone'.
- A zone between 105° and 145° from epicentre was identified as the shadow zone for both the types of waves.
- The entire zone beyond 105° does not receive S-waves.

- **The shadow zone of S-wave is much larger than that of the P-waves.**
- The shadow zone of P-waves appears as a band around the earth between 105° and 145° away from the epicentre.

Types of Earthquakes

- Tectonic earthquakes - These are generated due to sliding of rocks along a fault plane.
- Volcanic earthquake - A special class of tectonic earthquake is sometimes recognised as volcanic earthquake. However, these are confined to areas of active volcanoes.
- Collapse earthquakes - In the areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors.
- Explosion earthquakes - Ground shaking may also occur due to the explosion of chemical or nuclear devices.
- Reservoir induced earthquakes - These earthquakes occurs in the areas of large reservoirs.

Measuring Earthquakes

- The earthquake events are scaled either according to the magnitude or intensity of the shock.
  1. The **magnitude scale** is known as the **Richter scale.** The magnitude relates to the energy released during the quake. The magnitude is expressed in absolute numbers, 0-10.
  2. The **intensity scale** is named after **Mercalli,** an Italian seismologist. The intensity scale takes into account the visible damage caused by the event. The range of intensity scale is from 1-12.

Effects of earthquake

- Earthquake is a natural hazard. The following are the immediate hazardous effects of earthquake:
  1. Ground Shaking
  2. Differential ground settlement
  3. Land and mud slides
  4. Soil liquefaction
  5. Ground lurching
  6. Avalanches
  7. Ground displacement
  8. Floods from dam and levee failures
  9. Fires
  10. Structural collapse
  11. Falling objects
  12. Tsunami
- The first six listed above have some bearings upon landforms, while others may be considered the effects causing immediate concern to the life and properties of people in the region.
- The effect of tsunami would occur only if the epicentre of the tremor is below oceanic waters and the magnitude is sufficiently high. Tsunamis are waves generated by the tremors and not an earthquake in itself.

Structure of the Earth

The Crust

- It is the outermost solid part of the Earth.
- Oceanic crust is thinner as compared to the continental crust. The mean thickness of oceanic crust is 5km whereas that of the continental is around 30km. The oceanic crust is made up of basalt rocks.
- The continental crust is thicker in the areas of major mountain systems.

The Mantle

- The portion of the interior beyond the crust is called the Mantle.
- The upper portion of the mantle is a weaker zone called asthenosphere, it is considered to be extending up to 400km and the main source of magma. Once the magma reaches the surface it is referred to as lava.
- The mantle has higher density that of crust.

The Core

- The outer core is in liquid state while the inner core is in solid state.
- The core is made up of a very heavy material mostly constituted by nickel and iron referred to as the nife layer.

Volcanoes and Volcanic Landforms

- The mantle contains a weaker zone called asthenosphere. It is from that the molten rock material find their way to the surface.
- The material that reaches the ground includes lava flows, pyroclastic debris, volcanic bombs, ash and dust and gases such as nitrogen compounds, sulphur compounds and minor amounts of chlorene, hydrogen and argon.

Types of Volcanoes

- Volcanoes are classified on the basis of nature of eruption and the form developed at the surface.
  1. **Shield Volcanoes**
     - It is the largest of all the volcanoes.
     - These volcanoes are mostly made up of basalt, a type of lava i.e. very fluid when erupted.
     - They are not steep and becomes explosive only if water gets into the vent otherwise, they are low explosive volcanoes.
     - The upcoming lava moves in the form of a fountain and throws out the cone at the top of the vent and develops into cinder cone.
     - Example: Hawaiian volcanoes.
  2. **Composite Volcanoes**
     - These volcanoes are characterised by eruptions of cooler and more viscous lavas than basalt.
     - These volcanoes often result in explosive eruptions.
     - Along with lava large quantities of pyroclastic materials and ashes find their way to ground and accumulates in the vent openings leading to formation of layers and this makes the mounts appears as composite volcanoes.
  3. **Caldera**
     - These are the most explosive of the earth's volcanoes.
     - They are usually so explosive that when they erupt, they tend to collapse on themselves rather than building any tall structure. The collapsed depressions are called calderas.
  4. **Flood Basalt Provinces**
     - These volcanoes outpour highly fluid lava that flows for long distances.
     - Example: Deccan Traps from India covering most of the Maharashtra plateau are a much larger flood basalt province.
  5. **Mid Oceanic Ridges Volcanoes**
     - These volcanoes occur in the oceanic area.
     - The centre portion of the ridge experiences frequent eruptions.

Volcanic Landforms

Intrusive forms

- The lava that is released during volcanic eruptions on cooling develops into igneous rocks.
- Depending on the location of the cooling of lava, igneous rocks are classified as
  i. Volcanic rocks - cooling at the surface
  ii. Plutonic rocks - cooling in the crust
- The lava that cools within the crustal portions assumes different forms called as intrusive forms. They are

1. **Batholith**
   - A large body of magmatic material that cools in the deeper depth of the crust develops in the form of large domes.
   - They appear on the surface only after the denudational processes remove the overlying materials.
   - They cover large areas, and at times, assume depth that may be several km. These are granitic bodies.
   - Batholiths are the cooled portion of magma chambers.
2. **Lacolith**
   - These are large dome shape intrusive bodies with a level base and connected by a pipe like conduit from below.
   - It resembles the surface volcanic domes of composite volcano, only these are located at deeper depths.
   - It can be regarded as the localised source of lava that finds its way to the surface.
   - The Karnataka plateau is spotted with domal hills of granite rocks.
3. **Lapolith**
   - As and when the lava moves upwards, a portion of the same may tend to move in a horizontal direction wherever it finds a weak plane.
   - It may get rested in different forms. In case it develops into a saucer shape, concave to the sky body, it is called lapolith.
4. **Phacolith**
   - A wavy mass of intrusive rocks, at times, is found at the base of synclines or at the top of anticline in folded igneous country. Such wavy materials have a definite conduit to source beneath in the form of magma chambers (subsequently developed as batholiths). These are called the phacoliths.
5. **Sills and Sheets**
   - The near horizontal bodies of the intrusive igneous rocks are called sill or sheet, depending on the thickness of the material.
   - The thinner ones are called sheets while the thick horizontal deposits are called sills.
6. **Dykes**
   - When the lava makes its way through cracks and the fissures developed in the land, it solidifies almost perpendicular to the ground.
   - It gets cooled in the same position to develop a wall-like structure. Such structures are called dykes.
   - These are the most commonly found intrusive forms in the western Maharashtra area. These are considered the feeders for the eruptions that led to the development of the Deccan raps.

3 Distribution of Oceans and Continents

Continental Drift Theory

- Alfred Wegener – a German meteorologist put forth this theory in the year 1912
- According to Wegener all continents formed a single continental mass and mega ocean surrounded the same.
- The super Continent was named PANGEA, which meant all earth. The mega-ocean was called PANTHALASSA, meaning all water.
- Around 200 million year ago, Pangea broke into two large continental masses as Laurasia and Gondwanaland.

Evidence in Support of the Continental Drift theory:

1. The Matching of Continents (Jig-saw-fit)
    - The shorelines of Africa and South America facing each other have a remarkable and unmistakable match.
2. Rocks of Same Age Across the Oceans
    - The belt of ancient rocks of 2000 million years from Brazil coast matches with those from Western Africa.
    - The earliest marine deposits along the coastline of South Africa and Africa are of the Jurassic Age. This suggests that the ocean did not exist prior to that time.
3. Tillite
    - It is the sedimentary rocks formed out of the deposits of glaciers.
    - The Gondwana system of sediments from India is known to have its counter parts in six different landmasses of the Southern Hemisphere.
    - At the base the system has thick tillite indicating extensive and prolonged glaciation. Counter parts of this succession are found in Africa, Falkland Island, Madagascar, Antarctica and Australia besides India.
    - The glacial tillite provides unambiguous evidence of paleoclimates and also of drifting of continents.
4. Placer Deposits
    - The occurrence of rich placer deposits of gold in the Ghana coast and the absolute absence of source rock in the region is an amazing fact. The gold bearing veins are in Brazil and it is obvious that the gold deposits of the Ghana are derived from the Brazil plateau when the two continents lay side by side.
5. Distribution of fossils
    - The observations that Lemurs occur in India, Madagascar and Africa led some to consider a contiguous landmass "Lemuria" linking these three landmasses.
    - Mesosaurus was a small reptile adapted to shallow brackish water. The skeletons of these are found only in two localities: The Southern Cape province of South Africa and Iraver formations of Brazil. The two localities presently are 4,800 km apart with an ocean in between them.

Force for Drifting:

- Wegener suggested that the movement responsible for the drifting of the continents was caused by
  1. Pole-fleeing force
  2. Tidal force
- Pole-Fleeing Force: The polar-fleeing force relates to the rotation of the earth. The earth is not a perfect sphere; it has a bulge at the equator. This bulge is due to the rotation of the earth.
- Tidal Force: It is due to the attraction of the moon and the sun that develops tides in oceanic waters.

Conventional Current Theory

- Arthur Holmes in 1930s discussed the possibility of convection currents operating in the mantle portion.
- These currents are generated due to radioactive elements causing thermal differences in the mantle portion. Holmes argued that there exists a system of such currents in the entire mantle portion.

Mapping of the Ocean Floor:

- The mid-oceanic ridges were found to be most active in terms of volcanic eruptions.
- The dating of the rocks from the oceanic crust revealed the fact that they are much younger than the continental areas.
- Rocks on either side of the crest of oceanic ridges and having equi-distant locations from the crest were found to have remarkable similarities both in terms of their constituents and their age.

Ocean Floor Configuration:

- The ocean floor may be segmented into three major divisions based on the depth as well as the forms of relief. These divisions are continental margins, deep-sea basins and mid-ocean ridges.
  1. **Continental Margins**
     - These form the transition between continental shores and deep-sea basins.
     - They include continental shelf, continental slope, continental rise and deep-oceanic trenches.
  2. **Abyssal Plains**
     - These are extensive plains that lie between the continental margins and mid-oceanic ridges.
     - The abyssal plains are the areas where the continental sediments that move beyond the margins get deposited.
  3. **Mid-Oceanic Ridges**
     - This forms an interconnected chain of mountain system within the ocean.
     - It is the longest mountain-chain on the surface of the earth though submerged under the oceanic waters.
     - It is characterised by a central rift system at the crest, a fractionated plateau and flank zone all along its length.
     - The rift system at the crest is the zone of intense volcanic activity.

Distribution of Earth quakes and volcanoes:

- The foci of the earthquake in the areas of mid-oceanic ridges are at shallow depths whereas along the Alpine-Himalayan belt as well as the rim of the Pacific, the earthquakes are deep-seated ones.
- The map of volcanoes also shows a similar pattern. The rim of the Pacific is also called rim of fire due to the existence of active volcanoes in this area.

Concept Of Sea Floor Spreading

- The mapping of the ocean floor and palaeomagnetic studies of rocks from oceanic regions revealed the following facts:
  - i. It was realised that all along the mid oceanic ridges, volcanic eruptions are common and they bring huge amounts of lava to the surface in this area.
  - ii. The age of the rocks increases as one moves away from the crest.
  - iii. The ocean crust rocks are much younger than the continental rocks. The sediments on the ocean floor are unexpectedly very thin.
  - iv. The deep trenches have deep-seated earthquake occurrences while in the mid oceanic ridge areas, the quake foci have shallow depths.
- These facts and a detailed analysis of magnetic properties of the rocks on either sides of the mid-oceanic ridge led Hess (1961) to propose his hypothesis, known as the "sea floor spreading".

Plate Tectonics

- McKenzie, Parker and Morgan came out with the concept termed as Plate Tectonics in 1967.
- A tectonic plate (also called lithospheric plate) is a massive, irregularly-shaped slab of solid rock, generally composed of both continental and oceanic lithosphere.
- Plates move horizontally over the asthenosphere as rigid units.
- The lithosphere includes the crust and top mantle with its thickness range varying between 5 and 100 km in oceanic parts and about 200 km in the continental areas.
- A plate may be referred to as the continental plate or oceanic plate depending on which of the two occupy a larger portion of the plate.
- Pacific plate is largely an oceanic plate whereas the Eurasian plate may be called a continental plate.
- The theory of plate tectonics proposes that the earth's lithosphere is divided into seven major and some minor plates.
- Young Fold Mountain ridges, trenches, and/or faults surround these major plates

The Major Plates are as follows:

1. Antarctica and the surrounding oceanic plate
2. North American (with western Atlantic floor separated from the South American plate along the Caribbean islands) plate
3. South American (with western Atlantic floor separated from the North American plate along the Caribbean islands) plate
4. Pacific plate
5. India-Australia-New Zealand plate
6. Africa with the eastern Atlantic floor plate
7. Eurasia and the adjacent oceanic plate.

The Minor Plates are as follows:

1. Cocos plate: Between Central America and Pacific plate
2. Nazca plate: Between South America and Pacific plate
3. Arabian plate: Mostly the Saudi Arabian landmass
4. Philippine plate: Between the Asiatic and Pacific plate

5. Caroline plate: Between the Philippine and Indian plate (North of New Guinea)
6. Fuji plate: North-east of Australia.

Types of Plate Boundaries:

Divergent Boundaries:

- Where new crust is generated as the plates pull away from each other.
- The sites where the plates move away from each other are called spreading sites.
- The best-known example of divergent boundaries is the Mid-Atlantic Ridge.

