IIPA2022

Indian & World Geography Chapter 8

Short Answers

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2022

This Chapter Contains

- Origin of Solar System and Sun
- Stars, Sun & Planet
- Latitudes and Longitudes
- Motions of the Earth: Rotation and Revolution
- Geomorphic Processes: Endogenic Forces and Evolution of Landforms
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1. Origin of Solar System and Sun

1.1 Solar System

The Solar System is the gravitationally bound system of the Sun and the objects that orbit it, either directly or indirectly. It consists of the sun (the star) at the centre with eight planets (i.e. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune), satellites, asteroids, meteors and comets that move around the Sun.

The solar system, according to scientists, was formed when a cloud of gas and dust in space was disturbed, possibly by the explosion of a nearby star known as **SUPERNOVA.** This explosion sent shockwaves into space, compressing the gas and dust cloud. Gravity drew the gas and dust together, forming a solar nebula, as the cloud began to collapse.At the dense center of this nebula, the sun's nuclear flames erupted. In the churning currents of the vast cloud, the planets were created.Mercury, Venus, Earth, and Mars all began as rock globes orbiting the Sun. It was impossible to capture them since they were too small and had weak gravitational fields.The enormous planets Jupiter and Saturn, which are far from the sun and have powerful gravitational fields, did, nevertheless, draw and hold thick gaseous atmospheres of Hydrogen and Helium.

Another group of Scientists believe that the Sun has been formed from a moving cloud of gases, which is called Nebula. The Sun and the planets were born out of this cloud. The force of gravity has created them. For over millions of years, these balls of dust and gas are moving around the Sun. The Sun by virtue of its mass and weight, controls the movement of the planets. This force is called the force of gravity.

Till 2006, there were nine planets in the solar system. Pluto was the farthest planet from the Sun. In 2006, the International Astronomical Union (IAU) adopted a new definition of a planet. Pluto and other celestial bodies like Ceres, 2003 UB313 does not fit this definition. It is no longer considered as a planet of the solar system. The solar system is enormous, with a diameter of at least 100 Astronomical Units (15 trillion km). Our Solar System is thought to be over 4.6 billion years old, according to several experts.

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.
- All the planets were formed in the same period sometime about 4.6 billion years ago.

2. Stars, Sun & Planets

2.1 Sun

The Sun is at the centre of our solar system and also the largest objects of our solar system. However, it is an average star. It is roughly 109 times the size of Earth. The Sun has a diameter of 1,392,000 kilometres. It comprises 99.8% of the mass of the solar system. It isn't the hottest, it isn't the coolest, and it isn't the oldest. Nor is it brightest, biggest, etc. The surface temperature of sun is 60000 degrees Celsius. It is largely made up of hydrogen gas, with a minor quantity of helium thrown in for good measure. The Sun accounts for 99.85% of all the matter of the solar system.

The Sun is the solar system's closest star. It belongs to the Milky Way galaxy. It's thought to be more than 4 billion years old. The Sun is a yellow dwarf, a medium-sized star. As it rotates around the galaxy, the Sun spins gently on its axis. It is composed mainly of hydrogen and helium. Nuclear fusion in the core of the Sun is source of all its energy. The glowing surface of the Sun is called Photosphere. About it is red coloured Chromosphere and beyond it is Corona (visible during eclipses). The surface of the Sun changes continuously. Bright regions are called Plages and dark spots are called Sun spots which frequently form and disappear.

The Earth would be a dead sphere of rock and ice if it were not for the Sun. The Sun warms our globe, influences our weather, and provides energy to plants, which provides food and energy for life on Earth. The Sun's energy reaches the Earth and other planets in all directions. The planet absorbs less energy as it gets further away from the Sun.

2.2 Sun Statistics

- Distance from the Earth - 150 mn km
- Diameter-1391980 km
- Core temperature - 15000000°C
- Rotation time - 25 days
- Age - 5 billion years
- Composition – H_2 - 71%, He - 26.5% and other 2.5%
- Mass-1.99 x $l0^{33}$kg

2.3 Solar Eclipse

- Solar eclipse is caused when the Moon revolving around the Earth comes in between the Earth and the Sun, thus making a part or whole of the Sun invisible from a particular patrol the Earth.

2.4 Lunar Eclipse

- During the revolution of Earth, when comes between moon and the Sun the shadow of the Earth hides moon either fully or partially. This is called lunar edips.

2.4 The Planets

Planets are actually spinning around the Sun. They have their own elliptical path of movement known as the orbits. Movement around its own axis is called rotation and around the Sun is revolution. Planets, unlike stars, have no light or heat of their own. The word ‘planet’ comes from the Greek word “Planetai” which means ‘wanderers’. Planets keep changing their positions with respect to the stars.

Mercury: It is nearest to the Sun. It is the smallest planet of the solar system, nearly of the same size and mass as the moon. It takes 88 days for one orbit around the Sun and 59 days for one spin on its axis. It has no satellite. There is no atmosphere on mercury. The surface of mercury is rocky and mountainous. One side of the surface facing the Sun receives maximum heat and light. The surface of this planet does not receive Sunlight or heat on its other side. One part of mercury, therefore, is very hot while the other part is very cold.

Venus: It has no moon or satellite of its own. It rotates on its axis is somewhat unusual i.e. from east to west. The mass of Venus is nearly 4/5 times that of the earth. It takes 255 days for one orbit around the Sun and 243 days for one spin on its axis. Therefore it is often called a morning or an evening star. It has an atmosphere that consists of mainly carbon dioxide. It is the hottest planet in our solar system.

The Earth: Our earth rotates from west to east. Our earth is more or less like a sphere, which is slightly flattened in the north and south. Slightly flattened or tapered at the poles, the earth is best to be described as geoids which mean earth like shape. It is the third nearest planet to the Sun. It is called blue planet due to presence of water and landmasses the earth appears blue-green in colour from the space. The earth is the only planet where some special environment conditions are responsible for the existence and continuation of life because it has the right temperature range, the presence of water, soil, minerals, suitable atmosphere and a blanket of ozone.

Mars: It is almost half the size of the earth. It takes 687 days for one orbit around the Sun and 1 day for one spin on its axis. It appears slightly reddish and, therefore, it is also called the red planet. Mars has two small natural satellites named Phobos and Deimos.

Jupiter: It is the largest planet of the solar system. It takes 11 years and 11 months for one orbit around the Sun and 9 hours, 56 minutes for one spin on its axis. It has 16 satellites. It also has faint rings around it. Its most distinguishing feature is the great red spot. Because of its large mass, it exerts a strong gravitational pull on other objects which pass by it. It is consists of hydrogen and helium in gaseous form. Its cloud like outer regions consists of methane in gaseous form while ammonia is present in crystalline form.

Saturn: Beyond Jupiter is Saturn which appears yellowish in colour. What make it unique in the solar system are its three beautiful rings. It takes 29 years, 5 months for one orbit around the Sun and 10 hours, 40 minutes for one spin on its axis. It has 18 satellites. Saturn is the least dense among all the planets. Its density is less than that of water. It is similar in size, mass and composition to Jupiter. It is however cooler than the Jupiter.

Uranus: It was the first planet to be discovered with the help of a telescope by William Herschel in 1781. Hydrogen and methane have been detected in the atmosphere of Uranus. It rotates from east to west. The most remarkable feature of Uranus is that it has highly tilted rotational axis. As a result, in its orbital motion it appears to roll on its side. It takes 84 years for one orbit around the Sun and 17 hours, 14 minutes for one spin on its axis. It has 17 satellites.

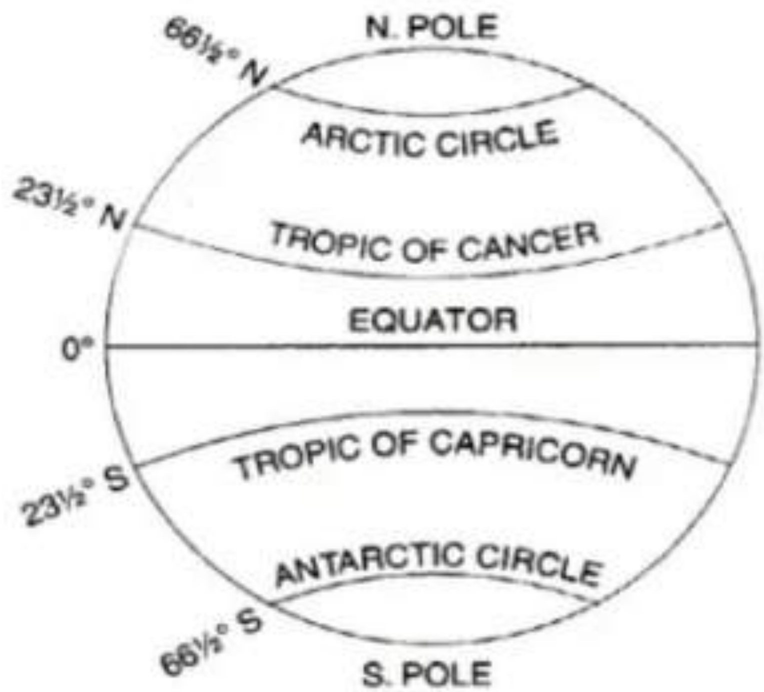
Neptune: It takes 164 years for one orbit around the Sun and 16 hours 7 minutes for one spin on its axis. It has 8 satellites.

3. Latitudes and Longitudes

The Earth is an Oblate Spheroid. Therefore it is difficult to locate places on it unless a mathematical system is used. There are two reference points on the Earth- the North Pole and South Pole. With the help of these two points it has been possible to draw the Equator, as it lies exactly midway between the poles. In order to locate places accurately, a network of lines are drawn o the globe. The horizontal lines are the lines of latitudes and the vertical ones are the lines of longitudes. These lines intersect each other at right angles and create a network called a grid or graticule. The graticule helps us to locate places on the surface of the Earth accurately.

3.1 Latitudes

The latitude is the angle formed by a line going from the center of the earth to the equator at the point on the equator that is closed to the point of interest and another line that goes from the center of the earth to the parallel that goes through the point of interest. In other terms it is a measurement on a globe or map of location north or south of the Equator. Lines joining places with the same latitudes are called parallels ie the lines running East to West are called “Parallels” or “lines of latitude”



Technically, there are different kinds of latitude—geocentric, astronomical, and geographic (or geodetic)—but there are only minor differences between them. In most common references, geocentric latitude is implied. Given in degrees, minutes, and seconds, geocentric latitude is the arc subtended by an angle at Earth’s centre and measured in a north-south plane poleward from the Equator. Therefore, the greatest possible latitudes are 90° N and 90° S. The value of equator is 0° and the latitude of the poles are 90°N and 90°S.

If parallels of latitude are drawn at an interval of one degree, there will be 89 parallels in the northern and the southern hemispheres each. The total number of parallels thus drawn, including the equator, will be 179. Depending upon the location of a feature or a place north or south of the equator, the letter N or S is written along with the value of the latitude.

If the earth were a perfect sphere, the length of 10 of latitude (a one degree arc of a meridian) would be a constant value, i.e. 111 km everywhere on the earth. This length is almost the same as that of a degree of longitude at the equator. But to be precise, a degree of latitude changes slightly in length from the equator to the poles. While at the equator, it is 110.6 km at the poles, it is 111.7 km. Latitude of a place may be determined with the help of the altitude of the sun or the Pole Star.

Distances between them are measured in ‘degrees of longitude’; each degree is further divided into minutes, and minutes into seconds.

- A Circle = 360 Degrees
- 1 Degree = 60 Minutes
- 1 Minute = 60 Seconds

They are *semi-circles and the distance between them decreases steadily polewards until it becomes zero at the poles,* where all the meridians meet.

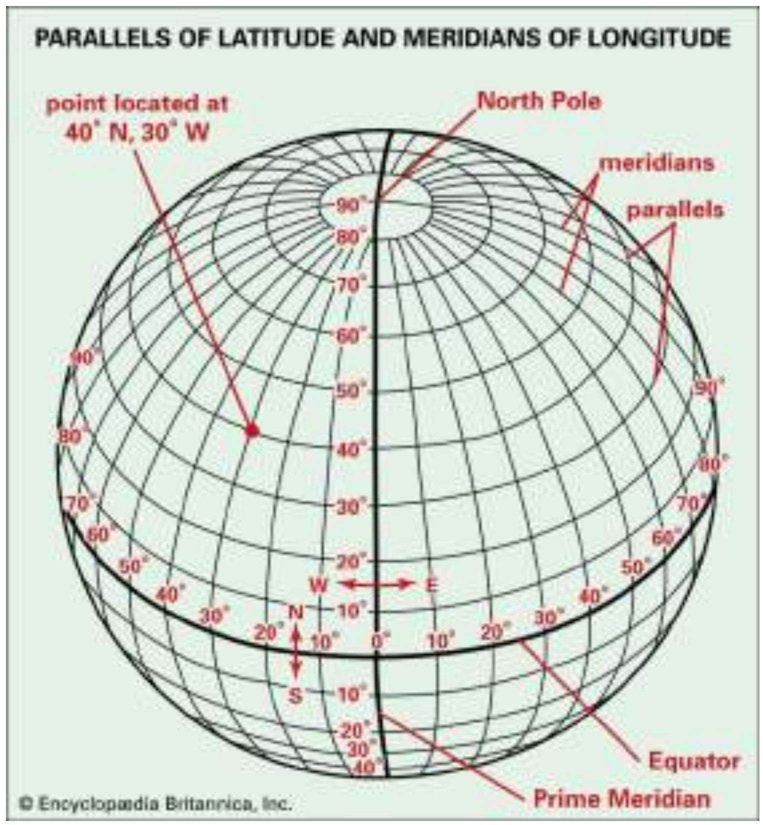
3.2 Heat Zones

The mid-day sun is exactly overhead at least once a year on all latitudes in between the Tropic of Cancer and the Tropic of Capricorn. Therefore, this area gets maximum heat and is called the Torrid Zone. On 21st June the Sun is directly over the Tropic of cancer. On 22nd Dec the Sun is directly over the Tropic of Capricorn. These two latitudes form the outer limit of the Torrid Zone. It is the hottest part of the world. Most of the deserts are located here.

The midday sun never shines overhead on any latitude beyond the Tropic of Cancer and the Tropic of Capricorn. The angle of the sun’s rays goes on decreasing towards the poles. The areas bounded by the tropic of cancer and the Arctic Circle in the Northern hemisphere and the Tropic of Capricorn and the Antarctic Circle in the southern hemisphere, have moderate temperature i.e. neither very hot nor very cold. So this is Temperate Zone.

Areas lying between the Arctic Circle and the North Pole in the Northern Hemisphere and the Antarctic Circle and the South Pole in the Southern Hemisphere, are very cold. It is because the sun does not shine much above the Horizon. Therefore its rays are always slanting. So this is Frigid Zone.

3.3 Longitudes



A set of imaginary lines which divide the earth into eastern hemisphere and western hemisphere run over the earth in north south directions are called "meridians of longitudes". These lines are not parallel to one another. They all converge at poles. The distances between them are measured in 'degrees of longitude'.

They form semi-circles. They are also drawn at an interval of 10. These meridians of longitude and parallels of latitude form a network which is called grid. Unlike the parallels of latitudes, the meridians of longitudes are equal in length.

As one go from the equator to the poles the distance between two meridians decreases. There was an agreement world over that the longitude passing through Greenwich Observatory near the city of London will be considered as the Prime Meridian. It is considered to be 00 Longitude and from it we count 1800 eastward as well as 1800 westward. It is interesting that 1800 east and 1800 west meridians are the same line. To avoid the confusion letters 'E' and 'W' are written with the values of meridians for the eastern hemisphere and western hemisphere respectively.

3.4 Time Zones

The earth takes about 24 hours to complete a rotation. This period of rotation is known as the earth-day. This means in 24 hours the earth completes 360 degree. Therefore, it takes about one hour to complete each 150 or 4 minutes for each degree. Accordingly, the earth has been divided into 24 time zones of one hour each. As the earth rotates from west to east, day starts at different times in different places. Places east of the Greenwich meridian experience sunrise earlier than the place lying west of the prime meridian. All the places situated along the same meridian will have the same local time.

- In India the longitudinal span is from 680 7' to 970 25' E. Therefore, it was felt necessary to adopt the local time of central meridian of our country as the standard time for the country as a whole.
- In India 820 30' E has been considered for this purpose. It is called the standard meridian. This is known as Indian Standard Time (IST).
- The Greenwich Mean Time is 5 hours and 30 minutes behind the Indian standard time. In global context Greenwich (00) time is followed which is called the Greenwich Mean Time (GMT).

4. Motions of the Earth: Rotation and Revolution.

Earth's axis is an imaginary line which runs right across and passes through the centre of the earth. The earth spins round its axis which always remains inclined at an angle of 661/2° to the plane of the Earth's orbit. Earth has primarily two types of motions- Rotation and Revolution.

4.1 Rotation

Rotation is the Movement of the earth on its axis. Earth rotates along its axis from west to east. It takes approximately 24 hrs to complete on rotation. Days and nights occur due to rotation of the earth. The circle that divides the day from night on the globe is called the circle of illumination. It is important to note that Earth rotates on a tilted axis. Earth's rotational axis makes an angle of **23.5°** with the normal i.e. it makes an angle **of 66.5°** with the orbital plane. Orbital plane is the plane of earth's orbit around the Sun. The earth rotates from west to east and takes 23 hours, 56 minutes and 4.091 seconds to complete one rotation. Days and nights are caused due to the rotation of the earth. At the equator there is a 12 hours day and 12 hours night.

Rotation causes **the tides**- the twice daily rise and fall of sea level. Tides are complicated complicated because because they are the result of both the gravity gravity of the moon and the gravity of the sun. Sometimes the sun and the moon are lined up with the earth, but most of the time they are not. Tides are highest when the earth, sun and moon are in a straight line.

4.2 The Coriolis Force

Rotation causes a deflection of ocean and air currents. The earth rotates much faster than the winds or currents move. This causes a large deflection in the direction that winds move and ultimately results in rotation around low pressure cells and high pressure cells. It also causes large rotating pools of water in the oceans called gyres.

4.3 Revolution

Earth revolves around the Sun and this movement is called revolution. The earth moves around the sun at a speed of about 100,000 kmper hour. It takes 365 days, 5hours, 48 minutes and 45.51 seconds to complete one revolution. Change of seasons is caused due to the revolution of the earth. It takes 365¼ days (one year) to revolve around the sun. We consider a year as consisting of 365 days only and ignore six hours for the sake of convenience.

Six hours saved every year are added to make one day (24 hours) over a span of four years. This surplus day is added to the month of February. Thus every fourth year, February is of 29 days instead of 28 days. Such a year with 366 days is called a leap year. The gravitational pull of the Sun keeps Earth and the other planets in orbit around the star. Like the other planets, Earth's orbital path is an **ellipse** so the planet is sometimes farther away from the Sun than at other times.

The closest Earth gets to the Sun each year is at perihelion (147 million km) on about January 3rd and the furthest is at aphelion (152 million km) on July 4th. Earth's elliptical orbit has nothing to do with Earth's seasons. During one revolution around the Sun, Earth travels at an average distance of about 150 million km.

Earth revolves around the Sun at an average speed of about 27 km (17 mi) per second, but the speed is not constant. The planet moves slower when it is at aphelion and faster when it is at perihelion. The reason the Earth (or any planet) has seasons is that Earth is tilted 23 1/2oon its axis. During the Northern Hemisphere summer the North Pole points toward the Sun, and in the Northern Hemisphere winter the North Pole is tilted away from the Sun.

4.4 Summer solstice

On 21st June, the Northern Hemisphere is tilted towards the sun. The rays of the sun fall directly on the Tropic of Cancer. As a result, these areas receive more heat. The areas near the poles receive less heat as the rays of the sun are slanting. The North Pole is inclined towards the sun and the places beyond the Arctic Circle experience continuous daylight for about six months. Since a large portion of the Northern Hemisphere is getting light from the sun, it is summer in the regions north of the equator. The longest day and the shortest night at these places occur on 21st June. At this time in the Southern Hemisphere all these conditions are reversed. It is winter season there. The nights are longer than the days. This position of the earth is called the Summer Solstice

4.5 Winter solstice

On 22nd December, the Tropic of Capricorn receives direct rays of the sun as the South Pole tilts towards it. As the sun's rays fall vertically at the Tropic of Capricorn (23½° S), a larger portion of the Southern Hemisphere gets light. Therefore, it is summer in the Southern Hemisphere with longer days and shorter nights. The reverse happens in the Northern Hemisphere. This position of the earth is called the Winter Solstice

4.6 Equinox

On 21st March and September 23rd, direct rays of the sun fall on the equator. At this position, neither of the poles is tilted towards the sun; so, the whole earth experiences equal days and equal nights. This is called an equinox. On 23rd September, it is autumn season in the Northern Hemisphere and spring season in the Southern Hemisphere. The opposite is the case on 21st March, when it is spring in the Northern Hemisphere and autumn in the Southern Hemisphere.

4.7 Effects of revolution

Revolution along with the earth's tilted axis leads to changing seasons across the hemispheres. The speed of the Earth's revolution has influenced the state of the Earth. On account of the speed of pivot, a diffusive power is made which prompts the straightening of the Earth at shafts and protruding at the middle. The Earth's revolution influences the development of water in the seas. The tides are redirected because of the turn.

The speed of revolution additionally influences the development of the breeze. Because of revolution, winds and the sea flow redirect to one side in the Northern Hemisphere and to one side in the Southern Hemisphere.

5. Geomorphic Processes: Endogenic Forces and Evolution of Landforms

The formation and deformation of landforms on the surface of the earth are a continuous process which is due to the continuous influence of external and internal forces. The internal and external forces causing stresses and chemical action on earth materials and bringing about changes in the configuration of the surface of the earth are known as geomorphic processes. The internal forces is known as Endogenic Forces and external forces is known as exogenic forces

5.1 Endogenic Forces

Endogenic forces are those internal forces which derive their strength from the earth's interior and play a crucial role in shaping the earth crust. Examples – mountain building forces, continent building forces, earthquakes, volcanism etc.

The endogenic forces are mainly land building forces. 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.

Endogenic forces a can be classified as (i) **slow movements** (diastrophic) and (ii) **sudden movements**. Slow movements cause changes very gradually which might not be visible during a human lifetime.

5.1.1 Slow Movements (Diastrophic forces)

Diastrophic forces refer to forces generated by the movement of the solid material of the earth's crust. All the processes that move, elevate or build portions of the earth's crust come under diastrophism. Diastrophism includes:

1. orogenic processes involving mountain building through severe folding and affecting long and narrow belts of the earth's crust.
2. epeirogenic processes involving uplift or warping of large parts of the earth's crust.
3. earthquakes involving local relatively minor movements.
4. plate tectonics involving horizontal movements of crustal plates.

   Slow movements can again be classified as vertical movements and horizontal movements.

5.1.2 Vertical Movements (Epeirogenic movements):

- Vertical movements are mainly associated with the formation of continents and plateaus. They are also called as Epeirogenic movements
- The broad central parts of continents are called cratons and are subject to epeirogeny.
- They do not bring any changes in the horizontal rock strata.
- While they cause upliftment of continent, they can also cause subsidence of continent.
- These movements are originated from the centre of the earth.

5.1.3 Horizontal Movements (Orogenic Movements):

- Horizontal forces acts on the earth's crust from side to side to cause these movements.They are also known as orogenic movements (mountain building).
- They bring a lot of disruptions to the horizontal layer of strata leading to a large structural deformation of earth's crust.
- They can be classified as forces of compression and forces of tension.

5.1.4 Forces of Tension

Forces of tension work horizontally, but in opposite directions. Under the operation of intense tensional forces, the rock stratum gets broken or fractured which results in the formation of cracks and fractures in the crust.

The displacement of rock upward or downward from their original position along such a fracture is termed as **faulting**. The line along which displacement of the fractured rock strata take place is called as the **fault line**. Faulting results in the formation of well-known relief features such as **Rift Valleys and Block Mountains.** (E.g. Vindhya and Satpura Mountains) A rift valley is formed by sinking of rock strata lying between two almost parallel faults. (E.g. Valley of Nile, Rift valley of Narmada and Tapti) Rift valleys with steep parallel walls along the fault are called as **Graben** and the uplifted landmass with steep slopes on both sides are called as **Horst**. The very steep slope in a continuous line along a fault is termed as **Escarpment.**

5.1.5 Forces of Compression:

Forces of compression are the forces which push rock strata against a hard plane from one side or from both sides. The compressional forces lead to the bending of rock layers and thus lead to the formation of Fold Mountains. Most of the great mountain chains of the world like the Himalayas, the Rockies (N. America), the Andes (S. America), the Alps (Europe) etc are formed in this manner.

5.2 Exogenic Forces

Exogenic forces are those forces which derive their strength from the earth's exterior or are originated within the earth's atmosphere.

Examples of forces – the wind, waves, water etc.

Examples of exogenic processes – weathering, mass movement, erosion, deposition.

Exogenic forces are mainly land wearing forces.

Exogenic forces can take the form of weathering, erosion, and deposition. Weathering is the breaking of rocks on the earth's surface by different agents like rivers, wind, sea waves and glaciers. Erosion is the carrying of broken rocks from one place to another by natural agents like wind, water, and glaciers.

The actions of exogenic forces result in wearing down (degradation) of relief/elevations and filling up (aggradation) of basins/ depressions, 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.