Convergent Boundaries:

- Where the crust is destroyed as one plate dived under another. The location where sinking of a plate occurs is called a subduction zone. There are three ways in which convergence can occur.
- These are:
  - i. Between an oceanic and continental plate
  - ii. Between two oceanic plates
  - iii. Between two continental plates.

Transform Boundaries:

- Where the crust is neither produced nor destroyed as the plates slide horizontally past each other.
- Transform faults are the planes of separation generally perpendicular to the mid-oceanic ridges.
- As the eruptions do not take all along the entire crest at the same time, there is a differential movement of a portion of the plate away from the axis of the earth.
- Also, the rotation of the earth has its effect on the separated blocks of the plate portions.

Rate of Plate Movement:

- The strips of normal and reverse magnetic field that parallel the mid-oceanic ridges help scientists determine the rates of plate movement. These rates vary considerably.
- The Arctic Ridge has the slowest rate (less than 2.5 cm/yr), and the East Pacific Rise near Easter Island, in the South Pacific about 3,400 km west of Chile, has the fastest rate (more than 15 cm/yr.)

Force for the Plate Movement:

- Concepts of sea floor spreading and the unified theory of plate tectonics have emphasized that both the surface of the earth and the interior are not static and motionless but are dynamic.
- The mobile rock beneath the rigid plates is believed to be moving in a circular manner.
- The heated material rises to the surface, spreads and begins to cool, and then sinks back into deeper depths. This cycle is repeated over and over to generate what scientists call a convection cell or convective flow.
- Heat within the earth comes from two main sources:
  - i. Radioactive decay
  - ii. Residual heat

Movement of the Indian Plate:

- The Indian plate includes Peninsular India and the Australian continental portions.
- The subduction zone along the Himalayas forms the northern plate boundary in the form of continent-continent convergence.

- In the east, it extends through Rakinyoma Mountains of Myanmar towards the island arc along the Java Trench. The eastern margin is a spreading site lying to the east of Australia in the form of an oceanic ridge in SW Pacific.
- The Western margin follows Kirthar Mountain of Pakistan. It further extends along the Makrana coast and joins the spreading site from the Red Sea rift south-eastward along the Chagos Archipelago.
- The boundary between India and the Antarctic plate is also marked by oceanic ridge (divergent boundary) running in roughly W-E direction and merging into the spreading site, a little south of New Zealand.
- India was a large island situated off the Australian coast, in a vast ocean. The Tethys Sea separated it from the Asian continent till about 225 million years ago.
- India is supposed to have started her northward journey about 200 million years ago at the time when Pangaea broke. India collided with Asia about 40-50 million years ago causing rapid uplift of the Himalayas.
- The two major plates were separated by the Tethys Sea and the Tibetan block was closer to the Asiatic landmass. During the movement of the Indian plate towards the Asiatic plate, a major event that occurred was the outpouring of lava and formation of the Deccan Traps.
- Scientists believe that the process is still continuing and the height of the Himalayas is rising even to this date.

Unit - II LANDFORMS

1 Minerals and Rocks

- Mineral is a naturally occurring organic and inorganic substance, having an orderly atomic structure and a definite chemical composition and physical properties.
- A mineral is composed of two or more elements. But, sometimes single element minerals like sulphur, copper, silver, gold, graphite etc. are found. These elements are in solid form in the outer layer of the earth and in hot and molten form in the interior.
- About 98 per cent of the total crust of the earth is composed of eight elements: -

Oxygen	46.60
Silicon	27.72
Aluminium	8.13
Iron	5.00
Calcium	3.63
Sodium	2.83
Potassium	2.59
Magnesium	2.09
Others	1.41

- The basic source of all minerals is the hot magma in the interior of the earth. When magma cools, crystals of minerals appear and a systematic series of minerals are formed in sequence to solidify so as to form rocks.
- Minerals such as coal, petroleum and natural gas are organic substances found in solid, liquid and gaseous forms respectively.

Rocks

- The earth's crust is composed of rocks. A rock is an aggregate of one or more minerals. Rock may be hard or soft and in varied colours.
- Rocks do not have definite composition of mineral constituents. Feldspar and quartz are the most common minerals found in rocks.
- Petrology is science of rocks. A petrologist studies rocks in all their aspects viz., mineral composition, texture, structure, origin, occurrence, alteration and relationship with other rocks.

Types of Rocks

1. Igneous Rocks

- As igneous rocks form out of magma and lava from the interior of the earth, they are known as primary rocks.

- The igneous rocks are formed when magma cools and solidifies. When magma in its upward movement cools and turns into solid form it is called igneous rock.
- The process of cooling and solidification can happen in the earth's crust or on the surface of the earth.
- Igneous rocks are classified based on texture. Texture depends upon size and arrangement of grains or other physical conditions of the materials.
  i. If molten material is cooled slowly at great depths, mineral grains may be very large.
  ii. Sudden cooling (at the surface) results in small and smooth grains.
  iii. Intermediate conditions of cooling would result in intermediate sizes of grains making up igneous rocks.
- Granite, gabbro, pegmatite, basalt, volcanic breccia and tuff are some of the examples of igneous rocks.

2. Sedimentary Rocks

- Rocks (igneous, sedimentary and metamorphic) of the earth's surface are exposed to denudational agents, and are broken up into various sizes of fragments. Such fragments are transported by different exogenous agencies and deposited. These deposits through compaction turn into rocks. This process is called lithification.
- In many sedimentary rocks, the layers of deposits retain their characteristics even after lithification. Hence, we see a number of layers of varying thickness in sedimentary rocks like sandstone, shale etc.
- Depending upon the mode of formation, sedimentary rocks are classified into three major groups:
  a) Mechanically formed — Sandstone, conglomerate, limestone, shale, loess etc.,
  b) Organically formed — Geyserite, chalk, limestone, coal etc.,
  c) Chemically formed — Chert, limestone, halite, potash etc.,

3. Metamorphic Rocks

- The word metamorphic means 'change of form'. These rocks form under the action of pressure, volume and temperature (PVT) changes.
- Metamorphism occurs when rocks are forced down to lower levels by tectonic processes or when molten magma rising through the crust comes in contact with the crustal rocks or the underlying rocks are subjected to great amounts of pressure by overlying rocks.
- Metamorphism is a process by which already consolidated rocks undergo recrystallisation and reorganisation of materials within original rocks.
  i. Mechanical disruption and reorganisation of the original minerals within rocks due to breaking and crushing without any appreciable chemical changes is called **dynamic metamorphism.**
  ii. The materials of rocks chemically alter and recrystallise due to **thermal metamorphism.** There are two types of thermal metamorphism
    a) Contact metamorphism
      - In contact metamorphism the rocks come in contact with hot intruding magma and lava and the rock materials recrystallise under high temperatures. Quite often new materials form out of magma or lava are added to the rocks.

    b) Regional metamorphism
      - In regional metamorphism, rocks undergo recrystallisation due to deformation caused by tectonic shearing together with high temperature or pressure or both.
- In the process of metamorphism in some rocks grains or minerals get arranged in layers or lines. Such an arrangement of minerals or grains in metamorphic rocks is called foliation or lineation.

- Sometimes minerals or materials of different groups are arranged into alternating thin to thick layers appearing in light and dark shades. Such a structure in metamorphic rocks is called banding and rocks displaying banding are called banded rocks.
- Types of metamorphic rocks depend upon original rocks that were subjected to metamorphism. Metamorphic rocks are classified into two major groups — foliated rocks and non-foliated rocks. Gneissoid, granite, syenite, slate, schist, marble, quartzite etc. are some examples of metamorphic rocks.

Rock Cycle

- Rocks do not remain in their original form for long but may undergo transformation. Rock cycle is a continuous process through which old rocks are transformed into new ones.
- Igneous rocks are primary rocks and other rocks (sedimentary and metamorphic) form from these primary rocks. Igneous rocks can be changed into metamorphic rocks.
- The fragments derived out of igneous and metamorphic rocks form into sedimentary rocks. Sedimentary rocks themselves can turn into fragments and the fragments can be a source for formation of sedimentary rocks.
- The crustal rocks (igneous, metamorphic and sedimentary) once formed may be carried down into the mantle (interior of the earth) through subduction process (parts or whole of crustal plates going down under another plate in zones of plate convergence) and the same melt down due to increase in temperature in the interior and turn into molten magma, the original source for igneous rocks.

2 Geomorphic Process

- The earth's crust is dynamic. The earth's surface is being continuously subjected to
  i. By external forces originating within the earth's atmosphere – **EXOGENIC**
     - The actions of exogenic forces result in wearing down (degradation) of relief/elevations and filling up of basins/depressions (aggradation), on the earth's surface.
     - The phenomenon of wearing down of relief variations of the surface of the earth through erosion is known as gradation.
  ii. By internal forces from within the earth – **ENDOGENIC**
     - The endogenic forces continuously elevate or build up parts of the earth's surface and hence the exogenic processes fail to even out the relief variations of the surface of the earth.
- In general terms, **the endogenic forces are mainly land building forces and the exogenic processes are mainly land wearing forces.**

Geomorphic Processes

- The endogenic and exogenic forces causing physical stresses and chemical actions on earth materials and bringing about changes in the configuration of the surface of the earth are known as geomorphic processes.
- Diastrophism and volcanism are endogenic geomorphic processes
- Weathering, mass wasting, erosion and deposition are exogenic geomorphic processes.
- Geomorphic Agent
  - Any exogenic element of nature capable of acquiring and transporting earth materials can be called a geomorphic agent.
  - An agent is a mobile medium which removes, transports and deposits earth materials.
  - Running water, groundwater, glaciers, wind, waves and currents, etc., can be called geomorphic agents.
- Gravity besides being a directional force activating all downslope movements of matter also causes stresses on the earth's materials. So, gravitational stresses are as important as the other geomorphic processes.

Endogenic Processes

- The energy emanating from within the earth is the main force behind endogenic geomorphic processes. This energy is mostly generated by radioactivity, rotational and tidal friction and primordial heat from the origin of the earth.
- This energy due to geothermal gradients and heat flow from within induces diastrophism and volcanism in the lithosphere.
- Due to variations in geothermal gradients and heat flow from within crustal thickness and strength, the action of endogenic forces is not uniform and hence the tectonically controlled original crustal surface is uneven.

Diastrophism:

- All processes that move, elevate or build up portions of the earth's crust come under diastrophism. They include
  i. Orogenic processes involving mountain building through severe folding and affecting long and narrow belts of the earth's crust.

ii. Epeirogenic processes involving uplift or warping of large parts of the earth's crust.
iii. Earthquakes involving local relatively minor movements.
iv. Plate tectonics involving horizontal movements of crustal plates.

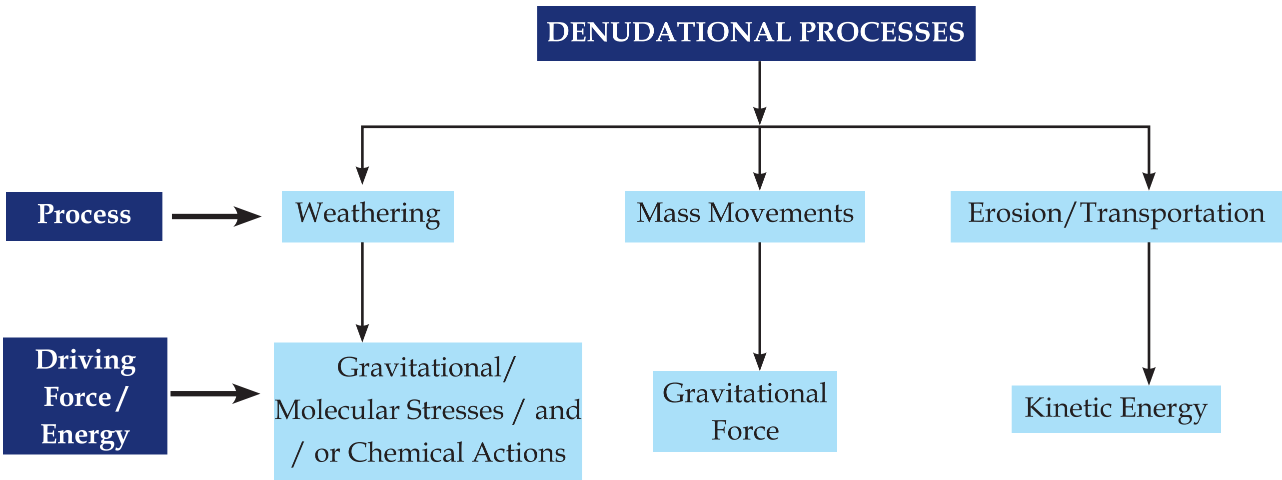
- **Orogeny:**
  - In the process of orogeny, the crust is severely deformed into folds.
  - Orogeny is a mountain building process.
- **Epeirogeny:**
  - Due to epeirogeny, there may be simple deformation.
  - Epeirogeny is continental building process.
- Through the processes of orogeny, epeirogeny, earthquakes and plate tectonics, there can be faulting and fracturing of the crust. All these processes cause pressure, volume and temperature (PVT) changes which in turn induce metamorphism of rocks.

Volcanism:

- Volcanism includes the movement of molten rock (magma) onto or toward the earth's surface and also formation of many intrusive and extrusive volcanic forms

Exogenic Processes

- The exogenic processes derive their energy from atmosphere determined by the ultimate energy from the sun and also the gradients created by tectonic factors.
- Temperature and precipitation are the two important climatic elements that control various processes.
- All the exogenic geomorphic processes are covered under a general term, denudation. The word 'denude' means to strip off or to uncover.