6. Origin of the Earth

Scientists and philosophers have propounded from time to time their concepts, hypotheses and theories to unravel the mystery and to solve the riddle of the problems of the origin and evolution of our solar system in general and of the earth in particular but none of these could be accepted by majority of the scientific community. Though there is no common consensus among the scientists about the origin of our solar system but it can be safely argued that all planets of our solar system are believed to have been formed by the same process. It means that all the concepts, hypotheses and theories propounded for the origin of the solar system are also applicable for the origin of the earth.

i. **Hot origin concepts:** According to the school of 'hot origin', our solar system was believed to have been formed from the matter which as either initially hot or was heated up in the process of the origin of the earth.

ii. **Cold origin concepts:** On the other hand, according to the school of 'cold origin' our solar system was formed of the matter which was either initially cold or always remained cold. After the formation the earth might have been heated up due to the presence of radioactive elements or only the interior of the earth might have been heated up due to intense pressure exerted by the super incumbent load of the upper layers.

6.1 Nebular hypothesis:

The nebular hypothesis is the most widely accepted model to explain the formation of the Solar System. It suggests the Solar System is formed from gas and dust orbiting the Sun. The theory was developed by Immanuel Kant initially in 1755 and then modified in 1796 by Pierre Laplace.

According to the nebular theory, stars form in massive and dense clouds of molecular hydrogen giant molecular clouds (GMC). These clouds are gravitationally unstable, and matter coalesces within them to smaller denser clumps, which then rotate, collapse, and form stars. Star formation is a complex process, which always produces a gaseous proto planetary disk around the young star. This may give birth to planets in certain circumstances. Thus the formation of planetary systems is thought to be a natural result of star formation. A Sun-like star usually takes approximately 1 million years to form, with the proto planetary disk evolving into a planetary system over the next 10 – 100 million years. If the disk is massive enough, the runaway accretions begin, resulting in the rapid—100,000 to 300,000 years—formation of Moon- to Mars-sized planetary embryos. Near the star, the planetary embryos go through a stage of violent mergers, producing a few terrestrial planets. The last stage takes approximately 100 million to a billion years. Super-Earths and other closely orbiting planets are thought to have either formed in situ or ex situ, that is, to have migrated inward from their initial locations.

6.2 Tidal hypothesis:

This hypothesis was given by James Jeans and Harold Jeffreys, explained the origin of the solar system as a result of a close encounter between the Sun and a second star. After as a detailed mathematical analysis, Jeans concluded in 1916 that the tidal interaction between the Sun and a passing star would raise tides on the Sun resulting in the loss of a single cigar-shaped filament of hot gas. This hot gas would then condense directly into the planets. The central section of the "cigar" would give rise to the largest planets – Jupiter and Saturn – while the tapering ends would provide the substance for the smaller worlds.

6.3 Binary Start Hypothesis:

The “Binary” hypothesis was put forth by Russell (1937) who believed in the existence of many stars as pairs in the universe. Our solar system was born from one of these star pairs which consisted of the sun and another smaller star known as the companion star. A huge-sized third star came into the region of this paired stars and caused tidal explosion in the companion star which was completely disrupted, When the third star came close to the companion star some parts of the companion star, were carried away along with the third star which eventually receded away. The rest fell into the sun’s gravitational control, these parts retained by the sun revolved round it and gradually cooled down to form the planets.

6.4 Stages in Evolution of the Earth:

C. Chamberlin (1905) has attempted to describe and explain the evolution of different components of the earth. e.g. continents and ocean basins, folds and faults, volcanoes and earthquakes, mountains and plains, heat of the interior of the earth and its structure and the origin and evolution of its atmosphere through specific periods or stages.

6.4.1 First stage –

‘The period of planetesimal accession’ or ‘the period of acquisition of the present shape and size by the earth’.

6.4.2 Second stage –

“The period of dominant volcanism” or ‘the period of the evolution of the earth’s interior and the evolution of continents and ocean basins’.

6.4.3 Third stage –

‘The actual geological period’ or ‘the period of the formation of the folds and faults, mountains and plateaux etc.

These stages of the evolution of the earth are separated from each other only for the sake of convenience; otherwise these are so interlinked with each other that it is quite difficult to differentiate one stage from the other. The planet earth initially was a barren, rocky and hot object with a thin atmosphere of hydrogen and helium. This is far from the present day picture of the earth. Hence, there must have been some events–processes, which may have caused this change from rocky, barren and hot earth to a beautiful planet with ample amount of water and conducive atmosphere favouring the existence of life.

Between the 4,600 million years and the present, led to the evolution of life on the surface of the planet. The earth was mostly in a volatile state during its primordial stage. Due to gradual increase in density the temperature inside has increased. As a result, the material inside started getting separated depending on their densities. This allowed heavier materials (like iron) to sink towards the centre of the earth and the lighter ones to move towards the surface. With passage of time it cooled further and solidified and condensed into a smaller size. This later led to the development of the outer surface in the form of a crust. During the formation of the moon, due to the giant impact, the earth was further heated up. It is through the process of differentiation that the earth forming material got separated into different layers. Starting from the surface to the central parts, we have layers like the crust, mantle, outer core and inner core. From the crust to the core, the density of the material increases.

7. Interior Structure of the Earth

The structure of earth is in spherical form and is composed of four layers, three solid and one liquid which is in the form of molten metal, and is hot as the surface of the sun. A fruit such as a peach are in analogy to earth's interior. A fruit with large pits, when cut in two pieces has three parts which are similar to earth's crust.

7.1 Sources of Information about the interior of the earth

7.1.1 Direct Sources:

1. **Rocks** from mining area

2. **Volcanic eruptions**

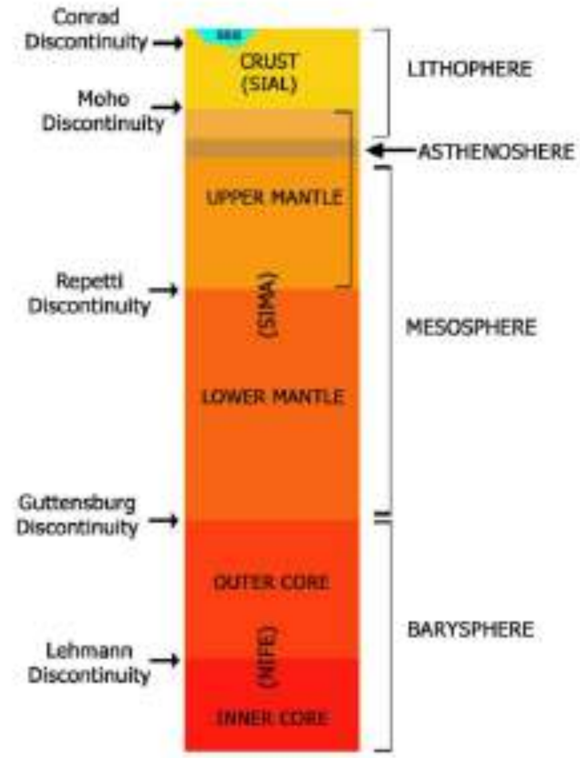
7.1.2 Indirect Sources

1. By analyzing the **rate of change of temperature and pressure** from the surface towards the interior.
2. **Meteors**, as they belong to the same type of materials earth is made of.
3. **Gravitation**, which is greater near poles and less at the equator.
4. **Gravity anomaly**, which is the change in gravity value according to the mass of material, gives us information about the materials in the earth's interior.
5. **Magnetic sources**.
6. **Seismic Waves**: the shadow zones of body waves (Primary and secondary waves) give us information about the state of materials in the interior.

In 1692, Edmund Halley brought forward the idea that the Earth's structure is hollow shell approximately of 500 miles.

Layer from Surface	Earth Layer's Name	Kilometre
1	Crust	0–35
2	Mantle	35–2,890
3	Inner core	2,890–5,150
4	Outer core	5,150–6,360

7.2 Structure of the earth's interior



The structure of the earth's interior is made up of several concentric layers. Structure of Interior of the Earth is divided into three layers-

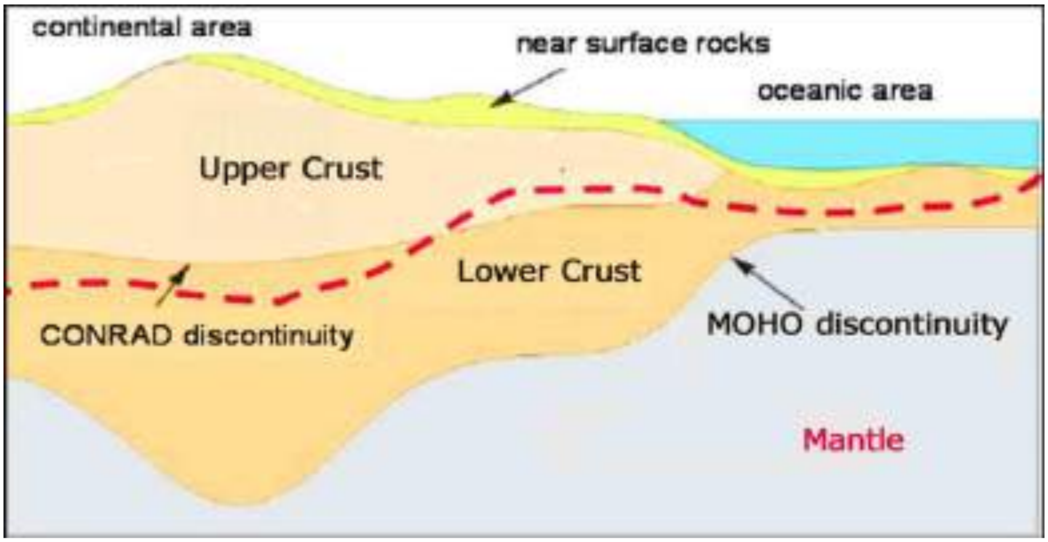
- **Crust**
- **Mantle**
- **Core**

The planet Earth is made up of three main shells: the very thin, brittle crust, the mantle, and the core; the mantle and core are each divided into two parts. All parts are drawn to scale on the cover of this publication, and a table at the end lists the thicknesses of the parts. Although the core and mantle are about equal in thickness, the core forms only 15 percent of the Earth's volume, whereas the mantle occupies 84 percent. The crust makes up the remaining 1 percent. Our knowledge of the layering and chemical composition of the Earth is steadily being improved by earth scientists doing laboratory experiments on rocks at high pressure and analyzing earthquake records on computers.

7.2.1 Crust

It is the outermost solid part of the earth, normally about 8-40 kms thick.It is brittle in nature. Nearly 1% of the earth's volume and 0.5% of earth's mass are made of the crust.The thickness of the crust under the oceanic and continental areas are different. Oceanic crust is thinner (about 5kms) as compared to the continental crust (about 30kms).

Major constituent elements of crust are Silica (Si) and Aluminium (Al) and thus, it is often termed as **SIAL** (Sometimes SIAL is used to refer Lithosphere, which is the region comprising the crust and uppermost solid mantle, also). The mean density of the materials in the crust is 3g/cm3. The discontinuity between the **hydrosphere and crust** is termed as the **Conrad Discontinuity.**

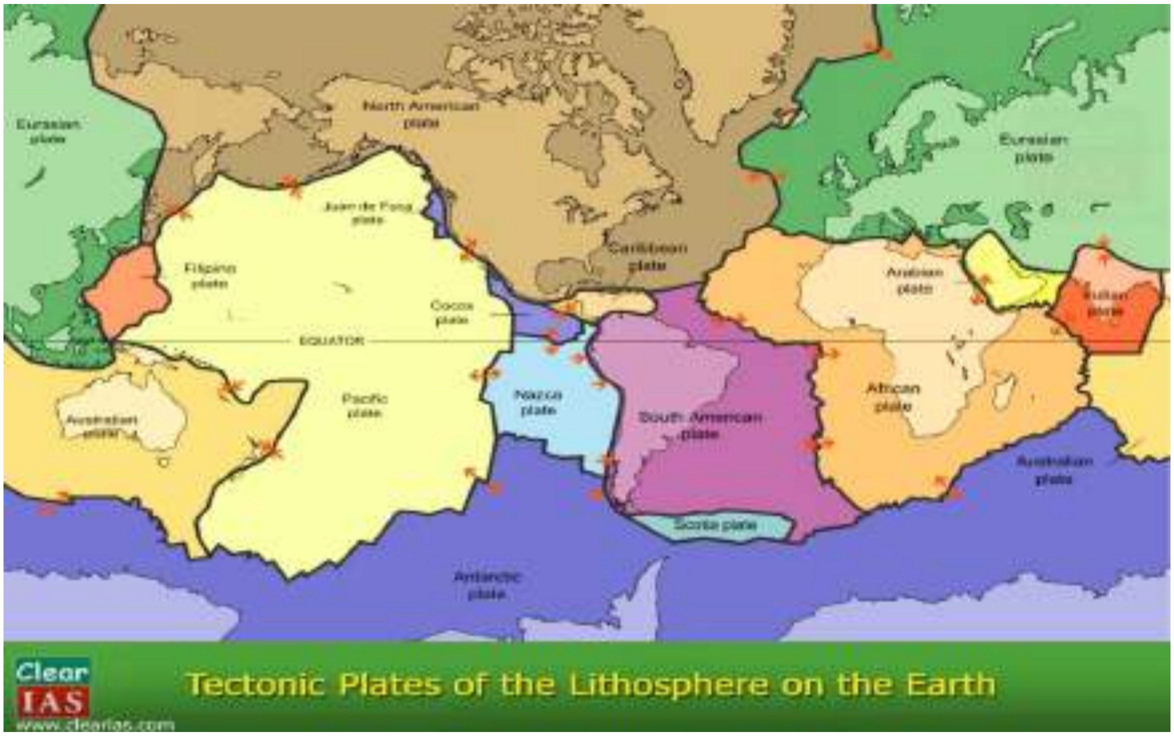


7.2.2 Mantle

The portion of the interior beyond the crust is called as the mantle.The discontinuity between the **crust and mantle** is called as the **Mohorovich Discontinuity or Moho discontinuity.** The thickness of mantle is about 2900 kms. Nearly 84% of the earth's volume and 67% of the earth's mass is occupied by the mantle.