Weathering

- Weathering is action of elements of weather and climate over earth materials. There are a number of processes within weathering which act either individually or together to affect the earth materials in order to reduce them to fragmental state.
- Weathering is defined as mechanical disintegration and chemical decomposition of rocks through the actions of various elements of weather and climate.
- As very little or no motion of materials takes place in weathering, it is an in-situ or on-site process.

- There are three major groups of weathering processes:
  - (i) Chemical
  - (ii) Physical or mechanical
  - (iii) Biological weathering processes.
- Very rarely does any one of these processes ever operate completely by itself, but quite often a dominance of one process can be seen.

Chemical Weathering:

- A group of weathering processes viz; solution, carbonation, hydration, oxidation and reduction act on the rocks to decompose, dissolve or reduce them to a fine clastic state through chemical reactions by oxygen, surface and/or soil water and other acids.
- Water and air (oxygen and carbon dioxide) along with heat must be present to speed up all chemical reactions.

Physical Weathering:

- Physical or mechanical weathering processes depend on some applied forces. The applied forces could be:
  - i. Gravitational forces such as overburden pressure, load and shearing stress.
  - ii. Expansion forces due to temperature changes, crystal growth or animal activity.
  - iii. Water pressures controlled by wetting and drying cycles.
- Many of these forces are applied both at the surface and within different earth materials leading to rock fracture. Most of the physical weathering processes are caused by thermal expansion and pressure release.

Biological Activity and Weathering:

- Biological weathering is contribution to or removal of minerals and ions from the weathering environment and physical changes due to growth or movement of organisms.
- Burrowing and wedging by organisms like earthworms, termites, rodents etc., help in exposing the new surfaces to chemical attack and assists in the penetration of moisture and air.
- Human beings by disturbing vegetation, ploughing and cultivating soils, also help in mixing and creating new contacts between air, water and minerals in the earth materials.
- Decaying plant and animal matter help in the production of humic, carbonic and other acids which enhance decay and solubility of some elements.

Special Effects of Weathering:

Exfoliation

- Exfoliation is a result but not a process. Flaking off of more or less curved sheets of shells from over rocks or bedrock results in smooth and rounded surfaces.
- It can occur due to expansion and contraction induced by temperature changes. Exfoliation domes and tors result due to unloading and thermal expansion respectively.

Significance of Weathering:

- Weathering processes are responsible for breaking down the rocks into smaller fragments and preparing the way for formation of not only regolith and soils, but also erosion and mass movements.
- Biomes and bio- diversity is basically a result of forests (vegetation) and forests depend upon the depth of weathering mantles.

- Erosion cannot be significant if the rocks are not weathered. That means, weathering aids mass wasting, erosion and reduction of relief and changes in landforms are a consequence of erosion.
- Weathering of rocks and deposits helps in the enrichment and concentrations of certain valuable ores and helps in soil formation.

Mass Movements

- These movements transfer the mass of rock debris down the slopes under the direct influence of gravity.
- The movements of mass may range from slow to rapid, affecting shallow to deep columns of materials and include creep, flow, slide and fall.
- Gravity exerts its force on all matter, both bedrock and the products of weathering.
- Mass movements are very active over weathered slopes rather than over unweathered materials.
- Several activating causes precede mass movements. They are
  a) Removal of support from below to materials above through natural or artificial means
  b) Increase in gradient and height of slopes
  c) Overloading through addition of materials naturally or by artificial filling
  d) Overloading due to heavy rainfall, saturation and lubrication of slope materials
  e) Removal of material or load from over the original slope surfaces
  f) Occurrence of earthquakes, explosions or machinery
  g) Excessive natural seepage
  h) Heavy drawdown of water from lakes, reservoirs and rivers leading to slow outflow of water from under the slopes or river banks
  i) Indiscriminate removal of natural vegetation.
- Heave (heaving up of soils due to frost growth and other causes), flow and slide are the three forms of movements.

Landslides:

- Depending upon the type of movement of materials several types are identified in this category.
  a) Slump - slipping of one or several units of rock debris with a backward rotation with respect to the slope over which the movement takes place.
  b) Debris slide - Rapid rolling or sliding of earth debris without backward rotation of mass.
  c) Debris fall - Nearly a free fall of earth debris from a vertical or overhanging face.
  d) Rockslide - Sliding of individual rock masses down bedding, joint or fault surfaces. Rock sliding is very fast and destructive.
  e) Rock fall - free falling of rock blocks over any steep slope keeping itself away from the slope. Rock falls occur from the superficial layers of the rock face, an occurrence that distinguishes it from rockslide which affects materials up to a substantial depth.

Soil Formation

- Soil is a dynamic medium in which many chemical, physical and biological activities go on constantly. Soil is a result of decay; it is also the medium for growth. Biological activity is slowed or stopped if the soil becomes too cold or too dry. Organic matter increases when leaves fall or grasses die.

Process of Soil Formation

- Soil formation or pedogenesis depends first on weathering. It is this weathering mantle (depth of the weathered material) which is the basic input for soil to form.
- The dead remains of organisms and plants help in humus accumulation.

Soil-forming Factors

- Five basic factors control the formation of soils
  1. **Parent material**
  2. **Topography**
     - Soils will be thin on steep slopes and thick over flat upland areas
     - Over gentle slopes where erosion is slow and percolation of water is good, soil formation is very favourable. Soils over flat areas may develop a thick layer of clay with good accumulation of organic matter giving the soil dark colour.
  3. **Climate**
     - The climatic elements involved in soil development are
       - ***Moisture in terms of its intensity, frequency and duration of precipitation - evaporation and humidity***
         i. Excess of water helps in the downward transportation of soil components through the soil (eluviation) and deposits the same down below (illuviation).
         ii. In climates like wet equatorial rainy areas with high rainfall, not only calcium, sodium, magnesium, potassium etc. but also a major part of silica is removed from the soil. Removal of silica from the soil is known as desilication.
         iii. In dry climates, because of high temperature, evaporation exceeds precipitation and hence ground water is brought up to the surface by capillary action and in the process the water evaporates leaving behind salts in the soil. Such salts form into a crust in the soil known as hardpans.
         iv. In tropical climates and in areas with intermediate precipitation conditions, calcium carbonate nodules (kanker) are formed.
       - ***Temperature in terms of seasonal and diurnal variations.***
         i. Chemical activity is increased in higher temperatures, reduced in cooler temperatures (with an exception of carbonation) and stops in freezing conditions.
  4. **Biological activity**
     - Intensity of bacterial activity shows up differences between soils of cold and warm climates.
       - Humus accumulates in cold climates as bacterial growth is slow. With undecomposed organic matter because of low bacterial activity, layers of peat develop in subarctic and tundra climates.
       - With undecomposed organic matter because of low bacterial activity, layers of peat develop in subarctic and tundra climates.
       - In humid tropical and equatorial climates, bacterial growth and action is intense and dead vegetation is rapidly oxidised leaving very low humus content in the soil.
  5. **Time**
     - A soil becomes mature when all soil-forming processes act for a sufficiently long time developing a profile. Soils developing from recently deposited alluvium or glacial till are considered young and they exhibit no horizons or only poorly developed horizons.

3 Landform and their Evolution

- Small to medium tracts or parcels of the earth's surface are called landforms. Several related landforms together make up landscapes.
- Each landform has its own physical shape, size, materials and is a result of the action of certain geomorphic processes and agent(s).
- Many varieties of landforms develop by the action of each of the geomorphic agents depending upon especially the type and structure i.e. folds, faults, joints, fractures, hardness and softness, permeability and impermeability, etc.
- There are some other independent controls like (i) stability of sea level; (ii) tectonic stability of landmasses; (iii) climate, which influence the evolution of landforms.

Running Water

- In humid regions, which receive heavy rainfall running water is considered the most important of the geomorphic agents in bringing about the degradation of the land surface.
- There are two components of running water. One is overland flow on general land surface as a sheet. Another is linear flow as streams and rivers in valleys.
- Most of the erosional landforms made by running water are associated with vigorous and youthful rivers flowing over steep gradients, over the period of time due to continued erosion, and as a consequence, lose their velocity, facilitating active deposition.

Youth stage

- Few streams with poor integration and flow over shallow V-shaped valley with no or narrow flood plains along the trunk streams.
- Streams- divides are broad and flat with marshes, swamps lakes.
- Meanders- develop over broad upland surfaces. Waterfalls and rapids may exist on hard rock.

Mature stage

- More stream with good integration, with deep V-shaped valley, trunk streams are broader with wider flood plains.
- Meanders- flow of meander confined within the valley.
- Waterfalls and rapids, Flat and broad inter streams areas and swamps and marshes of youth stage disappears in this stage.

Old stage

- Few smaller tributaries with gentle gradients.
- Streams meander freely over vast floodplains showing natural levees, oxbow lakes, etc. Divides are broad and flat with lakes, swamps and marshes. Most of the landscape is at or slightly above sea level.

EROSIONAL LANDFORMS

Valleys

- Valleys start as small and narrow rills; the rills will gradually develop into long and wide gullies; the gullies will further deepen, widen and lengthen to give rise to valleys.
- Depending upon dimensions and shape, many types of valleys like V-shaped valley, gorge, canyon, etc. can be recognised.
- Valley types depend upon the type and structure of rocks in which they form.
- Gorge- deep valley with very steep to straight sides and it is almost equal width at its top as well as both bottom and top. Gorge forms in hard rocks.
- Canyon- steep step like side slopes and may be as deep as gorge. It is wider at its top than at it bottom.

Potholes and Plunge Pools

- The rocky beds of hill-streams more or less circular depressions called potholes form because of stream erosion aided by the abrasion of rock fragments.
- Once a small and shallow depression forms, pebbles and boulders get collected and get rotated by flowing water and consequently the depressions grow in dimensions.
- A series of such depressions eventually join and the stream valley gets deepened. At the foot of waterfalls also, large potholes, quite deep and wide, form because of the sheer impact of water and rotation of boulders. Such large and deep holes at the base of waterfalls are called plunge pools.

Incised or Entrenched Meanders

- In streams that flow rapidly over steep gradients, normally erosion is concentrated on the bottom of the stream channel.
- In the case of steep gradient streams, lateral erosion on the sides of the valleys is not much when compared to the streams flowing on low and gentle slopes.
- Because of active lateral erosion, streams flowing over gentle slopes, develop sinuous or meandering courses.
- Entrenched meanders- It is common to find meandering courses over floodplains and delta plains where stream gradients are very gentle. But very deep and wide meanders can also be found cut in hard rocks.
- Meander loops develop over original gentle surfaces in the initial stages of development of streams and the same loops get entrenched into the rocks normally due to erosion or slow, continued uplift of the land over which they start.
- They widen and deepen over time and can be found as deep gorges and canyons in hard rock areas.

River Terraces

- River terraces are surfaces marking old valley floor or floodplain levels.
- The river terraces may occur at the same elevation on either side of the rivers in which case they are called paired terraces.
- When a terrace is present only on one side of the stream and with none on the other side or one at quite a different elevation on the other side, the terraces are called unpaired terraces.
- Unpaired terraces are typical in areas of slow uplift of land or where the water column changes are not uniform along both the banks.

- The terraces may result due to
  - (i) Receding water after a peak flow
  - (ii) Change in hydrological regime due to climatic changes
  - (iii) Tectonic uplift of land
  - (iv) Sea level changes in case of rivers closer to the sea.

Depositional Landforms

Alluvial Fans

- Alluvial fans are formed when streams flowing from higher levels break into foot slope plains of low gradient.
- The coarse load is carried by streams flowing over mountain slopes and it becomes too heavy for the streams to be carried over gentler gradients and gets dumped and spread as a broad low to high cone shaped deposit called alluvial fan.
- The streams which flow over fans are not confined to their original channels for long and shift their position across the fan forming many channels called distributaries.

Deltas

- Deltas are like alluvial fans but develop at a different location.
- The load carried by the rivers is dumped and spread into the sea. If this load is not carried away far into the sea or distributed along the coast, it spreads and accumulates as a low cone.
- Unlike in alluvial fans, the deposits making up deltas are very well sorted with clear stratification. The coarsest materials settle out first and the finer fractions like silts and clays are carried out into the sea. As the delta grows, the river distributaries continue to increase in length and continues to build up into the sea.

Floodplains, Natural Levees and Point Bars

- Floodplain is a major landform of river deposition. Large sized materials are deposited first when stream channel breaks into a gentle slope and fine sized materials like sand, silt and clay are carried by relatively slow-moving waters in gentler channels usually found in the plains and deposited over the bed and when the waters spill over the banks during flooding above the bed.
- The floodplain above the bank is inactive floodplain. Inactive floodplain above the banks basically contain two types of deposits — flood deposits and channel deposits.
- In plains, channels shift laterally and change their courses occasionally leaving cut-off courses which get filled up gradually. Such areas over flood plains built up by abandoned or cut-off channels contain coarse deposits.
- The flood deposits of spilled waters carry relatively finer materials like silt and clay. The flood plains in a delta are called delta plains.
- Natural levees- found along the banks of large rivers. They are low, linear and parallel ridges of coarse deposits along the banks of rivers, quite often cut into individual mounds.
- Point bars are also known as meander bars. They are found on the convex side of meanders of large rivers and are sediments deposited in a linear fashion by flowing waters along the bank.

Meanders

- Loop-like channel patterns called meanders develop over flood and delta plains.
- Meander is not a landform but is only a type of channel pattern. This is because of

(i) Propensity of water flowing over very gentle gradients to work laterally on the banks

(ii) Unconsolidated nature of alluvial deposits making up the banks with many irregularities which can be used by water exerting pressure laterally

(iii) Coriolis force acting on the fluid water deflecting it like it deflects the wind.

- When the gradient of the channel becomes extremely low, water flows leisurely and starts working laterally and irregularities along the banks slowly get transformed into a small curvature in the banks; the curvature deepens due to deposition on the inside of the curve and erosion along the bank on the outside.
- If there is no deposition and no erosion or undercutting, the tendency to meander is reduced. Normally, in meanders of large rivers, there is active deposition along the concave bank and undercutting along the convex bank. The concave bank is known as cut-off bank which shows up as a steep scarp and the convex bank presents a long, gentle profile.
- As meanders grow into deep loops, the same may get cut-off due to erosion at the inflection points and are left as ox-bow lakes.

Braided Channels

- When rivers carry coarse material, there can be selective deposition of coarser materials causing formation of a central bar which diverts the flow towards the banks; and this flow increases lateral erosion on the banks.
- Deposition and lateral erosion of banks are essential for the formation of braided pattern.

Groundwater

- The surface water percolates well when the rocks are permeable, thinly bedded and highly jointed and cracked. Physical or mechanical removal of materials by moving groundwater is insignificant in developing landforms.
- In rocks like limestones or dolomites rich in calcium carbonate, the surface water as well as groundwater through the chemical process of solution and precipitation deposition develop varieties of landforms. These two processes of solution and precipitation are active in limestones or dolomites occurring either exclusively or interbedded with other rocks. Any limestone or dolomitic region showing typical landforms produced by the action of groundwater through the processes of solution and deposition is called Karst topography.
- The karst topography is also characterised by erosional and depositional landforms.

Erosional Landforms

Pools, Sinkholes, Lapies and Limestone pavements

- Small to medium sized round to sub-rounded shallow depressions called **swallow holes** form on the surface of limestones through solution.
- Sinkholes are very common in limestone/karst areas. A **sinkhole** is an opening more or less circular at the top and funnel-shaped towards the bottom.
- The term doline is sometimes used to refer the collapse sinks. When sink holes and dolines join together because of slumping of materials along their margins or due to roof collapse of caves, long, narrow to wide trenches called **Valley Sinks** or **Uvalas** formation.
- These ridges or Lapies form due to differential solution activity along parallel to sub-parallel joints. The Lapie field may eventually turn into smooth **limestone pavements.**

Caves

- In areas where there are alternating beds of rocks with limestones or dolomites in between or in areas where limestones are dense, massive and occurring as thick beds, **cave formation** is prominent.
- Water percolates down either through the materials or through cracks and joints and moves horizontally along bedding planes that the limestone dissolves and long and narrow to wide gaps called caves result.

Depositional Landforms

- Many depositional forms develop within the limestone caves. The chief chemical in limestone is calcium carbonate which is easily soluble in carbonated water.

Stalactites, Stalagmites and Pillars

- **Stalactites** hang as icicles of different diameters; they are broad at their bases and taper towards the free ends showing up in a variety of forms.
- **Stalagmites** rise up from the floor of the caves. It formed due to dripping water from the surface or through the thin pipe, of the stalactite, immediately below it.
- The stalagmite and stalactites eventually fuse to give rise to **columns and pillars** of different diameters.

Glaciers

- Masses of ice moving as sheets over the land or as linear flows down the slopes of mountains in broad trough-like valleys are called **glaciers.**

Cirque

- The cirques quite often are found at the heads of glacial valleys. The accumulated ice cuts these cirques while moving down the mountain tops.
- A lake of water can be seen quite often within the cirques after the glacier disappears. Such lakes are called **cirque or tarn lakes.**

Horns and Serrated Ridges

- Horns form through head ward erosion of the cirque walls. If three or more radiating glaciers cut headward until their cirques meet, high, sharp pointed and steep sided peaks called **horns.**

Glacial Valleys/Troughs

- **Glaciated valleys** are trough-like and U -shaped with broad floors and relatively smooth, and steep sides.
- The valleys contain littered debris or debris shaped as **moraines** with swampy appearance.
- **Hanging valleys** at an elevation on one or both sides of the main glacial valley. The faces of divides or spurs of such hanging valleys opening into main glacial valleys are quite often truncated to give them an appearance like triangular facets.
- Very deep glacial troughs filled with sea water and making up shorelines (in high latitudes) are called **fjords/fiords.**

Depositional Landforms

- The unassorted coarse and fine debris dropped by the melting glaciers is called glacial till.
- Some amount of rock debris small enough to be carried by such meltwater streams is washed down and deposited. Such glacio-fluvial deposits are called **outwash deposits.**

Moraines

- Moraines are long ridges of deposits of glacial till.
  i. Terminal moraines are long ridges of debris deposited at the end of the glaciers.
  ii. Lateral moraines form along the sides parallel to the glacial valleys.
- These moraines partly or fully owe their origin to glacio-fluvial waters pushing up materials to the sides of glaciers. Many valley glaciers retreating rapidly leave an irregular sheet of till over their valley floors. Such deposits varying greatly in thickness and in surface topography are called ground moraines.
- The moraine in the centre of the glacial valley flanked by lateral moraines is called medial moraine. They are imperfectly formed as compared to lateral moraines. Sometimes medial moraines are indistinguishable from ground moraines.

Eskers

- When glaciers melt in summer, the water flows on the surface of the ice or seeps down along the margins or even moves through holes in the ice. These waters accumulate beneath the glacier and flow like streams in a channel beneath the ice.
- The coarse materials like boulders and blocks along with some minor fractions of rock debris carried into this stream settle in the valley of ice beneath the glacier and after the ice melts can be found as a sinuous ridge called esker.

Outwash Plains

- The plains at the foot of the glacial mountains or beyond the limits of continental ice sheets are covered with glacio-fluvial deposits in the form of broad flat alluvial fans which may join to form outwash plains of gravel, silt, sand and clay.

Drumlins

- Drumlins are smooth oval shaped ridge-like features composed mainly of glacial till with some masses of gravel and sand.
- One end of the drumlins facing the glacier called the **stoss** end is blunter and steeper than the other end called **tail.** The drumlins form due to dumping of rock debris beneath heavily loaded ice through fissures in the glacier.
- The stoss end gets blunted due to pushing by moving ice. Drumlins give an indication of direction of glacier movement.

Waves and Currents

- Some of the changes along the coasts take place very fast. At one place, there can be erosion in one season and deposition in another. Most of the changes along the coasts are accomplished by waves.
- When waves break, the water is thrown with great force onto the shore, and simultaneously, there is a great churning of sediments on the sea bottom.
- Other than the action of waves, the coastal landforms depend upon
  (i) The configuration of land and sea floor
  (ii) Whether the coast is advancing (emerging) seaward or retreating (submerging) landward.
- Assuming sea level to be constant, two types of coasts are considered to explain the concept of evolution of coastal landforms:
  (i) High, rocky coasts (submerged coasts)
  (ii) Low, smooth and gently sloping sedimentary coasts (emerged coasts)

High Rocky Coasts

- Along the high rocky coasts, the rivers appear to have been drowned with highly irregular coastline. The coastline appears highly indented with extension of water into the land where glacial valleys (fjords) are present; waves break with great force against the land shaping the hill sides into cliffs. With constant pounding by waves, the cliffs recede leaving a wave-cut platform in front of the sea cliff.
- The materials which fall off, and removed from the sea cliffs, gradually break into smaller fragments and roll to roundness, will get deposited in the offshore.

Low Sedimentary Coasts

- Along low sedimentary coasts the rivers appear to extend their length by building coastal plains and deltas.
- The coastline appears smooth with occasional incursions of water in the form of lagoons and tidal creeks. The land slopes gently into the water. Marshes and swamps may abound along the coasts.
- When waves break over a gently sloping sedimentary coast, the bottom sediments get churned and move readily building bars, barrier bars, spits and lagoons.

Erosional Landforms

Cliffs, Terraces, Caves and Stacks

- Wave-cut cliffs and terraces are two forms usually found where erosion is the dominant shore process.
- The sea cliff platforms occurring at elevations above the average height of waves is called a **wave cut terrace.** The lashing of waves against the base of the cliff and the rock debris that gets smashed against the cliff along with lashing waves create hollows and these hollows get widened and deepened to form **sea caves.**
- The roofs of caves collapse and the sea cliffs recede further inland. Retreat of the cliff may leave some remnants of rock standing isolated as small islands just off the shore. Such resistant masses of rock, originally parts of a cliff or hill are called sea **stacks.**

Depositional Landforms

Beaches and Dunes

- Beaches are characteristic of shorelines that are dominated by deposition, but may occur as patches along even the rugged shores.
- Most of the sediment making up the beaches comes from land carried by the streams and rivers or from wave erosion. Beaches are temporary features.
- The sandy beach which appears so permanent may be reduced to a very narrow strip of coarse pebbles in some other season.
- Most of the beaches are made up of sand sized materials. Beaches called shingle beaches contain excessively small pebbles and even cobbles.
- Just behind the beach, the sands lifted and winnowed from over the beach surfaces will be deposited as sand dunes. Sand dunes forming long ridges parallel to the coastline are very common along low sedimentary coasts.

Bars, Barriers and Spits

- A ridge of sand and shingle formed in the sea in the off-shore zone lying approximately parallel to the coast is called an **off-shore bar.**
- An off-shore bar which is exposed due to further addition of sand is termed a **barrier bar.**

- The off-shore bars and barriers commonly form across the mouth of a river or at the entrance of a **bay.** Sometimes such barrier bars get keyed up to one end of the bay when they are called spits.
- Spits may also develop attached to headlands/hills. The barriers, bars and **spits.**
- at the mouth of the bay gradually extend leaving only a small opening of the bay into
- the sea and the bay will eventually develop into a **lagoon.**

Winds

- Wind is one of the two dominant agents in hot deserts. The desert floors get heated up too much and too quickly because of being dry and barren.
- The heated floors heat up the air directly above them and result in upward movements in the hot lighter air with turbulence, and any obstructions in its path sets up eddies, whirlwinds, updrafts and downdrafts.
- Winds cause deflation, abrasion and impact. Deflation includes lifting and removal of dust and smaller particles from the surface of rocks. In the transportation process sand and silt act as effective tools to abrade the land surface.
- In fact, many features of deserts owe their formation to mass wasting and running water as sheet floods. Though rain is scarce in deserts, it comes down torrentially in a short period of time.
- The desert rocks devoid of vegetation, exposed to mechanical and chemical weathering processes due to drastic diurnal temperature changes, decay faster and the torrential rains help in removing the weathered materials easily i.e. the weathered debris in deserts is moved by not only wind but also by rain/sheet wash.

Erosional Landforms

Pediments and Pediplains

- Landscape evolution in deserts is primarily concerned with the formation and extension of pediments. Gently inclined rocky floors close to the mountains at their foot with or without a thin cover of debris, are called pediments.
- Erosion starts along the steep margins of the landmass or the steep sides of the tectonically controlled steep incision features over the landmass. Once, pediments are formed with a steep wash slope followed by cliff or free face above it, the steep wash slope and free face retreat backwards.
- Through parallel retreat of slopes, the pediments extend backwards at the expense of mountain front, and gradually, the mountain gets reduced leaving an inselberg which is a remnant of the mountain. That’s how the high relief in desert areas is reduced to low featureless plains called Pediplains.

Playas

- Plains are by far the most prominent landforms in the deserts.
- In basins with mountains and hills around and along, the drainage is towards the centre of the basin and due to gradual deposition of sediment from basin margins, a nearly level plain forms at the centre of the basin.
- In times of sufficient water, this plain is covered up by a shallow water body. Such types of shallow lakes are called as playas where water is retained only for short duration due to evaporation and quite often the playas contain good deposition of salts, the playa plain covered up by salts is called alkali flats.

Deflation Hollows and Caves

- Weathered mantle from over the rocks or bare soil, gets blown out by persistent movement of wind currents in one direction. This process may create shallow depressions called deflation hollows.

- Deflation also creates numerous small pits or cavities over rock surfaces.
- The rock faces suffer impact and abrasion of wind-borne sand and first shallow depressions called blow outs are created, and this blow outs become deeper and wider fit to be called caves.

Mushroom, Table and Pedestal Rocks

- Many rock-outcrops in the deserts easily susceptible to wind deflation and abrasion are worn out quickly leaving some remnants of resistant rocks in the shape of mushroom.
- The top surface is broad like a table top and quite often, the remnants standout like pedestals.

Depositional Landforms

- Depending upon the velocity of wind, different sizes of grains are moved along the floors by rolling or saltation and carried in suspension and in this process of transportation itself, the materials get sorted.

Sand Dunes

- Dry hot deserts are good places for sand dune formation.
- Crescent shaped dunes called **barchans** with the points or wings directed away from downward wind direction.
- **Parabolic dunes** form when sandy surfaces are partially covered with vegetation.
- **Seif** is similar to barchan with a small difference. It has only one wing or point, this happens when there is shift in wind direction is constant.
- **Longitudinal dunes** form when supply of sand is poor and wind direction is constant. They appear as long ridges of considerable length but low in height.
- **Transverse dunes** are aligned perpendicular to wind direction. These dunes form when the wind direction is constant and the source of sand is an elongated feature at right angles to the wind direction.

Unit - III CLIMATE

1 Composition and Structure of Atmosphere

Composition of the Atmosphere

- The atmosphere is composed of gases, water vapour and dust particles.
- The proportion of gases changes in the higher layers of the atmosphere in such a way that oxygen will be almost in negligible quantity at the height of 120 km similarly carbon dioxide and water vapour are found only up to 90 km from the earth surface.