The major constituent elements of the mantle are Silicon and Magnesium and hence it is also termed as **SIMA**. The density of the layer is higher than the crust and varies from 3.3 – 5.4g/cm3. The uppermost solid part of the mantle and the entire crust constitute the **Lithosphere**.

The **asthenosphere** (in between 80-200km) is a highly viscous, mechanically weak and ductile, deforming region of the upper mantle which lies just below the lithosphere. The asthenosphere is the main source of magma and it is the layer over which the lithospheric plates/ continental plates move (plate tectonics).



The discontinuity between the **upper mantle and the lower mantle** is known as **Repetti Discontinuity**. The portion of the mantle which is just below the lithosphere and asthenosphere, but above the core is called as **Mesosphere**.

7.2.3 Core

It is the innermost layer surrounding the earth's centre. The **core is separated from the mantle by Guttenberg's Discontinuity**. It is composed mainly of iron (Fe) and nickel (Ni) and hence it is also called as **NIFE**. The core constitutes nearly 15% of earth's volume and 32.5% of earth's mass.

The core is the densest layer of the earth with its density ranges between 9.5-14.5g/cm3. The Core consists of two sub-layers: the inner core and the outer core. The inner core is in solid state and the outer core is in the liquid state (or semi-liquid). The discontinuity between the upper core and the lower core is called as **Lehmann Discontinuity. Barysphere** is sometimes used to refer the core of the earth or sometimes the whole interior.

8. Temperature, Pressure and Density of the Earth's Interior

8.1 Temperature

- A rise in temperature with increase in depth is observed in mines and deep wells.
- These evidence along with molten lava erupted from the earth's interior supports that the temperature increases towards the centre of the earth.
- The different observations show that the rate of increase of temperature is not uniform from the surface towards the earth's centre. It is faster at some places and slower at other places.
- In the beginning, this rate of increase of temperature is at an average rate of 1^0C for every 32m increase in depth.
- While in the upper 100kms, the increase in temperature is at the rate of 12^0C per km and in the next 300kms, it is 20^0C per km. But going further deep, this rate reduces to mere 10^0C per km.
- Thus, it is assumed that the rate of increase of temperature beneath the surface is decreasing towards the centre (do not confuse rate of increase of temperature with increase of temperature. Temperature is always increasing from the earth's surface towards the centre).
- The temperature at the centre is estimated to lie somewhere between 3000^0C and 5000^0C, may be that much higher due to the chemical reactions under high-pressure conditions.
- Even in such a high temperature also, the materials at the centre of the earth are in solid state because of the heavy pressure of the overlying materials.

8.2 Pressure

- Just like the temperature, the **pressure is also increasing from the surface towards the centre** of the earth.
- It is due to the huge weight of the overlying materials like rocks.

- It is estimated that in the deeper portions, the pressure is tremendously high which will be nearly 3 to 4 million times more than the pressure of the atmosphere at sea level.
- At high temperature, the materials beneath will melt towards the centre part of the earth but due to heavy pressure, these molten materials acquire the properties of a solid and are probably in a plastic state.

8.3 Density

- Due to increase in pressure and presence of heavier materials like Nickel and Iron towards the centre, the **density of earth's layers also gets on increasing towards the centre**.
- The average density of the layers gets on increasing from crust to core and it is nearly 14.5g/cm3 at the very centre.

9. Volcanoes

A volcano is an opening in the earth's crust through which gases, molten rocks materials (lava), ash, steam etc. are emitted outward in the course of an eruption. Such vents or openings occur in those parts of the earth's crust where the rock strata are relatively weak. Volcanic activity is an example of endogenic process. Depending upon the explosive nature of the volcano, different land forms can be formed such as a plateau (if the volcano is not explosive) or a mountain (if the volcano is explosive in nature).

9.1 Causes of earthquakes

Earth's major earthquakes occur mainly in belts coinciding with the margins of tectonic plates. This has long been apparent from early catalogs of felt earthquakes and is even more readily discernible in modern seismicity maps, which show instrumentally determined epicentres. The most important earthquake belt is the Circum-Pacific Belt, which affects many populated coastal regions around the Pacific Ocean—for example, those of New Zealand, New Guinea, Japan, The Aleutian Islands, Alaska, and the western coasts of North and South America. It is estimated that 80 percent of the energy presently released in earthquakes comes from those whose epicenters are in this belt. The seismic activity is by no means uniform throughout the belt, and there are a number of branches at various points. Because at many places the Circum-Pacific Belt is associated with volcanic activity, it has been popularly dubbed the "Pacific Ring of Fire".

A second belt, known as the Alpide Belt, passes through the Mediterranean region eastward through Asia and joins the Circum-Pacific Belt in the East Indies. The energy released in earthquakes from this belt is about 15 percent of the world total. There also are striking connected belts of seismic activity, mainly along oceanic ridges—including those in theatric ocean, the Atlantic Ocean, and the western Indian Ocean—and along the Rift valleys of East Africa. This global seismicity distribution is best understood in terms of its Plate Tectonic Setting.

9.1.1 Natural forces

Earthquakes are caused by the sudden release of energy within some limited region of the rocks of the earth. The energy can be released by Elastic strain, gravity, chemical reactions, or even the motion of massive bodies. Of all these the release of elastic strain is the most important cause, because this form of energy is the only kind that can be stored in sufficient quantity in the Earth to produce major disturbances. Earthquakes associated with this type of energy release are called tectonic earthquakes.

9.1.2 Tectonics

The most common ones are the **tectonic earthquakes.** Although the Earth looks like a pretty solid place from the surface, it's actually extremely active just below the surface. The Earth is made of four basic layers (generally three): a **solid crust, a hot, nearly solid mantle, a liquid outer core and a solid inner core.**

9.1.3 Volcanic Earthquake

A special class of tectonic earthquake is sometimes recognised as volcanic earthquake. However, these are confined to areas of active volcanoes. Earthquakes produced by stress changes in solid rock due to the injection or withdrawal of magma (molten rock) are called volcano earthquakes These earthquakes can cause land to subside and can produce large ground cracks. These earthquakes can occur as rock is moving to fill in spaces where magma is no longer present. Volcano-tectonic earthquakes don't indicate that the volcano will be erupting but can occur at any time.

9.1.4 Human Induced Earthquakes

In the areas of intense mining activity, sometimes the roofs of underground mines collapse causing minor tremors. These are called collapse earthquakes. Ground shaking may also occur due to the explosion of chemical or nuclear devices. Such tremors are called explosion earthquakes. The earthquakes that occur in the areas of large reservoirs are referred to as reservoir induced earthquakes.

9.1.5 Earthquakes based on the depth of focus

The earthquakes are divided into three zones: shallow, intermediate, and deep based on their depth which range between 0 – 700 km.

- **Shallow earthquakes** have a focus 0 – 70 km deep.

- **Intermediate earthquakes** have a focus 70 – 300 km deep.
- **Deep earthquakes** have a focus 300 – 700 km deep.

9.2 Wadati–Benioff zone

- Deep earthquakes (300-700 km) are produced in this zone.
- It is a zone of subduction, along which earthquakes are common, which are produced by the interaction of a downgoing oceanic crustal plate against a continental plate.
- Some of the most powerful earthquakes occur along this zone.

These earthquakes can be produced by slip along the subduction thrust fault or by slip on faults within the downgoing plate as the plate is pulled into the mantle

Magma vs Lava: The difference

- **Magma** is the term used to denote the molten rocks and related materials seen inside earth. A weaker zone of the mantle called asthenosphere, usually is the source of magma.
- Once this magma came out to the earth surface through the vent of a volcano, it is called as the **Lava**. Therefore, Lava is nothing but the magma on earth surface.
- The process by which solid, liquid and gaseous material escape from the earth's interior to the surface of the earth is called as Volcanism.

9.3 Types of Volcanoes

Volcanoes are classified on the basis of nature of eruption and the form developed at the surface.

9.3.1 Shield Volcanoes

Shied Volcanoes are not very steep but are far and wider. They extend to great height as well as distance. They are the largest of all volcanoes in the world as the lava flows to a far distance. The Hawaiian volcanoes are the most famous examples. Shield volcanoes have low slopes and consist almost entirely of frozen lavas.

If you were to fly over top of a shield volcano, it would resemble a warrior's shield, hence the name. These volcanoes are mostly made up of basalt (less viscous), a type of lava that is very fluid when erupted. For this reason, these volcanoes are not steep. **They are of low explosive in general**, but if somehow water gets into the vent they may turn explosive. 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

9.3.2. Cinder Cone Volcanoes:

Cinders are extrusive igneous rocks. A more modern name for **cinder** is Scoria.

Small volcanoes: These volcanoes consist almost entirely of loose, grainy cinders and almost no lava. They have very steep sides and usually have a small crater on top.

9.3.3 Composite Volcanoes:

Shape: Cone shaped with moderately steep sides and sometimes have small craters in their summits.

Volcanologists call these "strato-" or composite volcanoes because they consist of layers of solid lava flows mixed with layers of sand- or gravel-like volcanic rock called cinders or volcanic ash.

They are characterized by the eruption of a 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 the ground. This material accumulates in the vicinity of the vent openings and leading to the formation of layers, and this makes the mount appears as composite volcanoes.

9.3.4 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. Their explosiveness indicates that its magma chamber is large and in close vicinity. A caldera differs from a crater in such a way that a caldera is a huge depression caused by a collapse after a large-scale eruption, whereas a crater is a small, steep side, volcanic depression bored out by an eruptive plume.

9.3.5 Flood Basalt Provinces

These volcanoes outpour highly fluid lava that flows for long distances. The Deccan Traps from India, presently covering most of the Maharashtra plateau, are a much larger flood basalt province.

9.3.6 Mid-Ocean Ridge Volcanoes

These volcanoes occur in the oceanic areas. There is a system of mid-ocean ridges more than 70,000 km long that stretches through all the ocean basins. The central portion of this ridge experiences frequent eruptions. Volcanoes can also be classified based on the frequency of eruption, mode of eruption and characteristic of lava.

9.4 Distribution of Earthquakes

Earthquakes can strike any location at any time, but history shows they occur in the same general patterns year after year, principally in three large zones of the earth:

The world's greatest earthquake belt, the **circum-Pacific seismic belt,** is found along the rim of the Pacific Ocean, where about 81 percent of our planet's largest earthquakes occur.