Gases

- Carbon dioxide is an important gas as it is transparent to the incoming solar radiation but opaque to the outgoing terrestrial radiation.
- It absorbs a part of terrestrial radiation and reflects back some part of it towards the earth's surface. It is largely responsible for the greenhouse effect.
- Ozone is another important component of the atmosphere found between 10 and 50 km above the earth's surface and acts as a filter and absorbs the ultra-violet rays radiating from the sun.

Water Vapour

- Water vapour is also a variable gas in the atmosphere, which decreases with altitude i.e. decreases from the equator towards poles.
- Water vapour also contributes to the stability and instability in the air.

Dust Particles

- Dust particles are generally concentrated in the lower layers of the atmosphere; yet, convectional air currents may transport them to great heights. The higher concentration of dust particles is found in subtropical and temperate regions due to dry winds in comparison to equatorial and polar regions.
- Dust and salt particles act as hygroscopic nuclei around which water vapour condenses to produce clouds.

Structure of the Atmosphere

- The atmosphere consists of different layers with varying density and temperature.
- Density is highest near the surface of the earth and decreases with increasing altitude.
- The column of atmosphere is divided into five different layers depending upon the temperature condition. They are:
    1. Troposphere
    2. Stratosphere
    3. Mesosphere

4. Thermosphere
5. Exosphere

Troposphere

- It is the lowermost layer of the atmosphere. Its average height is 13 km and extends roughly to a height of 8 km near the poles and about 18 km at the equator.
- Thickness of the troposphere is greatest at the equator because heat is transported to great heights by strong convectional currents.
- This layer contains dust particles and water vapour, **all changes in climate, weather and biological activity take place in this layer.**
- The zone separating the troposphere from stratosphere is known as the tropopause.

Stratosphere

- The stratosphere is found above the tropopause and extends up to a height of 50 km.
- The stratosphere contains the ozone layer. This layer absorbs ultra-violet radiation and shields life on the earth from intense, harmful form of energy.

Mesosphere

- The mesosphere lies above the stratosphere, which extends up to a height of 80 km. In this layer, once again, **temperature starts decreasing with the increase in altitude.**
- The upper limit of mesosphere is known as the mesopause.

Ionosphere

- The ionosphere is located between 80 and 400 km above the mesopause. It contains **electrically charged particles** known as ions, and hence, it is known as ionosphere.
- Radio waves transmitted from the earth are reflected back to the earth by this layer. Temperature here starts increasing with height. The uppermost layer of the atmosphere above the thermosphere.

Exosphere

- The uppermost layer of the atmosphere above the thermosphere is known as the exosphere.
- Whatever contents are there, these are extremely rarefied in this layer, and it gradually merges with the outer space.

2 Solar Radiation, Heat Balance and Temperature

- The earth receives almost all of its energy from the sun and it radiates back to space the energy received from the sun.
- The amount of heat received by different parts of the earth is not the same this variation causes pressure differences in the atmosphere and It leads to transfer of heat from one region to the other by winds.

Solar Radiation

- The earth's surface receives most of its energy in short wavelengths. The energy received by the earth is known as incoming solar radiation which in short is termed as **insolation.**
- As the earth is a geoid resembling a sphere, the sun's rays fall obliquely at the top of the atmosphere and the earth intercepts a very small portion of the sun's energy.
- During its revolution around the sun, the earth is farthest from the sun on 4th July- this position of the earth is called **aphelion.** On 3rd January, the earth is the nearest to the sun- this position is called **perihelion.**

Variability of Insolation at the Surface of the Earth

- The amount and the intensity of insolation vary during a day, in a season and in a year. The factors that cause these variations in insolation are:
  - i. The rotation of earth on its axis
  - ii. The angle of inclination of the sun's rays
  - iii. The length of the day
  - iv. The transparency of the atmosphere
  - v. The configuration of land in terms of its aspect.
- The fact that the earth's axis makes an angle of 66½ with the plane of its orbit round the sun has a greater influence on the amount of insolation received at different latitudes.
- The second factor that determines the amount of insolation received is the angle of inclination of the rays. This depends on the latitude of a place. The higher the latitude the less is the angle they make with the surface of the earth resulting in slant sun rays.
- The red colour of the rising and the setting sun and the blue colour of the sky are the result of scattering of light within the atmosphere.
- Maximum insolation is received over the subtropical deserts, where the cloudiness is the least. Equator receives comparatively less insolation than the tropics.
- Generally, at the same latitude the insolation is more over the continent than over the oceans. In winter, the middle and higher latitudes receive less radiation than in summer.

Heating And Cooling Of Atmosphere

- The earth after being heated by insolation transmits the heat to the atmospheric layers near to the earth in long wave form.
- **Conduction-** The process of air in contact with the land gets heated slowly and the upper layers in contact with the lower layers also get heated.

- Conduction takes place when two bodies of unequal temperature are in contact with one another, there is a flow of energy from the warmer to cooler body.

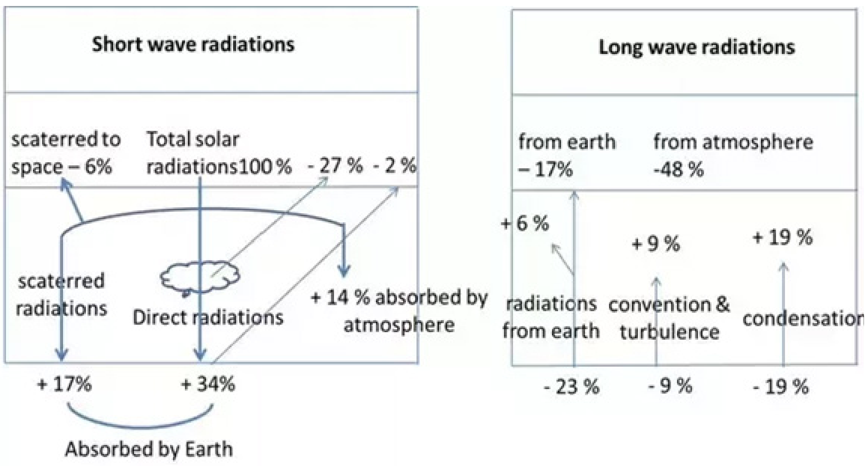
- **Convection** - The process of air in contact with the earth rises vertically on heating in the form of currents and further transmits the heat of the atmosphere.
  - The convective transfer of energy is confined only to the troposphere.
- The transfer of heat through horizontal movement of air is called advection.
  - In middle latitudes, most of diurnal variation in daily weather are caused by advection alone.
  - In tropical regions particularly in northern India during summer season local winds called 'loo' is the outcome of advection process.

Terrestrial Radiation

- Terrestrial Radiation- The insolation received by the earth is in short waves forms and heats up its surface. The earth after being heated itself becomes a radiating body and it radiates energy to the atmosphere in long wave form. This energy heats up the atmosphere from below.
- The long wave radiation is absorbed by the atmospheric gases particularly by carbon dioxide and the other greenhouse gases. Thus, the atmosphere is indirectly heated by the earth's radiation.

Heat Budget of the Planet Earth

- This can happen only if the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation.
- While passing through the atmosphere some amount of energy is reflected, scattered and absorbed and only the remaining part reaches the earth surface.
- The reflected amount of radiation is called the albedo of the earth.



Temperature

- The interaction of insolation with the atmosphere and the earth's surface creates heat which is measured in terms of temperature.
- **Factors Controlling Temperature Distribution:-**
- The temperature of air at any place is influenced by
  i. The latitude of the place
  ii. The altitude of the place

iii. Distance from the sea, the air-mass circulation
iv. The presence of warm and cold ocean currents
v. Local aspects

- **The latitude:** The temperature of a place depends on the insolation received. It has been explained earlier that the insolation varies according to the latitude hence the temperature also varies accordingly.
- **The altitude:** The atmosphere is indirectly heated by terrestrial radiation from below. Therefore, the places near the sea-level record higher temperature than the places situated at higher elevations.
- **Distance from the sea:** Another factor that influences the temperature is the location of a place with respect to the sea. Compared to land, the sea gets heated slowly and loses heat slowly; Land heats up and cools down quickly. Therefore, the variation in temperature over the sea is less compared to land.
- **Air-mass and Ocean currents:** Like the land and sea breezes, the passage of air masses also affects the temperature. The places, which come under the influence of warm airmasses experience higher temperature and the places that come under the influence of cold air-masses experience low temperature.

Distribution of Temperature: -

- The global distribution of temperature can well be understood by studying the temperature distribution in January and July.
- The **Isotherms** are lines joining places having equal temperature.
- In January the isotherms deviate to the north over the ocean and to the south over the continent.
- In July the isotherms generally run parallel to the latitude.

Inversion of Temperature

- Temperature decreases with increase in elevation it is called **normal lapse rate.**
- At times, the situations are reversed and the normal lapse rate is inverted it is called **Inversion of temperature.**
- A long winter night with clear skies and still air is ideal situation for inversion the heat of the day is radiated off during the night, and by early morning hours, the earth is cooler than the air above.
- Over polar areas, temperature inversion is normal throughout the year.
- Surface inversion promotes stability in the lower layers of the atmosphere.
- Smoke and dust particles get collected beneath the inversion layer and spread horizontally to fill the lower strata of the atmosphere.
- Dense fogs in mornings are common occurrences especially during winter season this inversion commonly lasts for few hours until the sun comes up and beings to warm the earth.
- The cold air acts almost like water and moves down the slope to pile up deeply in pockets and valley bottoms with warm air above this is called **air drainage.** It protects plants from frost damages.
- **Plank's law** states that hotter a body, the more energy it will radiate and shorter the wavelength of that radiation.
- **Specific heat** is the energy needed to raise the temperature of one gram of substance by one Celsius.

3 Atmospheric Circulation and Weather Systems

- Air expands when heated and gets compressed when cooled. This results in variations in the atmospheric pressure and it also determines when the air will rise or sink.
- The wind redistributes the heat and moisture across the planet, thereby, maintaining a constant temperature for the planet as a whole. The vertical rising of moist air cools it down to form the clouds and bring precipitation.

Atmospheric Pressure

- The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the atmospheric pressure.
- The pressure decreases with height. At any elevation it varies from place to place and its variation is the primary cause of air motion, i.e. wind which moves from high pressure areas to low pressure areas.

Vertical Variation of Pressure

- The vertical pressure gradient force is much larger than that of the horizontal pressure gradient. But it is generally balanced by a nearly equal but opposite gravitational force. Hence, we do not experience strong upward winds.

Horizontal Distribution of Pressure

- Horizontal distribution of pressure is studied by drawing isobars at constant levels. Isobars are lines connecting places having equal pressure.
- Low-pressure system is enclosed by one or more isobars with the lowest pressure in the centre.
- High-pressure system is also enclosed by one or more isobars with the highest pressure in the centre.

World Distribution of Sea Level Pressure

- Near the equator the sea level pressure is low and the area is known as **equatorial low.**
- Along 30° N and 30°S are found the high-pressure areas known as the subtropical highs. Further pole wards along 60° N and 60°S, the low-pressure belts are termed as the sub polar lows.
- Near the poles the pressure is high and it is known as the **polar high.**
- These pressure belts are not permanent in nature, in northern hemisphere in winter they move southwards and in summer northwards.

Forces Affecting the Velocity and Direction of Wind

- The air in motion is called wind. The wind blows from high pressure to low pressure. The wind at the surface experiences friction.
- In addition, rotation of the earth also affects the wind movement. The force exerted by the rotation of the earth is known as the **Coriolis force.**
- Thus, the horizontal winds near the earth surface respond to the combined effect of three forces – the pressure gradient force, the frictional force and the Coriolis force.

Pressure Gradient Force: -

- The differences in atmospheric pressure produces a force. The rate of change of pressure with respect to distance is the pressure gradient.
- The pressure gradient is strong where the isobars are close to each other and is weak where the isobars are apart.

Frictional Force: -

- It affects the speed of the wind. It is greatest at the surface and its influence generally extends up to an elevation of 1 - 3 km. Over the sea surface the friction is minimal.

Coriolis Force

- The rotation of the earth about its axis affects the direction of the wind. It deflects the wind to the right direction in the northern hemisphere and to the left in the southern hemisphere. The deflection is more when the wind velocity is high.
- The Coriolis force is directly proportional to the angle of latitude. It is **maximum at the poles and is absent at the equator.**
- The Coriolis force acts perpendicular to the pressure gradient force. The pressure gradient force is perpendicular to an isobar. The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind.
- As a result of these two forces operating perpendicular to each other, in the low-pressure areas the wind blows around it.
- At the equator, the Coriolis force is zero and the wind blows perpendicular to the isobars. The low pressure gets filled instead of getting intensified. That is the reason why tropical cyclones are not formed near the equator.

Pressure and Wind

- The velocity and direction of the wind are the net result of the wind generating forces.
- The winds in the upper atmosphere, 2 - 3 km above the surface, are free from frictional effect of the surface and are controlled mainly by the pressure gradient and the Coriolis force.
- When isobars are straight and when there is no friction, the pressure gradient force is balanced by the Coriolis force and the resultant wind blows parallel to the isobar. This wind is known as **the geostrophic wind.**
- The wind circulation around a low is called **cyclonic circulation.** Around a high it is called **anti cyclonic circulation.**
- The wind circulation at the earth's surface around low and high on many occasions is closely related to the wind circulation at higher level.

General circulation of the atmosphere

- The pattern of planetary winds largely depends on:
  - I. Latitudinal variation of atmospheric heating
  - II. Emergence of pressure belts
  - III. The migration of belts following apparent path of the sun
  - IV. The distribution of continents and oceans
  - V. The rotation of earth

- The pattern of the movement of the planetary winds is called **the general circulation of the atmosphere.** The general circulation of the atmosphere also sets in motion the ocean water circulation which influences the earth's climate.
- The air at the **Inter Tropical Convergence Zone** (ITCZ) rises because of convection caused by high insolation and a low pressure is created. The winds from the tropics converge at this low-pressure zone. The converged air rises along with the **convective cell.**
- It reaches the top of the troposphere up to an altitude of 14 km and moves towards the poles. This causes accumulation of air at about 30ºN and S.
- Part of the accumulated air sinks to the ground and forms a subtropical high. Another reason for sinking is the cooling of air when it reaches 30ºN and S latitudes. Down below near the land surface the air flows towards the equator as the easterlies.
- The easterlies from either side of the equator converge in the Inter Tropical Convergence Zone (ITCZ). Such circulations from the surface upwards and vice-versa are called cells. Such a cell in the tropics is called **Hadley Cell.**
- In the middle latitudes the circulation is that of sinking cold air that comes from the poles and the rising warm air that blows from the subtropical high. At the surface these winds are called westerlies and the cell is known as the **Ferrel cell.**
- At polar latitudes the cold dense air subsides near the poles and blows towards middle latitudes as the polar easterlies. This cell is called the **polar cell.**
- These three cells set the pattern for the general circulation of the atmosphere. The transfer of heat energy from lower latitudes to higher latitudes maintains the general circulation.
- The general circulation of the atmosphere also affects the oceans. The large-scale winds of the atmosphere initiate large and slow-moving currents of the ocean. Oceans in turn provide input of energy and water vapour into the air. These interactions take place rather slowly over a large part of the ocean.

Seasonal Wind

- The pattern of wind circulation is modified in different seasons due to the shifting of regions of maximum heating, pressure and wind belts. The most pronounced effect of such a shift is noticed in the monsoons, especially over Southeast Asia.

Local Winds

- Differences in the heating and cooling of earth surfaces and the cycles those develop daily or annually can create several common, local or regional winds.

Land and Sea Breezes

- During the day the land heats up faster and becomes warmer than the sea. Therefore, over the land the air rises giving rise to a low-pressure area, whereas the sea is relatively cool and the pressure over sea is relatively high. Thus, pressure gradient from sea to land is created and the wind blows from the sea to the land as the **sea breeze.**
- In the night the reversal of condition takes place. The land loses heat faster and is cooler than the sea. The pressure gradient is from the land to the sea and hence land breeze.

Mountain and Valley Winds

- In mountainous regions, during the day the slopes get heated up and air moves upslope and to fill the resulting gap the air from the valley blows up the valley. This wind is known as the valley breeze.
- During the night the slopes get cooled and the dense air descends into the valley as the mountain wind.

- The cool air, of the high plateaus and ice fields draining into the valley is called katabatic wind. Another type of warm wind occurs on the leeward side of the mountain ranges.
- The moisture in these winds, while crossing the mountain ranges condense and precipitate. When it descends down the leeward side of the slope the dry air gets warmed up by adiabatic process. This dry air may melt the snow in a short time.

Air Masses

- The air masses are classified according to the source regions. There are five major source regions. These are:
  I. Warm tropical and subtropical oceans
  II. The subtropical hot deserts
  III. The relatively cold high latitude oceans
  IV. The very cold snow-covered continents in high latitudes
  V. Permanently ice-covered continents in the Arctic and Antarctica

Fronts

- When two different air masses meet, the boundary zone between them is called a **front.** The process of formation of the fronts is known as frontogenesis. There are four types of fronts:
  a) Cold
  b) Warm
  c) Stationary
  d) Occluded.
- When the front remains stationary, it is called a **stationary front.**
- When the cold air moves towards the warm air mass, its contact zone is called the **cold front,** whereas if the warm air mass moves towards the cold air mass, the contact zone is a **warm front.**
- If an air mass is fully lifted above the land surface, it is called the **occluded front.**
- The fronts occur in middle latitudes and are characterised by steep gradient in temperature and pressure. They bring abrupt changes in temperature and cause the air to rise to form clouds and cause precipitation.

Extra Tropical Cyclones

- The systems developing in the mid and high latitude, beyond the tropics are called the middle latitude or extra tropical cyclones.
- The passage of front causes abrupt changes in the weather conditions over the area in the middle and high latitudes.
- In the northern hemisphere, warm air blows from the south and cold air from the north of the front.
- When the pressure drops along the front, the warm air moves northwards and the cold air move towards, south setting in motion an anticlockwise cyclonic circulation. The cyclonic circulation leads to a well-developed extra tropical cyclone, with a warm front and a cold front. The plan and cross section of a well-developed cyclone.
- There are pockets of warm air or warm sector wedged between the forward and the rear cold air or cold sector. The warm air glides over the cold air and a sequence of clouds appear over the sky ahead of the warm front and cause precipitation. The cold front approaches the warm air from behind and pushes the warm air up.
- As a result, cumulus clouds develop along the cold front. The cold front moves faster than the warm front ultimately overtaking the warm front. The warm air is completely lifted up and the front is occluded and the cyclone dissipates. The processes of wind circulation both at the surface and aloft are closely interlinked.

- The extra tropical cyclone differs from the tropical cyclone in number of ways. The extra tropical cyclones have a clear frontal system which is not present in the tropical cyclones.
- The extra tropical cyclone affects a much larger area as compared to the tropical cyclone. The wind velocity in a tropical cyclone is much higher and it is more destructive. The extra tropical cyclones move from west to east but tropical cyclones, move from east to west.

Tropical Cyclones

- Tropical cyclones are violent storms that originate over oceans in tropical areas and move over to the coastal areas bringing about large-scale destruction caused by violent winds, very heavy rainfall and storm surges are known as Cyclones in the Indian Ocean, Hurricanes in the Atlantic, Typhoons in the Western Pacific and South China Sea, and Willy-willies in the Western Australia.
- Tropical cyclones originate and intensify over warm tropical oceans. The conditions favourable for the formation and intensification of tropical storms are:
  I. Large sea surface with temperature higher than 27° C
  II. Presence of the Coriolis force
  III. Small variations in the vertical wind speed
  IV. A pre-existing weak low-pressure area or low-level-cyclonic circulation
  V. Upper divergence above the sea level system
- The energy that intensifies the storm, comes from the condensation process in the towering cumulonimbus clouds, surrounding the centre of the storm. With continuous supply of moisture from the sea, the storm is further strengthened. On reaching the land the moisture supply is cut off and the storm dissipates.
- The place where a tropical cyclone crosses the coast is called the landfall of the cyclone. The cyclones, which cross 20°N latitude generally, recurve and they are more destructive.
- A mature tropical cyclone is characterised by the strong spirally circulating wind around the centre, called the **eye.** The diameter of the circulating system can vary between 150 and 250 km.
- The eye is a region of calm with subsiding air. Around the eye is the eye wall, where there is a strong spiralling ascent of air to greater height reaching the tropopause.
- Torrential rain occurs here. From the eye wall rain bands may radiate and trains of cumulus and cumulonimbus clouds may drift into the outer region.
- The diameter of the storm over the Bay of Bengal, Arabian sea and Indian ocean is between 600 - 1200 km. The cyclone creates storm surges and they inundate the coastal low lands. The storm peters out on the land.
- Thunderstorms are caused by intense convection on moist hot days. A thunderstorm is a well-grown cumulonimbus cloud producing thunder and lightening.
- When the clouds extend to heights where sub-zero temperature prevails, hails are formed and they come down as hailstorm. If there is insufficient moisture, a thunderstorm can generate **dust storms.**
- A thunderstorm is characterised by intense updraft of rising warm air, which causes the clouds to grow bigger and rise to greater height and causes precipitation.
- Later, downdraft brings down to earth the cool air and the rain. From severe thunderstorms sometimes spiralling wind descends like a trunk of an elephant with great force, with very low pressure at the centre, causing massive destruction on its way, is a phenomenon is called a **tornado.**
- Tornadoes generally occur in middle latitudes and over the sea is called water **spouts.**
- The potential and heat energies are converted into kinetic energy in these storms and the restless atmosphere again returns to its stable state.

4 Water In The Atmosphere

- Water vapour present in the air is known as humidity.
- The actual amount of the water vapour present in the atmosphere is known as the **absolute humidity.**
- The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the **relative humidity.**
- The air containing moisture to its full capacity at a given temperature is said to be saturated. The temperature at which saturation occurs in a given sample of air is known as **dew point.**

Evaporation and Condensation

- The amount of water vapour in the atmosphere is added or withdrawn due to evaporation and condensation.
- The temperature at which the water starts evaporating is referred to as the **latent heat of vaporization.**
- Movement of air replaces the saturated layer with the unsaturated layer. Hence, the greater the movement of air, the greater is the evaporation.
- Condensation is caused by the loss of heat. When moist air is cooled, it may reach a level when its capacity to hold water vapour ceases. Then, the excess water vapour condenses into liquid form. If it directly condenses into solid form, it is known as **sublimation.**

Dew

- When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects such as stones, grass blades and plant leaves, it is known as dew.
- The ideal conditions for its formation are clear sky, calm air, high relative humidity, and cold and long nights. For the formation of dew, it is necessary that the dew point is above the freezing point.

Frost

- Frost forms on cold surfaces when condensation takes place below freezing point.
- The ideal conditions for the formation of white frost are the same as those for the formation of dew, except that the air temperature must be at or below the freezing point.

Fog and Mist

- When the temperature of an air mass containing a large quantity of water vapour falls all of a sudden, condensation takes place within itself on fine dust particles. So, the fog is a cloud with its base at or very near to the ground. Because of the fog and mist, the visibility becomes poor to zero.
- In urban and industrial centres smoke provides plenty of nuclei which help the formation of fog and mist. Such a condition when fog is mixed with smoke, is described as smog.
- The only difference between the mist and fog is that mist contains more moisture than the fog.
- Mists are frequent over mountains as the rising warm air up the slopes meets a cold surface. Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents.
- Fogs are mini clouds in which condensation takes place around nuclei provided by the dust, smoke, and the salt particles.

Clouds

- Cloud is a mass of minute water droplets or tiny crystals of ice formed by the condensation of the water vapour in free air at considerable elevations.
- As the clouds are formed at some height over the surface of the earth, they take various shapes.
- According to their height, expanse, density and transparency or opaqueness clouds are grouped under four types:
  I. Cirrus
  II. Cumulus
  III. Stratus
  IV. Nimbus

Cirrus:

- Cirrus clouds are formed at high altitudes (8,000 - 12,000m).
- They are thin and detached clouds having a feathery appearance. They are always white in colour.

Cumulus:

- Cumulus clouds look like cotton wool. They are generally formed at a height of 4,000m - 7,000 m.
- They exist in patches and can be seen scattered here and there and they have a flat base.

Stratus:

- As their name implies, these are layered clouds covering large portions of the sky.
- These clouds are generally formed either due to loss of heat or the mixing of air masses with different temperatures.

Nimbus:-

- Nimbus clouds are black or dark gray.
- They form at middle levels or very near to the surface of the earth. These are extremely dense and opaque to the rays of the sun.
- Sometimes, the clouds are so low that they seem to touch the ground. Nimbus clouds are shapeless masses of thick vapour.
  - A combination of these four basic types can give rise to the following types of clouds: high clouds – cirrus, cirrostratus, cirrocumulus; middle clouds – altostratus and altocumulus; low clouds – stratocumulus and nimbostratus and clouds with extensive vertical development – cumulus and cumulonimbus.

Precipitation

- The process of continuous condensation in free air helps the condensed particles to grow in size. When the resistance of the air fails to hold them against the force of gravity, they fall on to the earth's surface.
- After the condensation of water vapour, the release of moisture is known as precipitation. The precipitation in the form of water is called rainfall, when the temperature is lower than the zero degree Celsius, precipitation takes place in the form of fine flakes of snow and is called snowfall.
- Moisture is released in the form of hexagonal crystals. These crystals form flakes of snow. Besides rain and snow, other forms of precipitation are sleet and hail, though the latter are limited in occurrence and are sporadic in both time and space.
- Sleet is frozen raindrops and refrozen melted snow-water. Drops of rain after being released by the clouds become solidified into small rounded solid pieces of ice and which reach the surface of the earth are called **hailstones.**

Types of Rainfall

- On the basis of origin, rainfall may be classified into three main types – the convectional, orographic or relief and the cyclonic or frontal.

Convectional Rain:

- The, air on being heated, becomes light and rises up in convection currents.
- As it rises, it expands and loses heat and consequently, condensation takes place and cumulous clouds are formed.
- With thunder and lightening, heavy rainfall takes place but this does not last long this is common in the summer or in the hotter part of the day in the equatorial regions and interior parts of the continents, particularly in the northern hemisphere.