1. It has earned the nickname **"Ring of Fire".**

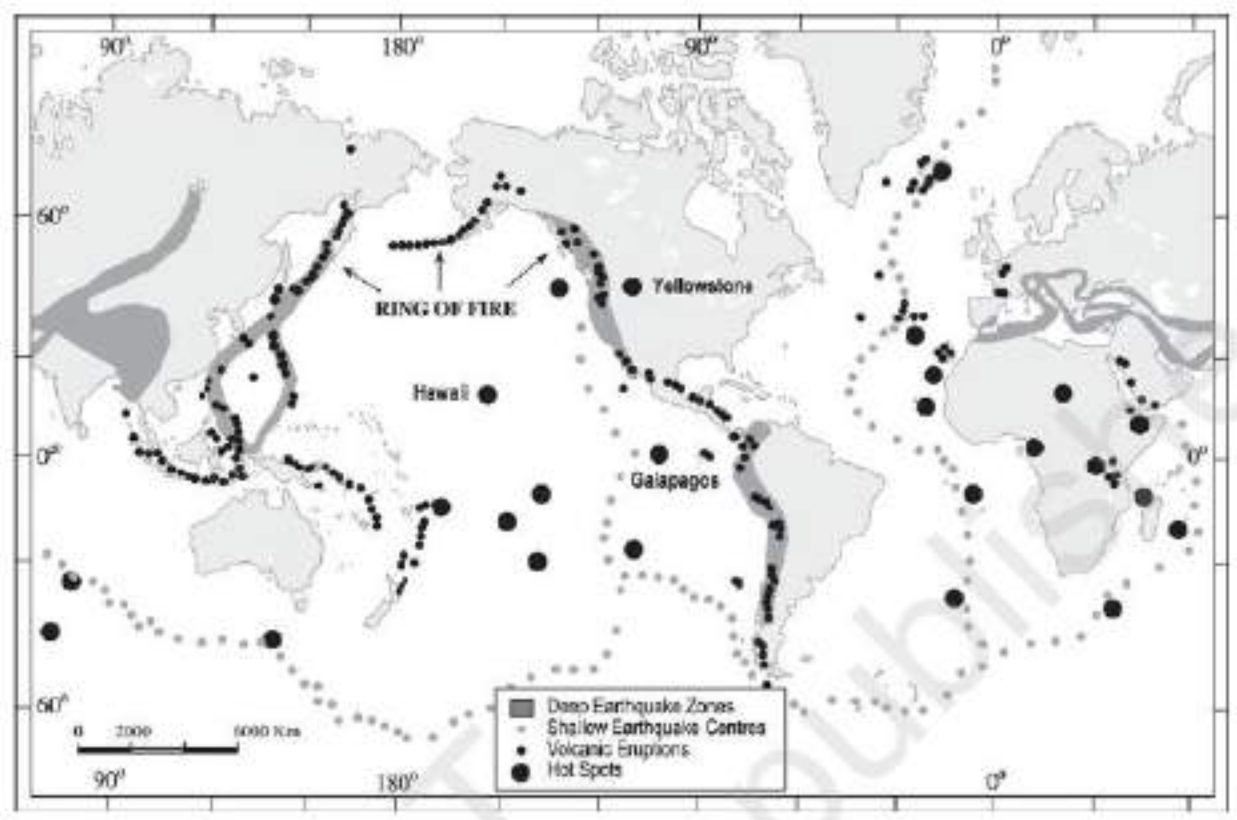
- The belt exists along boundaries of tectonic plates, where plates of mostly oceanic crust are sinking (or subducting) beneath another plate. Earthquakes in these subduction zones are caused by slip between plates and rupture within plates.

The **Alpide earthquake belt (mid Continental belt)** extends from Java to Sumatra through the Himalayas, the Mediterranean, and out into the Atlantic.

- This belt accounts for about 17 percent of the world's largest earthquakes, including some of the most destructive.

The third prominent belt follows the submerged **mid-Atlantic Ridge.** The ridge marks where two tectonic plates are spreading apart (a divergent plate boundary).

- Most of the mid-Atlantic Ridge is deep underwater and far from human development.



9.5 Measurement of Earthquakes

- The energy from an earthquake travels through Earth in vibrations called **seismic waves.**
- Scientists can measure these seismic waves on instruments called **seismometers.**
- A seismometer detects seismic waves below the instrument and records them as a series of zig-zags.
- Scientists can determine the time, location and intensity of an earthquake from the information recorded by a seismometer. This record also provides information about the rocks the seismic waves traveled through.
- The earthquake events are scaled either according to the magnitude or intensity of the shock. 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.

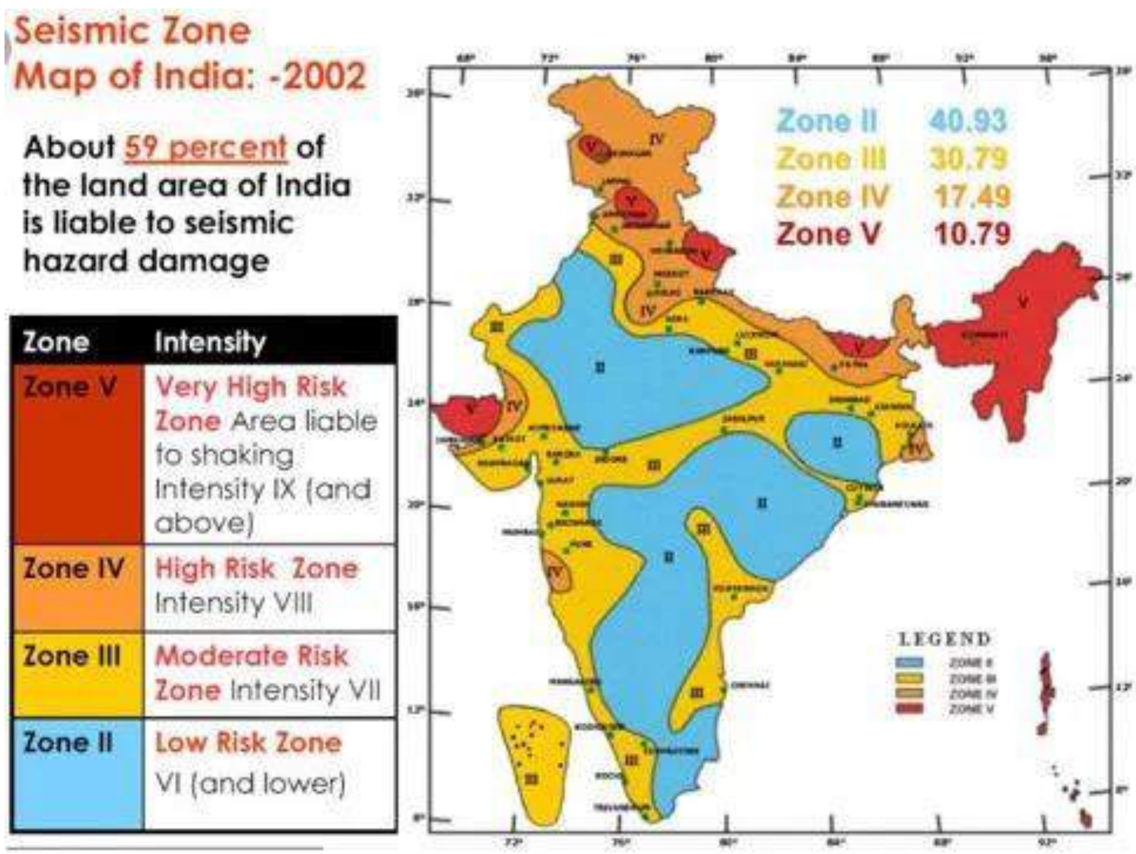
- The intensity scale is named after **Mercalli,** an Italian seismologist. The intensity scale takes into account the visible damage caused by the event. The range of intensity scale is from 1-12.

9.6 Richter scale:

The scale represents the **magnitude** of the earthquake. The magnitude is expressed in absolute numbers from 1-10. Each whole number increase in Richter scale represents a ten times increase in power of an earthquake.

9.7 Earthquake in India

- India is one of the highly earthquake affected countries because of the presence of technically active young fold mountains - Himalaya.
- India has been divided into **four seismic zones (II, III, IV, and V)** based on scientific inputs relating to seismicity, earthquakes occurred in the past and tectonic setup of the region.



10. Concepts of Geomorphic Cycles and Landscape Development

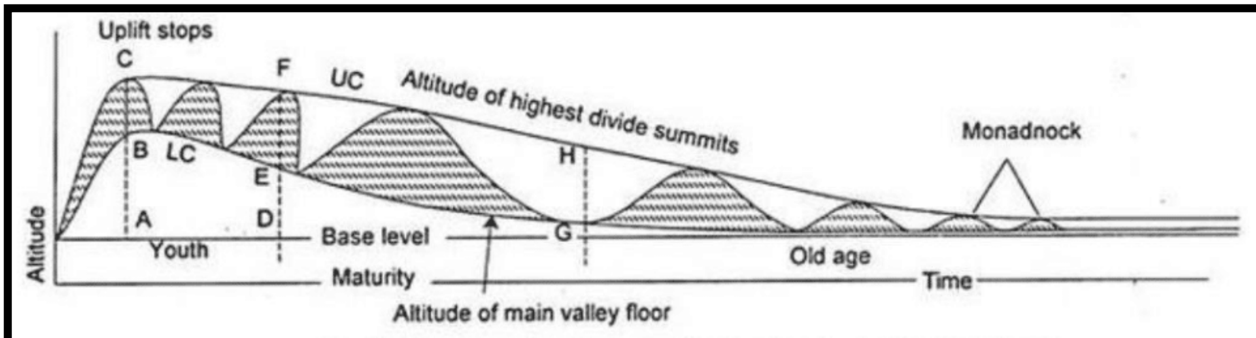
Many of us love visiting hill stations for vacations. It is a balm for the tired soul and does wonders for the mind. Some of us might love trekking up mountains and settling down on the top to either view sunrise or sunset or just stare in awe at the magnificent landscape all around. Have we ever looked at those fascinating mountains or the green plains and wondered how they might have been formed? Certainly, the process would not be simple! Set by William M. Davis, the theory of the geomorphic cycle tries to tell us how terrains are developed across landscapes. The model involves explanations for many different structures such as hilltops, valleys, mountains, and rivers. Because it describes the processes of erosion and deposition which eventually lead to relief or terrain formation, it is also known as the cycle of erosion or the theory of land evolution.

10.1 Meaning of Geomorphic Cycle

The geomorphic cycle is any cycle of events that leads to the formation of any relief (terrain) development in landscapes. It is a model explaining the formation of many different terrain structures such as hilltops, valleys, mountains, and river drainage systems. It is also known as the geographic cycle or the cycle of erosion for the development of various landscapes. Hence, a geomorphic cycle is the theory of evolution of landforms that includes many distinct events of erosion and deposition due to a variety of reasons that will be discussed below in this article.

10.2 The Geomorphic Cycle

William M. Davis first set the theory of the geomorphic cycle and laid down some concepts of geomorphic cycles and landscape development. According to the theory, there are commonly three stages of the cycle of erosion and the development of any landforms. The three periods are classified from youth to maturity and old age. These stages were considered to be gradually transitioning from one period to another. This model that explains the concepts of geomorphic cycles and landscape development is known as the Davis geomorphic cycle. Although certain aspects of the Davis geomorphic cycle are not currently accepted, it is still the primary and widely proclaimed theory of the geomorphic cycle that describes the various events leading to the formation of landscapes.



Graphical presentation of geographical cycle presented by W.M. Davis.

10.2.1 Stages of the Geomorphic Cycle

The Youthful Stage

The initial stage as put forward by the Davis geomorphic cycle is the youthful stage of landscape development. This stage of terrain development begins with the upliftment of the landform. It includes either the uplifted or to-be-uplifted periods of the development process. During this stage due to the processes that favour the uplifting of the landform, significant folds are produced in the crust of the Earth. These folds are generally the mountains or the block mountains. This uplifting process of mountain formation is widely known and an accepted phenomenon. The folding or uplifting can occur due to a variety of phenomena such as the movement and clashing of the tectonic plates of which the Himalayan mountain range is an example. During the youthful stage, the rivers flowing through the uplifted landform would create another distinction between the uplands and valley bottoms. The differences between the uplands and the valley bottoms increase rapidly throughout this stage and even during the height of the youthful stage.

The Mature Stage

Following the youthful or the youth stage, comes the mature stage of the geographical landscape development. During this stage, due to the dissection of the streams or rivers, the ever-increasing difference in-between the valley bottoms and the uplands or the mountains reaches its height. These height differences are the greatest in the mature stage of relief development. Another factor that plays a significant role in the mature stage is the slope decline. When the height difference between the uplands and the valley bottoms reaches the maximum, slope decline becomes an important phenomenon. The slope of the upland begins to decline faster than the incision or dissection by any river stream. This effectively leads to the decrease in the relief features of height and the difference between the uplands and the bottom of valleys starts to lessen and diminish gradually.

The Old Age Stage

The stage following the mature stage is the old age' stage of relief development. In old age, the initially uplifted terrain feature gradually diminishes or reduces to a surface known as the peneplain. During the old age, which is the latest stage in the process, the erosion has been acting upon the terrain so long that although the terrain was at a significant height when uplifted, it is now reduced to a lowland which is known as the peneplain. The peneplain is usually at sea level and sometimes is reduced so much that it drowns around the nearest water bodies. Although some of the peneplains may be submerged, some may maintain the residual height from the initial upliftment.

10.2.2 The Second Geomorphic Cycle

Following old age, the second geomorphic cycle starts again with the upliftment of the terrain. One of the important factors according to this theory of Davis geomorphic cycle which explains the concepts of geomorphic cycles and landscape development, is the contribution of time in the process of erosion. Time plays an important role according to the theory in the entire of erosion

But, there are certain cases when during any of the stages of the geomorphic cycle to upliftment can start before completion of old age. This event when it occurs is known as rejuvenation. It may or may not be a common phenomenon for a particular relief structure. This is because according to Davis, the full geomorphic cycle was a rare or special case as there are continuous geological changes taking place throughout the world which can cause changes in the stages of the geomorphic cycle.

This theory of the evolution of landscapes applies to hilltops, valleys, mountains, and river drainage systems. Based on this theory, it is assumed that once the stage of any landform is known, the history of the landform development can be known according to the established principles

10.2.3 Drawbacks of the Common Theories of the Geomorphic Cycle

Although Davis had been able to acknowledge the factors affecting the geomorphic cycle as rock type, structure, and processes of erosion, he emphasised the importance of time. But it is currently believed that time does play a significant role as Davis suggested and the contribution

by it is the same as other factors in relief development. This theory of the cycle of erosion has been widely accepted although there is accumulating evidence that refutes the theory of the Geomorphic cycle. It is now usually considered that the initial conditions or the conditions surrounding the upliftment of the landform may not significantly guide the stages towards the end products. Instead of a gradual transition of the landforms through various stages, there is a dynamic equilibrium reached in-between the landforms and the processes that act upon them, which in turn leads to erasing of the physiographic history of the region.

Another drawback of the theory is that originally the theory intended to provide explanations for the development of temperate landscapes as the major focus was put on the erosive activities by the river streams on the uplands or uplifted regions. Also, the nature of surface processes was poorly represented by the model. It was mostly theoretical and deductive and did not take into account the complexity of tectonic movements and climate change. Nevertheless, the cycle of erosion has been accepted by extending and including certain modifications that involve the arid, glacial, karst, coastal and periglacial areas.

IIPA2022

Indian & World Geography Chapter 9

Short Answers

CSM-03 Compilled by Dr Amit Kumar Singh

2022

This Chapter Contains

- Erosion and Deposition: Action of Running Water and Groundwater
- Action of Glaciers
- Action of Winds
- Action of Waves
- Formation of Landforms
- Ocean Floor
- Bottom topography of the Atlantic Oceans
- Bottom topography of the Pasific Oceans
- Bottom topography of the Indian Oceans
- Temperature and salinity of the oceans

Contents

1. Erosion and Deposition: Action of Running Water and Groundwater

Running water, which doesn't need any further explanation, has two components: one is overland flow on the general land surface as a sheet and the other is linear flow as streams and rivers in valleys.The overland flow causes **sheet erosion** and depending upon the irregularities of the land surface, the overland flow may concentrate into narrow to wide paths. During the sheet erosion, minor or major quantities of materials from the surface of the land are removed in the direction of flow and gradual small and narrow **rills** will form. These rills will gradually develop into long and wide **gullies**, the gullies will further deepen, widen and lengthen and unite to give rise to a network of **valleys**. (Note: A valley can be formed in various ways like faulting, but here we are dealing only with the formation by means of exogenic geomorphic agent). Once a valley is formed, it later develops into a **stream** or **river**.

1.1 Courses of a river

A river, which is the best example of the linear flow of running water through a valley, can be divided into three, on the basis of its course – upper course, middle course and lower course.

1.1.1 Upper Course / Stage of Youth (Erosion dominates):

It starts from the source of the river in hilly or mountainous areas. The river flows down the steep slope and, as a result, its velocity and eroding power are at their maximum. Streams are few, with poor integration. As the river flows down with high velocity, vertical erosion or downward cutting will be high which results in the formation of **V-Shaped Valleys.** Waterfalls, rapids, and gorges exist where the local hard rock bodies are exposed.

1.1.2 Middle Course/ Stage of Maturity (Transportation dominates):

In this stage, vertical erosion slowly starts to replace with lateral erosion or erosion from both sides of the channel. Thus, the river channel causes the gradual disappearance of its V-shaped valley (not completely). Streams are plenty at this stage with good integration. Wider flood plains start to visible in this course and the volume of water increases with the confluence of many tributaries. The work of river predominantly becomes transportation of the eroded materials from the upper course (little deposition too). Landforms like alluvial fans, piedmont alluvial plains, meanders etc. can be seen at this stage.

1.1.3 Lower Course/ Stage of Old (Deposition dominates):

The river starts to flow through a broad, level plain with heavy debris brought down from upper and middle courses. Vertical erosion has almost stopped and lateral erosion still goes on. The work of the river is mainly deposition, building up its bed and forming an extensive flood plain. Landforms like braided channels, floodplains, levees, meanders, oxbow lakes, deltas etc. can be seen at this stage.

Running water: erosion, transportation, and deposition

Erosion occurs when overland flow moves soil particles downslope. The rock materials carried by erosion is the load of the river. This load acts as a grinding tool helping in cutting the bottom and sides of the river bed, resulting in deepening and widening of the river channel.

1.2 Erosion Types

The work of river **erosion is accomplished in different ways**, all of which may operate together. They are corrasion, corrosion, hydraulic action etc.

- **Corrasion or Abration:** As the rock particles bounce, scrape and drag along the bottom and sides of the river, they break off additional rock fragments. This form of erosion is called corrasion or abration. They are two types: vertical corrosion which acts downward and lateral corrosion which acts on both sides.
- **Corrosion or Solution:** This is the chemical or solvent action of water on soluble or partly soluble rocks with which the river water comes in contact.
- **Hydraulic Action:** This is the mechanical loosening and sweeping away of material by the sheer force or river water itself. No load or material is involved in this process.

1.3 Transportation types

After erosion, the eroded materials get transported with the running water. This **transportation of eroded materials is carried in four ways**:

- **Traction:** The heavier and larger rock fragments like gravels, pebbles etc are forced by the flow of the river to roll along its bed. These fragments can be seen rolling, slipping, bumping and being dragged. This process is called as traction and the load transported in this way are called traction load.
- **Saltation:** Some of the fragments of the rocks move along the bed of a stream by jumping or bouncing continuously. This process is called as saltation.
- **Suspension:** The holding up of small particles of sand, silt and mud by the water as the stream flows is called suspension.
- **Solution:** Some parts of the rock fragments dissolved in the river water and transported. This type of transportation is called solution transportation.

When the stream comes down from the hills to plain areas with the eroded and transported materials, the absence of slope/gradient causes the river to lose it energy to further carry those transported materials. As a result, the load of the river starts to settle down which is termed as deposition. Erosion, transportation, and deposition continue until the slopes are almost completely flattened leaving finally a lowland of faint relief called **peneplains** with some low resistant remnants called **monadnocks**.

1.3.1 Erosional Landforms due to Running Water

Valleys, Gorges, Canyon

As we discussed above, valleys are formed as a result of running water. The rills which are formed by the overland flow of water later develop into gullies. These gullies gradually deepen and widen to form valleys. A **gorge** is a deep valley with very steep to straight sides. A **canyon** is characterized by steep step-like side slopes and may be as deep as a gorge. A gorge is almost equal in width at its top as well as bottom and is formed in hard rocks while a canyon is wider at its top than at its bottom and is formed in horizontal bedded sedimentary rocks.

Potholes, Plunge pools

Potholes are more or less circular depressions over the rocky beds of hills streams. Once a small and shallow depression forms, pebbles and boulders get collected in those depressions and get rotated by flowing water. Consequently, the depressions grow in dimensions to form potholes. Plunge pools are nothing but large, deep potholes commonly found at the foot of a waterfall. They are formed because of the sheer impact of water and rotation of boulders.

Incised or Entrenched Meanders

They are very deep wide meanders (loop-like channels) found cut in hard rocks. In the course of time, they deepen and widen to form gorges or canyons in hard rock. The difference between a normal meander and an incised/entrenched meander is that the latter found on hard rocks.

River Terraces

They are surfaces marking old valley floor or flood plains. They are basically the result of vertical erosion by the stream. When the terraces are of the same elevation on either side of the river, they are called as paired terraces. When the terraces are seen only on one side with none on the other or one at quite a different elevation on the other side, they are called as unpaired terraces.

1.3.2 Depositional Landforms due to Running Water

Alluvial Fans

They are found in the middle course of a river at the foot of slope/ mountains. When the stream moves from the higher level break into foot slope plain of low gradient, it loses its energy needed to transport much of its load. Thus, they get dumped and spread as a broad low to the high cone-shaped deposits called an alluvial fan. The deposits are not roughly very well sorted.

Deltas

Deltas are like an alluvial fan but develop at a different location. They are found in the mouth of the river, which is the final location of depositional activity of a river. Unlike alluvial fans, the deposits making up deltas are very well sorted with clear stratification. The coarser material settle out first and the finer materials like silt and clay are carried out into the sea.

Flood Plains, Natural Levees

Deposition develops a flood plain just as erosion makes valleys. A riverbed made of river deposits is the active flood plain and the flood plain above the bank of the river is the inactive flood plain. Natural levees are found along the banks of large rivers. They are low, linear and parallel ridges of coarse deposits along the banks of a river. The levee deposits are coarser than the deposits spread by flood water away from the river.

Meanders and oxbow lakes

Meanders are loop-like channel patterns develop over the flood and delta plains. They are actually not a landform but only a type of channel pattern formed as a result of deposition. They are formed basically because of three reasons: (i) propensity of water flowing over very gentle gradient to work laterally on the banks; (ii) unconsolidated nature of alluvial deposits making up the bank with many irregularities; (iii) Coriolis force acting on fluid water deflecting it like deflecting the wind.

The concave bank of a meander is known as cut-off bank and the convex bank is known as a slip-off As meanders grow into deep loops, the same may get cut-off due to erosion at the inflection point and are left as oxbow lakes. For large rivers, the sediments deposited in a linear fashion at the depositional side of a meander are called as **Point Bars or Meander Bars.**

Braided Channels

When selective deposition of coarser materials causes the formation of a central bar, it diverts the flow of river towards the banks, which increases lateral erosion. Similarly, when more and more such central bars are formed, braided channels are formed. Riverine Islands are the result of braided channels.

1.4 What does Groundwater do?

The part of rain or snow-melt water which accumulates in the rocks after seeping through the surface is called underground water or simply groundwater. The rocks through which water can pass easily are called as permeable rocks while the rocks which do not allow water to pass are called as impermeable rocks. After vertically going down to some depth, the water under the ground flows horizontally through the bedding planes, joints or through the materials themselves. Although the amount of groundwater varies from place to place, its role in shaping the surface features of the earth is quite important.

The works of groundwater are mainly seen in rocks like limestone, gypsum or dolomite which are rich in calcium carbonate. Any limestone, dolomite or gypsum region showing typical landforms produced by the action of groundwater through the process of solution and deposition is called as **Karst Topography** (Karst region in the Balkans). The zones or horizons of permeable and porous rocks which are fully filled with water are called as the **Zones of Saturation.**

The marks which show the upper surface of these saturated zones of the groundwater are called as the **Water Tables.** And these rocks, which are filled with underground water, are called as The water table is generally higher in the areas of high precipitation and also in areas bordering rivers and lakes. They also vary according to seasons. On the basis of variability, water tables are of two types: (i) Permanent water table, in which the water will never fall below a certain level and wells dug up to this depth provide water in all seasons; (ii) Temporary water tables, which are seasonal water tables.

Springs: They are the surface outflow of groundwater through an opening in a rock under hydraulic pressure. When such springs emit hot water, they are called as **Hot Springs.** They generally occur in areas of active or recent volcanism. When a spring emits hot water and steam in the form of fountains or jets at regular intervals, they are called as geysers. In a geyser, the period between two emissions is sometimes regular (Yellowstone National Park of USA is the best example).

1.4.1 Erosional Landforms due to Groundwater

Sinkholes and caves are erosional landforms formed due to the action of ground water.

Sinkholes

Small to medium sized rounded to sub-rounded shallow depressions called swallow holes forms on the surface of rocks like limestone by the action of the solution. A sinkhole is an opening more or less circular at the top and funnel-shaped towards the bottom. When as sinkhole is formed solely through the process of solution, it is called as a **solution sink**.

Some sinkhole starts its formation through the solution process but later collapse due to the presence of some caves or hollow beneath it and becomes a bigger sinkhole. These types are called as **collapse sinks**. The term **Doline** is sometimes used to refer collapse sinks. Solution sinks are more common than collapse sinks. When several sink holes join together to form valley of sinks, they are called as

Lapies are the irregular grooves and ridges formed when most of the surfaces of limestone are eaten by solution process.

Caves

In the areas where there are alternative beds of rocks (non-soluble) with limestone or dolomite in between or in areas where limestone are dense, massive and occurring as thick beds, cave formation is prominent. Caves normally have an opening through which cave streams are discharged Caves having an opening at both the ends are called tunnels.

1.4.2 Depositional Landforms of Groundwater

Stalactites and stalagmites

They are formed when the calcium carbonates dissolved in groundwater get deposited once the water evaporates. These structures are commonly found in limestone caves. Stalactites are calcium carbonate deposits hanging as icicles while Stalagmites are calcium carbonate deposits which rise up from the floor. When a stalactite and stalagmite happened to join together, it gives rise to **pillars** or **columns** of different diameters.