Orographic Rain: -

- When the saturated air mass comes across a mountain, it is forced to ascend and as it rises, it expands; the temperature falls, and the moisture is condensed.
- The chief characteristic of this sort of rain is that the windward slopes receive greater rainfall.
- After giving rain on the windward side, when these winds reach the other slope, they descend, and their temperature rises. Then their capacity to take in moisture increases and hence, these leeward slopes remain rainless and dry.
- The area situated on the **leeward side,** which gets less rainfall is known as the rain-shadow area. It is also known as the **relief rain.**

5 World Climate And Climate Change

Koeppen's Scheme Of Classification Of Climate

- The most widely used classification of climate is the empirical climate classification scheme developed by V. Koeppen. Koeppen identified a close relationship between the distribution of vegetation and climate. The table lists the climatic groups and their cha

Group	Characteristics
A - Tropical	Average temperature of the coldest month is 18ºC or higher
B - Dry Climates	Potential evaporation exceeds precipitation
C - Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3ºC but below 18ºC
D - Cold Snow Forest Climates	The average temperature of the coldest month is minus 3ºC but below
E - Cold Climates	Average temperature for all months is below 10ºC
H - High Land	Cold due to elevation

Group	Type	Letter Code	Characteristics
A - Tropical Humid Climate	Tropical wet	Af	No dry season
	Tropical monsoon	Am	Monsoonal, short dry season
	Tropical wet and dry	Aw	Winter dry season
B - Dry Climate	Subtropical steppe	BSh	Low-latitude semi arid or dry
	Subtropical desert	BWh	Low-latitude arid or dry
	Mid-latitude Steppe	BSk	Mid-latitude semi arid or dry
	Mid-latitude desert	BWk	Mid-latitude arid or dry
C-Warm temperate (Mid latitude) Climates	Humid subtropical	Cfa	No dry season, warn summer
	Mediterranean	Cs	Dry hot summer
	Marine west coast	Cfb	No dry season, warm and cool summer
D-Cold Snow-forest Climates	Humid continental	Df	No dry season, severe winter
	Subarctic	Dw	Winter dry and very severe
E-Cold Climates	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H-Highland	Highland	H	Highland with snow cover

Group A: Tropical Humid Climates

- Tropical humid climates exist between Tropic of Cancer and Tropic of Capricorn.
- The sun being overhead throughout the year and the presence of Inter Tropical Convergence Zone (ITCZ) make the climate hot and humid.

- Annual range of temperature is very low and annual rainfall is high.
- The tropical group is divided into three types, namely
  - I. Af- Tropical wet climate
  - II. Am - Tropical monsoon climate
  - III. Aw- Tropical wet and dry climate

Tropical Wet Climate (Af)

- Tropical wet climate is found near the equator.
- The major areas are the Amazon Basin in South America, western equatorial Africa and the islands of East Indies. Significant amount of rainfall occurs in every month of the year as thunder showers in the afternoon.
- The temperature is uniformly high and the annual range of temperature is negligible. The maximum temperature on any day is around 30°C while the minimum temperature is around 20°C.
- Tropical evergreen forests with dense canopy cover and large biodiversity are found in this climate.

Tropical Monsoon Climate (Am)

- It is found over the Indian sub-continent, North Eastern part of South America and Northern Australia.
- Heavy rainfall occurs mostly in summer, winter is dry.

Tropical Wet and Dry Climate (Aw)

- This climate occurs north and south of Af type climate regions and borders with dry climate on the western part of the continent and Cf or Cw on the eastern part.
- Extensive Aw climate is found to the north and south of the Amazon forest in Brazil and adjoining parts of Bolivia and Paraguay in South America, Sudan and south of Central Africa.
- Temperature is high throughout the year and diurnal ranges of temperature are the greatest in the dry season. Deciduous forest and tree-shredded grasslands occur in this climate.

Dry Climates: B

- Dry climates are characterised by very low rainfall that is not adequate for the growth of plants. These climates cover a very large area of the planet extending over large latitudes from 15° - 60° north and south of the equator.
- Dry climates are divided into steppe or semi-arid climate (BS) and desert climate (BW).
- They are further subdivided as subtropical steppe (BSh) and subtropical desert (BWh) at latitudes from 15° - 35° and mid-latitude steppe (BSk) and mid-latitude desert (BWk) at latitudes between 35° - 60°.

Subtropical Steppe (BSh) and Subtropical Desert (BWh) Climates

- These climates have common precipitation and temperature characteristics. Located in the transition zone between humid and dry climates, subtropical steppe receives slightly more rainfall than the desert, adequate enough for the growth of sparse grasslands.
- The rainfall in both the climates is highly variable and the variability in the rainfall affects the life in the steppe much more than in the desert, more often causing famine.

Warm Temperate (Mid-Latitude) Climates-C

- This climate extends from 30° - 50° of latitude mainly on the eastern and western margins of continents.
- These climates generally have warm summers with mild winters. They are grouped into four types:
  - I. Humid subtropical, i.e. dry in winter and hot in summer (Cwa)
  - II. Mediterranean (Cs)

III. Humid subtropical, i.e. no dry season and mild winter (Cfa)
IV. Marine west coast climate (Cfb)

Humid Subtropical Climate (Cwa)

- This climate occurs poleward of Tropic of Cancer and Capricorn, mainly in North Indian plains and South China interior plains. The climate is similar to Aw climate except that the temperature in winter is warm.

Mediterranean Climate (Cs)

- The Mediterranean climate occurs around Mediterranean Sea, along the west coast of continents in subtropical latitudes between 30° - 40° latitudes along the coast in south eastern and south western Australia.
- These areas come under the influence of sub-tropical high in summer and westerly wind in winter. Hence, the climate is characterised by hot, dry summer and mild, rainy winter.

Humid Subtropical (Cfa) Climate

- This climate lies on the eastern parts of the continent in subtropical latitudes.
- In this region the air masses are generally unstable and cause rainfall throughout the year.
- They occur in eastern United States of America, southern and eastern China, southern Japan, north-eastern Argentina, coastal south Africa and eastern coast of Australia.

Marine West Coast Climate (Cfb)

- This climate is located poleward from the Mediterranean climate on the west coast of the continents.
- Due to marine influence, the temperature is moderate and in winter, it is warmer than for its latitude.

Cold Snow Forest Climates (D)

- This climate occurs in the large continental area in the northern hemisphere between 40°-70° north latitudes in Europe, Asia and North America. Cold snow forest climates are divided into two types:
  I. Df- cold climate with humid winter
  II. Dw- cold climate with dry winter.
- The severity of winter is more pronounced in higher latitudes.

Cold Climate with Humid Winters (Df)

- Cold climate with humid winter occurs poleward of marine west coast climate and mid latitude steppe. The winters are cold and snowy. The frost-free season is short. The annual ranges of temperature are large.
- The weather changes are abrupt and short. Poleward, the winters are more severe.

Cold Climate with Dry Winters (Dw)

- Cold climate with dry winter occurs mainly over North-eastern Asia.
- The development of pronounced winter anti cyclone and its weakening in summer sets in monsoon like reversal of wind in this region.
- Poleward summer temperatures are lower and winter temperatures are extremely low with many locations experiencing below freezing point temperatures for up to seven months in a year.
- Precipitation occurs in summer and the annual precipitation is low from 12-15 cm.

Polar Climates (E)

- Polar climates exist poleward beyond 70° latitude. Polar climates consist of two types:
  I. Tundra (ET)
  II. Ice Cap (EF)

Tundra Climate (ET)

- This climate is so called after the types of vegetation, like low growing mosses, lichens and flowering plants.
- This is the region of permafrost where the sub soil is permanently frozen.
- The short growing season and water logging support only low growing plants.
- During summer, the tundra regions have very long duration of day light.

Ice Cap Climate (EF)

- This climate (EF) occurs over interior Greenland and Antarctica.
- Even in summer, the temperature is below freezing point and receives very little precipitation.
- The snow and ice get accumulated and the mounting pressure causes the deformation of the ice sheets and
- They break. They move as icebergs that float in the Arctic and Antarctic waters.

Highland Climates (H)

- In high mountains, large changes in mean temperature occur over short distances.
- Precipitation types and intensity also vary spatially across high lands. There is vertical zonation of layering of climatic types with elevation in the mountain environment.

Global Warming

- Due to the presence of greenhouse gases, the atmosphere is behaving like a greenhouse. The atmosphere also transmits the incoming solar radiation but absorbs the vast majority of long wave radiation emitted upwards by the earth's surface.
- The gases that absorb long wave radiation are called greenhouse gases. The processes that warm the atmosphere are often collectively referred to as the **greenhouse effect.**

Greenhouse Gases (GHGs)

- The primary GHGs of concern today are carbon dioxide (CO_2), Chlorofluorocarbons (CFCs), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Some other gases such as nitric oxide (NO) and carbon monoxide (CO) easily react with GHGs and affect their concentration in the atmosphere.
- The largest concentration of GHGs in the atmosphere is carbon dioxide. The emission of CO_2 comes mainly from fossil fuel combustion.
- Forests and oceans are the sinks for the carbon dioxide. So, deforestation due to changes in land use, also increases the concentration of CO2.
- Chlorofluorocarbons (CFCs) are products of human activity.
- Ozone occurs in the stratosphere where ultra-violet rays convert oxygen into ozone. Thus, ultra violet rays do not reach the earth's surface. The CFCs which drift into the stratosphere destroy the ozone.
- Large depletion of ozone occurs over Antarctica. The depletion of ozone concentration in the stratosphere is called the ozone hole.
- International efforts have been initiated for reducing the emission of GHGs into the atmosphere. The most important one is the Kyoto protocol proclaimed in 1997.

Unit - IV WATER

1 Water (Oceans)

Hydrological Cycle

- Water is a cyclic resource. It can be used and re-used.
- The hydrological cycle, is the circulation of water within the earth's hydrosphere in different forms i.e. the liquid, solid and the gaseous phases. It also refers to the continuous exchange of water between the oceans atmosphere, land surface and subsurface and the organisms.
- About 71 per cent of the planetary water is found in the oceans.
- The remaining is held as freshwater in glaciers and icecaps, groundwater sources, lakes, soil moisture, atmosphere, streams and within life.
- Nearly 59 per cent of the water that falls on land returns to the atmosphere through evaporation from over the oceans as well as from other places. The remainder runs-off on the surface, infiltrates into the ground or a part of it becomes glacier.
- It is to be noted that the renewable water on the earth is constant while the demand is increasing tremendously. This leads to water crisis in different parts of the world - spatially and temporally. The pollution of river waters has further aggravated the crisis.

Components	Processes
Water Storage in Oceans	Evaporation Evapotranspiration Sublimation
Water in the atmosphere	Condensation Precipitation
Water storage in ice and snow	Snowmelt runoff to streams
Surface runoff	Stream flow freshwater storage infiltration
Groundwater storage	Ground water discharge springs

Relief of the Ocean Floor

- The oceans are confined to the great depressions of the earth's outer layer. The geographers have divided the oceanic part of the earth into five oceans, namely the Pacific, the Atlantic, the Indian, Southern Ocean and the Arctic. The various seas, bays, gulfs and other inlets are parts of these four large oceans.
- A major portion of the ocean floor is found between 3-6 km below the sea level. The floors of the oceans are rugged with the world's largest mountain ranges, deepest trenches and the largest plains. These features are formed, like those of the continents, by the factors of tectonic, volcanic and depositional processes.

Divisions of the Ocean Floors

- The ocean floors can be divided into four major divisions:
  1. The Continental Shelf
     - The continental shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs. It is the shallowest part of the ocean showing an average gradient of 1° or even less.
     - The shelf typically ends at a very steep slope, called the shelf break.
     - The average width of continental shelves is about 80 km.
     - The shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc. On the contrary, the Siberian shelf in the Arctic Ocean, the largest in the world, stretches to 1,500 km in width. The depth of the shelves also varies. It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m
     - Massive sedimentary deposits received over a long time by the continental shelves, become the source of fossil fuels.
  2. The Continental Slope
     - The continental slope connects the continental shelf and the ocean basins.
     - It begins where the bottom of the continental shelf sharply drops off into a steep slope.
     - The gradient of the slope region varies between 2-5°.
     - The depth of the slope region varies between 200 and 3,000 m. The slope boundary indicates the end of the continents.
     - Canyons and trenches are observed in this region.
  3. The Deep-Sea Plain
     - Deep sea plains are gently sloping areas of the ocean basins.
     - These are the flattest and smoothest regions of the world.
     - The depths vary between 3,000 and 6,000m. These plains are covered with fine-grained sediments like clay and silt.
  4. The Oceanic Deep
     - These areas are the deepest parts of the oceans.
     - The trenches are relatively steep sided, narrow basins.
     - They are some 3-5 km deeper than the surrounding ocean floor.
     - They occur at the bases of continental slopes and along island arcs and are associated with active volcanoes and strong earthquakes.
- Besides, these divisions there are also major and minor relief features in the ocean floors like ridges, hills, sea mounts, guyots, trenches, canyons, etc.

Minor Relief Features

1. Mid-Oceanic Ridges

- A mid-oceanic ridge is composed of two chains of mountains separated by a large depression.
- The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface.
- Iceland, a part of the mid- Atlantic Ridge, is an example.

2. Seamount

- It is a mountain with pointed summits, rising from the seafloor that does not reach the surface of the ocean.
- Seamounts are volcanic in origin. These can be 3,000-4,500 m tall.
- The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean, is a good example

3. Submarine Canyons

- These are deep valleys, some comparable to the Grand Canyon of the Colorado River.
- They are sometimes found cutting across the continental shelves and slopes, often extending from the mouths of large rivers.
- The Hudson Canyon is the best-known submarine canyon in the world.

4. Guyots

- It is a flat-topped seamount.
- They show evidences of gradual subsidence through stages to become flat topped submerged mountains.
- It is estimated that more than 10,000 seamounts and guyots exist in the Pacific Ocean alone.

5. Atoll

- These are low islands found in the tropical oceans consisting of coral reefs surrounding a central depression.
- It may be a part of the sea (lagoon), or sometimes form enclosing a body of fresh, brackish, or highly saline water.

Temperature of Ocean Waters

- The process of heating and cooling of the oceanic water is slower than land.