2. Erosion and Deposition: Action of Glaciers

Glaciers are a **mass of ice moving under its own weight**. They are commonly found in the snow-fields. We know that the landmass on the earth is not entirely the same as we see around. Some areas are covered by thick green forests, some with dry hot deserts, some with permanent ice covers etc. Among these varied landmasses, the permanently ice-covered regions on the earth surface are called as snow-fields. The lowest limit of permanent snow or snow-field is called as the snowline. A Glacier forms in areas where the accumulation of snow exceeds its ablation (melting and sublimation) over many years, often centuries. They form features like **crevasses, seracs** etc. A **crevasse** is a deep crack, or fracture, found in an ice sheet or glacier, as opposed to a crevice that forms in rock. A **serac** is a block or column of glacial ice, often formed by intersecting crevasses on a glacier. ***Ogives*** are alternating wave crests and valleys (troughs) that appear as dark and light bands of ice on glacier surfaces. They are linked to seasonal motion of glaciers; the width of one dark and one light band generally equals the annual movement of the glacier.Glaciers cover about 10 percent of Earth's land surface and they are the largest freshwater reservoirs on earth.

2.1 Erosional landforms due to Glaciers

Cirque or Corris

They are deep, long and wide troughs or basins with very steep concave to vertically dropping high walls at its head as well as sides. They are simply a bowl-shaped depression formed due to the erosional activity of glaciers. When these depressions are filled with water, they are called as **Cirque lake or Corrie Lake or Tarn Lakes**.

Hanging Valleys or U-shaped Valleys, Fjords/fiords

The Glacier doesn't create a new valley like a river does but deepens and widens a pre-existing valley by smoothening away the irregularities. These valleys, which are formed by the glacial erosions assume the shape of letter 'U' and hence are called as U-shaped Valleys or Hanging Valleys. A fjord is a very deep glacial trough filled with sea water and making up shorelines. A fjord is formed when a glacier cuts a U-shaped valley by ice segregation and abrasion of the surrounding bedrock and this valley gradually gets filled with the seawater (formed in mountains nearby sea).

Horns and Aretes

Horns are sharp pointed and steep-sided peaks. They are formed by headward erosion of cirque wall. When the divide between two cirque walls gets narrow because of progressive erosions, it results in the formation of a saw-toothed ridge called **Arete**.

2.2 Depositional Landforms due to Glaciers

Glacial deposits are of two types:

1. **Glacial Till –** unassorted coarse and fine debris;
2. **Outwash –** assorted roughly stratified deposits.

Moraines

Moraines are long ridges of deposits of glacial till. When these deposits are at the end of a glacier, they are called as **Terminal moraines** and when they are deposited on both sides, they are called as **Lateral moraines**. When lateral moraines of two glaciers join together, they form **Medial moraines**. When the lateral moraines of both sides of a glacier join together, it forms a horse-shoe shape. Ground moraines are deposits left behind in areas once covered by glaciers.

Eskers

When glaciers melt in summer, the water which formed as a result of melting accumulates beneath the glacier and flows like streams in channels beneath that ice. Very coarse material like boulders, blocks and some minor fractions of rock debris are carried away by these streams. They later get deposited in the valleys itself and once the ice melts completely, they are visible to the surface as sinuous ridges.These ridges are called as Eskers.

Drumlins

They are smooth oval-shaped ridge-like structures composed mainly of glacial till. It shapes like an inverted spoon with the highest part is called as **Stoss End** and the lowest narrow part is called as **Tail End.** They are formed as a result of glacial movement over some minor obstruction like small surface rocks. The glacial till gets deposited in those obstructions and the movement of glacier shapes these deposits like an inverted spoon.

3. Erosion and Deposition: Action of Wind

The wind is the main geomorphic agent in the hot deserts. Winds in hot deserts have greater speed which causes erosional and depositional activities in the desert. The landforms which are created by erosional and depositional activities of wind are called as **Aeolian Landforms.** This process is not unique to the Earth, and it has been observed and studied on other planets, including Mars. An **erg** (also known as **sand sea** / **dune sea** / **sand sheet** if it lacks dunes) is a broad, flat area of desert covered with wind-swept sand with little or no vegetative cover. It is defined as a desert area that contains more than 125 square kilometres of aeolian or wind-blown sand and where sand covers more than 20% of the surface. Smaller areas are known as “dune fields”. The largest hot desert in the world, the Sahara, contains several ergs.

3.1 Erosional Landforms due to Wind

Pediplains

When the high relief structures in deserts are reduced to low featureless plains by the activities of wind, they are called as Pediplains.

Deflation Hollows

Deflation is the removal of loose particles from the ground by the action of wind. When deflation causes a shallow depression by persistent movements of wind, they are called as deflation hollows.

Mushroom Tables

Ventifacts are rocks that have been abraded, pitted, etched, grooved, or polished by wind-driven sand or ice crystals. These geomorphic features are most typically found in arid environments where there is little vegetation to interfere with aeolian particle transport, where there are frequently strong winds, and where there is a steady but not overwhelming supply of sand. **Mushroom Tables / Mushroom rocks** are Ventifacts in the shape of a mushroom. In deserts, a greater amount of sand and rock particles are transported close to the ground by the winds which cause more bottom erosion in overlying rocks than the top. This result in the formation of rock pillars shaped like a mushroom with narrow pillars with broad top surfaces.

3.2 Depositional Landforms of Wind

Sand dunes

Dry hot deserts are good places for sand dune formation. According to the shape of a sand dune, there are varieties of sand dune forms like Barchans, Seifs etc. The **crescent-shaped dunes** are called as **Barchans** and they are the most common one. **Seif** is similar to Barchans but has only one wing or point.

Loess

In several large areas of the world, the surface is covered by deposits of wind-transported silt that has settled out from dust storms over many thousands of years. These depositions are called as Loess.

4. Action of Waves:

Coastal processes are the most dynamic and hence most destructive. Some of the changes along the coast take place very fast. Storm waves and tsunami waves can cause far-reaching changes in short period of time than normal breaking waves.The coastal landforms in the world can be classified into two categories:

1. **High Rocky Coast/ Submerged Coast/ Retreating Coast**

In these type of coasts, the sea will be very close to the land without any coast or sometimes a narrow coast. The shores of these high rocky coasts do not show any depositional landforms. Erosional feature dominates here. Wave-cut platforms, cliffs, sea caves etc are common here. Most of the west coasts of the Indian Peninsula belong to this category.

2. Low Sedimentary Coast/ Emerging Coast/ Advancing Coast

The rivers in these coasts extend the length of the coast by building coastal plains and deltas. Thus, depositional features are dominant here. Bars, Barriers, spits, lagoons etc are common on these coasts. Most of the east coasts of the India Peninsula are of this category.

4.1 Erosional Landforms due to Waves

1. Cliffs, Terraces, Caves, Stacks and Stumps

Cliffs are common on the high rocky coasts. At the foot of such cliffs, there may be flat or gently sloping platform covered by rock debris derived from the sea cliff behind. Such platforms occurring at an elevation above the average height of waves is called as a wave-cut terrace. When the upper part of a coastal rock is hard and the lower part is soft, the erosion will not be uniform. The lower part erodes easily which results in the formation of a hollow part. This hollow part, by frequent wave action, gradually develops into a **sea-cave.** Sea arches are also formed in the same manner. **Sea stacks** are nothing but the isolated standing rocks in the sea which were once a part of the cliff. These stacks look will like small islands in the sea. Small underwater stacks are known as **stumps.**

4.2 Depositional Landforms due to Waves

1. Beaches and dunes

Beaches are characteristics of shorelines that are dominated by deposition. Beaches are temporary features which are made up of sand-sized materials. Beaches which contain excessively small pebbles and even cobbles are called as **Shingle Beaches.** Sand dunes are formed just behind the beaches as long ridges parallel to the coastline.

2. Bars, spits, and Lagoons

Bars are deposits of sand and gravel laid down by waves and currents which separate the shoreline from the sea. They act as a barrier between the mainland and the sea. When one end of such bar is attached to the coast and other extends into the sea, it is called as a **spit**.

Tombolo is a deposition landform in which an island is attached to the mainland by a narrow piece of land such as a spit or bar. Sometimes due to deposition of waves and currents, both ends of the bar join to enclose a part of sea water between the coast and the bar. This enclosed part of the sea forms a lake of saline water called as **Lagoon**. A **lagoon** is generally connected with the sea through a narrow passage. **Chilika and Pulicat lakes are examples of Lagoon Lake.**

5. Formation of Landforms

Landforms are the physical features on the Earth's surface. Mountains, Plateaus and Plains are some major landforms of the Earth. Natural processes such as weathering, water, elevation, sinking, and erosion of the soil are constantly shaping the Earth's surface. It doesn't really happen overnight. In fact, it takes hundreds and thousands of years for us to notice these changes. These processes lead to the formation of various landforms. In other words, landforms originate from these geological processes. Let's understand the processes that shape the landforms.

5.1 External Process

External process means effects caused by external factors such as rain or wind. These cause erosion and deposition. *Erosion* and d*eposition are* natural processes that change the surface of the Earth. To clarify, e*rosion* is a process in which *sediments* get deposited or dropped off in a different location. And sediments are nothing but the materials on the Earth's surface such as soil and rocks.

5.2 Internal Process

As the name suggests, internal processes are processes that occur inside the surface of the Earth i.e. beneath the crust. For example, v*olcanic eruption* and p*late tectonics.* These occur because of the intense heat in the Earth's core which causes the molten rock in the mantle layer to move. As a result, creating uneven movement on the surface. These layers are either uplifting or sinking.

5.3 Types of Landforms

Depending upon the elevation and slope, landforms can be categorized into **Mountains**, **Plateaus**, and **Plains**. Let us look at them individually.

Mountains

A Mountain is any landmass that is higher and steeper than a hill. A hill is a landform that extends above the surrounding terrain. In general, the mountains are higher than 2000 ft. Like in any other natural elevation such as atmosphere, as you go higher, the temperature drops and the climate becomes colder. Thus, habitation becomes harsher. And that's why there is less habitation in the mountainous areas.

Furthermore, because of the temperature drop, it is not uncommon for high mountains to develop ice on them. In fact, some of them have glaciers. Glaciers are permanently frozen rivers of ice. Also, because of the steep slopes of the mountains, there is less land available for proper farming.

Considering the sea base as the scale, if we calculate the height of the surface, then there are mountains even under the ocean. For example, Mauna Kea (Hawaii) in the Pacific Ocean. In fact, it is elevated higher than Mt. Everest.

A range is a line of mountains. The Himalayas in Asia, the Alps in Europe and the Andes in South America are some examples of mountain ranges. These ranges are the storehouses of water. Many rivers have their origins in these mountains. In fact, the glaciers of this landform are the source of these rivers. Mountains are generally untouched by civilisations and thus have the endangered species of plants and animals.

Plateaus

Plateaus are elevated flatlands. In other words, it is flat land which is standing high above the surrounding area. Furthermore, they may have one or more sides with steep slopes. Also, depending upon the plateau, their height varies from a few hundred meters to several thousand meters.

The most familiar plateau in India is the Deccan Plateau. They are mainly formed by lava, meaning they are volcanic in origin. The extension of Deccan Plateau is the Chhotanagpur plateau in India. It's a reserve for minerals such as iron ore, manganese and coal. Other examples include the African plateau and the Tibetian plateau. The African plateau is most famous for gold and diamond mining. And the Tibetan plateau is the highest plateau in the world.

Plateau regions give birth to the waterfall. For example, Hundru falls in the Chhotanagpur plateau and the Jog falls in Karnataka. Moreover, these landforms are also centres for tourism and scenic activities.

Plain

Plains are the most fertile regions. They are stretches of largely flat land. These stretches of land are the most suitable for human habitation and agriculture activities like farming and poultry. Rivers and their tributaries form plains. The rivers flow down the mountains and erode them. They deposit sediments along their courses and in valleys. These deposits form plains. In India, the Indo-Gangetic plains are the most densely populated regions of the country. As can be seen, where there is water, there is life.

6. Ocean Floor

The overwhelming majority of our Earth's surface – 71% – is water. Of that water, 97% of it is located in our oceans. Somewhat counterintuitively, this means that the vast majority of Earth's topographic features – valleys, plains, mountains – are located under water as well. Today, let's take a "deep dive" and examine some ocean floor features you should know about.

6.1 Oceanic Topography

Today we'll take a look at many prominent submerged features. Before taking the plunge, stop for a moment to examine the above diagram from the National Oceanic and Atmospheric Administration. It will serve as a convenient visual guide as we descend into the deep.

6.1.1 Continental Shelf

Continental shelves are large landmasses that surround each of the continents. This area is usually very shallow (comparatively), typically less than a few hundred feet. Continental shelves account for roughly 8% of all submerged features. Interestingly, continental shelves can drastically vary in size. For example, the continental shelf off the coast of Siberia extends 1,500 km (930 miles) into the Arctic Ocean. Conversely, off the coast of Africa, the continental shelf extends only 10 km (6 miles) into the Atlantic Ocean.