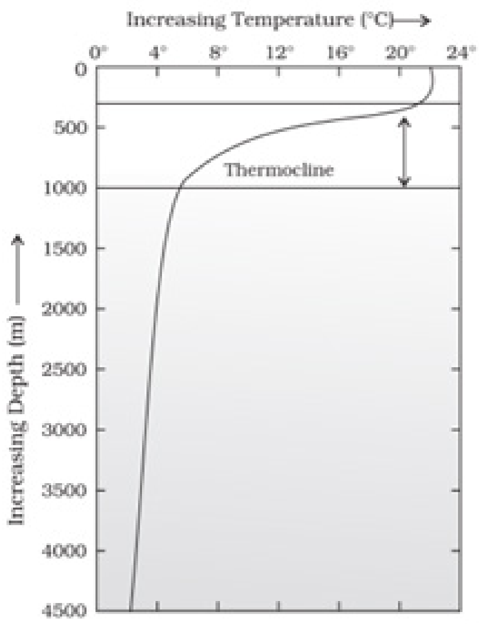
Factors Affecting Temperature Distribution

1. **Latitude:** The temperature of surface water decreases from the equator towards the poles because the amount of insolation decreases poleward.
2. **Unequal distribution of land and water:** The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than the oceans in the southern hemisphere.
3. **Prevailing wind:** The winds blowing from the land towards the oceans drive warm surface water away from the coast resulting in the upwelling of cold water from below. It results into the longitudinal variation in the temperature. Contrary to this, the onshore winds pile up warm water near the coast and this raises the temperature.
4. **Ocean currents:** Warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas. Gulf Stream (warm current) raises the temperature near the eastern coast of North America and the West Coast of Europe while the Labrador Current (cold current) lowers the temperature near the north-east coast of North America.

Horizontal and Vertical Distribution of Temperature

- The temperature-depth profile for the ocean water shows how the temperature decreases with the increasing depth. The profile shows a boundary region between the surface waters of the ocean and the deeper layers.
- The boundary usually begins around 100 - 400 m below the sea surface and extends several hundred of metres downward. This boundary region, from where there is a rapid decrease of temperature, is called the thermocline.

- About 90 per cent of the total volume of water is found below the thermocline in the deep ocean. In this zone, temperatures approach 0° C. Three-layer system from surface to the bottom.
- The first layer represents the top layer of warm oceanic water and it is about 500m thick with temperatures ranging between 20° and 25° C. This layer, within the tropical region, is present throughout the year but in mid-latitudes it develops only during summer.
- The second layer called the thermocline layer lies below the first layer and is characterized by rapid decrease in temperature with increasing depth. The thermocline is 500 -1,000 m thick.
- The third layer is very cold and extends up to the deep ocean floor.
- In the Arctic and Antarctic circles, the surface water temperatures are close to 0° C and so the temperature change with the depth is very slight. Here, only one layer of cold water exists, which extends from surface to deep ocean floor.
- The average temperature of surface water of the oceans is about 27°C and it gradually decreases from the equator towards the poles.
- The rate of decrease of temperature with increasing latitude is generally 0.5°C per latitude.



- The oceans in the northern hemisphere record relatively higher temperature than in the southern hemisphere.
- The highest temperature is not recorded at the equator but slightly towards north of it. This variation is due to the unequal distribution of land and water in the northern and southern hemispheres.
- The heat is transmitted to the lower sections of the oceans through the process of convection.

Salilnity of Ocean Water

- Salinity is the term used to define the total content of dissolved salts in sea.
- It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater.
- It is usually expressed as parts per thousand or ppt.
- Salinity of 24.7 %has been considered as the upper limit to demarcate 'brackish water'.

Factors affecting Ocean Salinity

- The salinity of water in the surface layer of oceans depends mainly on evaporation and precipitation.
- Surface salinity is greatly influenced in coastal regions by the fresh water flow from rivers, and in Polar Regions by the processes of freezing and thawing of ice.
- Wind, also influences salinity of an area by transferring water to other areas. The ocean currents contribute to the salinity variations.
- Salinity, temperature and density of water are interrelated. Hence, any change in the temperature or density influences the salinity of water in an area. Spatial pattern of surface temperature (°C) of the oceans Highest salinity in water bodies Lake Van in Turkey (330 o/oo), Dead Sea (238 o/oo), Great Salt Lake (220 o/oo).
  - Highest salinity in water bodies
  - Lake Van in Turkey (330 o/oo)
  - Dead Sea (238 o/oo)
  - Great Salt Lake (220 o/oo)

Horizontal Distribution of Salinity

- The salinity for normal open ocean range between 33o/oo and 37 o/oo .
- In the land locked Red Sea, it is as high as 41o/oo, while in the estuaries and the Arctic, the salinity fluctuates from 0 – 35 o/oo, seasonally.
- In hot and dry regions, where evaporation is high, the salinity sometimes reaches to 70 o/oo.
- The salinity variation in the Pacific Ocean is mainly due to its shape and larger areal extent.
- Salinity decreases from 35 o/oo - 31 o/oo on the western parts of the northern hemisphere because of the influx of melted water from the Arctic region.
- The highest salinity is recorded between 15° and 20° latitudes. Maximum salinity (37 o/oo) is observed between 20° N and 30° N and 20° W - 60° W. It gradually decreases towards the north.
- The North Sea, in spite of its location in higher latitudes, records higher salinity due to more saline water brought by the North Atlantic Drift.
- Baltic Sea records low salinity due to influx of river waters in large quantity.
- The Mediterranean Sea records higher salinity due to high evaporation.
- Salinity is, however, very low in Black Sea due to enormous fresh water influx by rivers.
- The average salinity of the Indian Ocean is 35 o/oo.
- The low salinity trend is observed in the Bay of Bengal due to influx of river water. On the contrary, the Arabian Sea shows higher salinity due to high evaporation and low influx of fresh water.

Vertical Distribution of Salinity

- Changes with depth, but the way it changes depends upon the location of the sea.
- Salinity at the surface increases by the loss of water to ice or evaporation, or decreased by the input of fresh waters, such as from the rivers.
- Salinity at depth is very much fixed, because there is no way that water is 'lost', or the salt is 'added.' There is a marked difference in the salinity between the surface zones and the deep zones of the oceans.
- The lower salinity water rests above the higher salinity dense water. Salinity, generally, increases with depth and there is a distinct zone called the halocline, where salinity increases sharply.
- Other factors being constant, increasing salinity of seawater causes its density to increase. High salinity seawater, generally, sinks below the lower salinity water. This leads to stratification by salinity.

2 Movements of Ocean Water

- The ocean water is dynamic. Its physical characteristics like temperature, salinity, density and the external forces like of the sun, moon and the winds influence the movement of ocean water.
- The horizontal and vertical motions are common in ocean water bodies. The horizontal motion refers to the ocean currents and waves. The vertical motion refers to tides.

Waves

- Waves are actually the energy, not the water as such, which moves across the ocean surface.
- Water particles only travel in a small circle as a wave passes.
- Wind provides energy to the waves. Wind causes waves to travel in the ocean and the energy is released on shorelines.
- The characteristics of waves are:
  - **Wave crest and trough:** The highest and lowest points of a wave are called the crest and trough respectively.
  - **Wave height:** It is the vertical distance from the bottom of a trough to the top of a crest of a wave.
  - **Wave amplitude:** It is one-half of the wave height.
  - **Wave period:** It is merely the time interval between two successive wave crests or troughs as they pass a fixed point.
  - **Wavelength:** It is the horizontal distance between two successive crests.
  - **Wave speed:** It is the rate at which the wave moves through the water, and is measured in knots.
  - **Wave frequency:** It is the number of waves passing a given point during a one second time interval.

Tides

- The periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a tide.
- Movement of water caused by meteorological effect are called surges. Surges are not regular like tides.
- The moons gravitational pull to a great extent and to a lesser extent the sun's gravitational pull, are the major causes for the occurrence of tides.
- Another factor is centrifugal force, which is the force that acts to counter balance the gravity.
- Together, the gravitational pull and the centrifugal force are responsible for creating the two major tidal bulges on the earth. On the side of the earth facing the moon, a tidal bulge occurs while on the opposite side though the gravitational attraction of the moon is less as it is farther away, the centrifugal force causes tidal bulge on the other side
- The tidal bulges on wide continental shelves have greater height. When tidal bulges hit the mid-oceanic islands, they become low. The shape of bays and estuaries along a coastline can also magnify the intensity of tides.
- Funnel-shaped bays greatly change tidal magnitudes.
- When the tide is channelled between islands or into bays and estuaries, they are called tidal currents.

Types of Tides

- Tides based on Frequency: -
  1. **Semi-diurnal tide:** The most common tidal pattern, featuring two high tides and two low tides each day. The successive high or low tides are approximately of the same height.
  2. **Diurnal tide:** There is only one high tide and one low tide during each day. The successive high and low tides are approximately of the same height.
  3. **Mixed tide:** Tides having variations in height are known as mixed tides. These tides generally occur along the west coast of North America and on many islands of the Pacific Ocean.
- Tides based on the Sun, Moon and the Earth Positions: -
  - The height of rising water varies appreciably depending upon the position of sun and moon with respect to the earth. Spring tides and neap tides come under this category

Spring tides:

- The position of both the sun and the moon in relation to the earth has direct bearing on tide height.
- When the sun, the moon and the earth are in a straight line, the height of the tide will be higher.
- They occur twice a month, one on full moon period and another during new moon period.

Neap tides:

- Normally, there is a seven-day interval between the spring tides and neap tides.
- At this time the sun and moon are at right angles to each other and the forces of the sun and moon tend to counteract one another
- The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull.

- Once in a month, when the moon's orbit is closest to the earth (perigee), unusually high and low tides occur.
- During this time the tidal range is greater than normal. Two weeks later, when the moon is farthest from earth (apogee), the moon's gravitational force is limited and the tidal ranges are less than their average height.
- The time between the high tide and low tide, when the water level is falling, is called the **ebb.** The time between the low tide and high tide, when the tide is rising, is called the **flow or flood.**

Importance of Tides

- Since tides are caused by the earth-moon-sun positions which are known accurately, the tides can be predicted well in advance.
- This helps the navigators and fishermen plan their activities. Tidal flows are of great importance in navigation and helps to generate electricity.
- Tidal heights are very important, especially harbours near rivers and within estuaries having shallow **'bars'** at the entrance, which prevent ships and boats from entering into the harbour.
- Tides are also helpful in desilting the sediments and in removing polluted water from river estuaries.

Ocean Currents

- Ocean currents are like river flow in oceans. They represent a regular volume of water in a definite path and direction.
- Ocean currents are influenced by two types of forces namely:

1. Primary forces that initiate the movement of water

- Heating by solar energy - Heating by solar energy causes the water to expand. That is why, near the equator the ocean water is about 8 cm higher in level than the middle latitudes. This causes a very slight gradient and water tends to flow down the slope.
- Wind - Wind blowing on the surface of the ocean pushes the water to move. Friction between the wind and the water surface affects the movement of the water body in its course.
- Gravity - Gravity tends to pull the water down the pile and create gradient variation.
- Coriolis force - The Coriolis force intervenes and causes the water to move to the right in the northern hemisphere and to the left in the southern hemisphere. These large accumulations of water and the flow around them are called Gyres.

2. Secondary forces that influence the currents to flow

- Differences in water density affect vertical mobility of ocean currents Temperature difference and salinity difference are the secondary forces.
- Differences in water density affect vertical mobility of ocean currents (vertical currents).
- Water with high salinity is denser than water with low salinity and in the same way cold water is denser than warm water. Denser water tends to sink, while relatively lighter water tends to rise.
- Cold-water ocean currents occur when the cold water at the poles sinks and slowly moves towards the equator. Warm-water currents travel out from the equator along the surface, flowing towards the poles to replace the sinking cold water.

Characteristics of Ocean Currents

- Currents are referred to by their "drift".
- Usually, the currents are strongest near the surface and may attain speeds over five knots.
- At depths, currents are generally slow with speeds less than 0.5 knots
- The speed of a current is referred as "drift." Drift is measured in terms of knots. The strength of a current refers to the speed of the current.

Types of Ocean Current

- The ocean currents may be classified based on their depth
  1. **Surface currents**
     - It constitutes about 10 per cent of all the water in the ocean, these waters are the upper 400 m of the ocean
  2. **Deep-water currents**
     - It makes up the other 90 per cent of the ocean water. These waters move around the ocean basins due to variations in the density and gravity. Deep waters sink into the ocean basins at high latitudes, where the temperatures are cold enough to cause the density to increase.
- Ocean currents can also be classified based on temperature
  1. **Cold Currents**
     - These currents are usually found in the low and middle latitudes (true in both hemispheres) on the west coast of the continents on the east coast in the higher latitudes in the Northern Hemisphere

2. **Warm Currents**
    - It brings warm water into cold water areas and are usually observed on the east coast of continents in the low and middle latitudes (true in both hemispheres). In the northern hemisphere they are found on the west coasts of continents in high latitudes.

Major Ocean Currents

- Major ocean currents are greatly influenced by the stresses exerted by the prevailing winds and Coriolis force.
- The oceanic circulation pattern roughly corresponds to the earth's atmospheric circulation pattern.
- The air circulation over the oceans in the middle latitudes is mainly anticyclonic (more pronounced in the southern hemisphere than in the northern hemisphere).
- The oceanic circulation pattern also corresponds with the same at higher latitudes.
- Where the wind flow is mostly cyclonic, the oceanic circulation follows this pattern. In regions of pronounced monsoonal flow, the monsoon winds influence the current movements.