Continental shelves also serve as bastions of biological diversity. According to some estimates, about 90% of the world's fish are found along the continental shelf. More interestingly, practically all of the world's oceanic plants and most types of algae also live along the continental shelf.

Perhaps the most famous of continental shelves is the Bering Strait. A mountain of evidence supports the hypothetical land bridge that anthropologists, geologists, and climate scientists believe allowed humans to cross over to North America from Asia some 17,000 years ago. Although the strait is now underwater, it is just barely submerged. The deepest section is less than 55m (180 feet) underwater.

6.1.2 Continental Slope

The end of the continental shelf is referred to as the continental slope. Geologists may refer to this location as the "seaward border of the continental shelf." This ocean feature accounts for roughly 9% of the entirety of the ocean floor. On average, the ocean's continental slope descends into the sea at an angle of 4°. This may not seem like much, but over the course of 100km (60 miles) of the continental slope, the ocean depth will increase by 70 km (43 miles)!

While the average slope of descent for continental slopes is 4°, some are much steeper. About 1,600 km (1000 miles) off the Cape of Good Hope, Africa, the continental slope drops some

20,000 feet over the course of only 16 km (10 miles). This corresponds to an average slope of 70°!

6.1.3 Abyssal Plain

Abyssal plains are the most common land feature on planet earth. They make up half of all of the ocean floor. The International Hydrographic Organization (IHO) defines abyssal plains as "extensive, flat, gently sloping or nearly level region at abyssal depths." Abyssal depths are approximately 3,000-6,000 meters (10,000-20,000 feet). When the IHO says that these plains are flat – they're not kidding. Compared to continental slopes, which fall roughly 2,800 meters (9,000 feet) for every 1,000 meters (3,000 feet), abyssal plains fall, on average, less than 1 meter per 1000 meters! **Abyssal plains are also the largest habitat on earth.** Even so, extremely little is known about the organisms that inhabit this zone. This is mainly due to the stark lack of sunlight that penetrates to these depths. Sunlight only reaches roughly 1,000 meters (3,000 feet) down into the ocean. Considering that the abyssal plains exist, at the shallowest depth, at 3,000 meters, absolutely no sun reaches the floor here.

6.1.4 Abyssal Hill

Abyssal hills are exactly what they sound like: relatively small hills that rise out of the abyssal plain. These features comprise roughly 30% of the ocean floor. Typically, they rise no more than a few hundred meters above the abyssal plain and are less than 100 meters (300 feet) in width.

6.1.5 Seamount

Breaking down the term seamount we see two parts: sea and mount. The "sea" part references the fact that these features are under water. The "mount" part stems from "mountain." Putting these two together, you have the definition of a seamount: an underwater mountain! Importantly, seamounts cannot break the water's surface.

6.1.6 Ocean Trench

Deep, deep below the water's surface lie vast, unexplored regions of the ocean floor: trenches. These underwater canyons are the deepest spots in the ocean. In fact, from sea level, the surface of the earth extends further down than it does up! Mt. Everest is the tallest point on earth (elevation wise) at 8,848 meters (29,029 feet). In comparison, the Mariana Trench stretches down 11,034 meters (36,201 feet) below the surface. If we were to place Mt. Everest in the bottom of the trench, its summit would still be about 1.6 km (1 mile) below the surface!

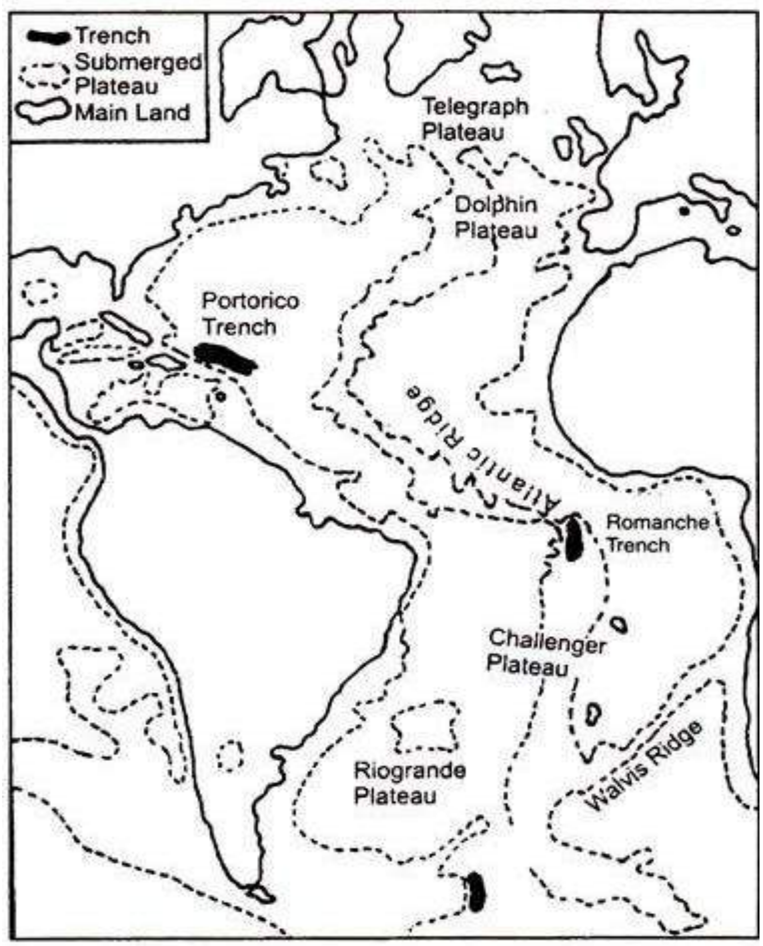
6.1.7 Volcanic Island

Volcanic islands are usually referred to by their common name: islands. By definition, seamounts that break the water's surface are called islands. In places like Hawaii, one can actually see the process of new land being formed as lava cools as it enters the ocean. Hawai'i Volcanoes National Park is a prime example of this. Islands make up a relatively tiny fraction of the total area, but they are very numerous. The amount of islands in the world is practically impossible to estimate. Presently, the estimation ranges from about 5,000 oceanic islands to over 100,000. This figure also changes over geologic time. Islands tend to be somewhat unstable, and as global sea levels fluctuate over millions of years, new islands are exposed while others are submerged.

7. Bottom topography of the Atlantic Oceans

7.1 Atlantic Ocean

The Atlantic Ocean located between North and South Americas in the west and Europe



Bottom configuration of the Atlantic Ocean and Africa in the east covers an area of 82,000,000 km2 which is 1/6th of the geographical area of the globe and half of the area of the Pacific Ocean. The ‘S’ shape of the ocean indicates the fact that landmasses (continents) on its either side were once a contiguous part. The Atlantic Ocean was formed due to drifting of North and South Americas to the west due to plate tectonics. The ocean widens to the south of equator and attains the maximum width of 5,920 km at 35°S latitude. It narrows down towards the equator. It is only 2560 km wide between Liberian coast and Cape Sao Roque. The width further increases northward and it becomes 4800 km at 40°N latitude. It narrows down in the extreme north where it maintains its contact with the Arctic Ocean through Norwegian Sea, Denmark Strait and Davis Bay.

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- The width further increases northward and it becomes 4800 km at 40°N latitude.
- It narrows down in the extreme north where it maintains its contact with the Arctic Ocean through Norwegian Sea, Denmark Strait and Davis Bay.
- The average depth of the ocean is less than the Pacific Ocean because of extensive continental shelves and marginal and enclosed seas.
- About 24 per cent of the Atlantic Ocean is less than 915m deep.
- The Atlantic Ocean was first formed about 700 million years ago due to seafloor spreading (see fig. 5.13) and westward movement of the Eurasian and African plates from the mid-Atlantic ridge.
- About 300 million years BP (before present) the Atlantic Ocean was closed due to convergence of the American and Eurasian-African plates.

- The ocean again started to open about 150 million years BP due to the movement of aforesaid plates in opposite directions.
- The widening of the ocean still continues which is evidenced through seafloor spreading at an average rate of 4 cm per year.

7.2 Continental Shelf:

Continental shelves have developed along both the coasts of the Atlantic Ocean and the width ranges from 2-4 km to more than 80 km. In fact, the width of continental shelves has been largely controlled by the reliefs of the coastal lands. These become significantly narrow where mountains and hills border the coasts e.g., the African shelves between Bay of Biscay and Cape of Good Hope and Brazilian shelves between 5°S and 10°S latitudes. The shelves become 200 to 400 km wide along the north-eastern coast of North America and the north-western coast of Europe.

Extensive shelves are found around Newfoundland (Grand Bank) and British Islands (Doggar Bank). Similarly, the conti-nental shelves around Greenland and Iceland are quite wide. Very extensive continental shelves are found in the South Atlantic Ocean mainly between Bahia Blanca and Antarctica. Many marginal seas are located on the continental shelves in the North Atlantic but such seas are practically absent in the South Atlan-tic. Among the continental shelf-seated seas signifi-cant are the Hudson Bay, the Baltic Sea, the North Sea, the Davis Strait, the Denmark Strait etc.

The Caribbean and Mediterranean seas represent enclosed seas. There are several islands which are located on the continental shelves e.g. British Isles, Iceland, Faeroes, Azores, Ascension, Tristan da Cuncha, Newfoundland, West Indies, Maderia, St. Helena, Trinidad, Falkland, South Orkneys, Shetlands,Georgia, Sandwitch, Canaries, Cape Verde etc. are significant islands representing different locations and origin.

7. 3 Mid-Atlantic Ridge:

- The mid-Atlantic ridge representing the zone of divergent or constructive plate margins (American plates moving westward and Eurassian and African plates moving to the east) is the most striking relief feature which having S shape extends for 14,450 km from Iceland in the north and to Bouvet Island in the south.

- Though swinging west and east it maintains its central position and nowhere goes down more than 4000m below sea level.
- The ridge is known as **Dolphin Rise to the north** and **Challenger Rise to the south** of equator.
- It is known as **Wyville Thompson Ridge** between Iceland and Scotland.
- The ridge becomes quite extensive to the south of Greenland and Iceland and is called **Telegraphic Plateau** because first cabbies were laid down in this area.
- A significant branch emerges from this central ridge near 50° latitude and extends north-westward as Newfoundland Rise and continues upto New-found-land.
- Another important branch known as Azores Rise bifurcates from the mid- Atlantic Ridge to the south of 40°N latitude and extends up to Azores Islands.
- At the equator the ridge sends off two branches.
- Sierra Leone Rise extends towards north-east and Para Rise stretches in northwest direction.
- Guinea Ridge, a minor branch of the central ridge, runs north-eastward and extends up to Guinea coast.
- Two significant branches come out of the central ridge near 40°S latitude.
- The Walvis Ridge extends towards north-east and merges with African continental shelf while Rio Grande Rise extends towards South American coast.
- Though major part of the mid-Atlantic Ridge is submerged under oceanic water but a host of peaks and sea mounts project well above the water surface and form islands.
- **The Pico Island of Azores** is the highest peak which rises 8,229.6m (27,000 feet) above the sea floor and 213.36m to 243.84 m above sea level.
- Besides, the mid-Atlantic Ridge has several well-marked fracture zones e.g. Gibbs Fracture Zone (near 40°N), Atlantis Fracture zone (near 30°N), Oceanographic Fracture Zone (32°N), Kane Fracture Zone (25°N), Vema Fracture Zone (10°N), Romancha Fracture Zone (near equator) etc.
- As regards the origin of this unique feature all the previous theories based on compressive and tensional forces stand redundant due to advent of plate tectonic theory.

- The mid-Atlantic Ridge is the result of **westward movement of American plate and eastward movement of Eurasian and African plates.**
- This ridge represents the zone of the divergent or constructive plate margins where basaltic lavas rise continuously, get solidified and are slided equally on both sides of the ridge.
- The divergence of plates from this ridge is evidenced by the presence of several transform faults (fracture zones, as referred to above).

7.4 Ocean Basins:

The mid-Atlantic Ridge divides the Atlantic Ocean into two major basins viz. East and West Atlantic Basins. There are few important basins within these two major basins :

1. Labrador basin extends between the conti-nental shelf of Greenland in the north and Newfound-land Rise in the south covering latitudinal extent of 40° N to 50°N where the depth of the basin ranges from 4,000 to 4,500m.
2. North American basin is the most extensive basin of the Atlantic Ocean and extends between 12°N and 40° latitudes. The east-west section lies between the continental shelves off the east coast of N. America and 50°W meridian. The depth of the basin is more than 5000m but a few deeps measure more than 6000m depth.
3. Brazilian basin is confined between the equa-tor and 30°S latitude and east coast of Brazil in the west and Para Rise in the east. The depth is more than 4,000m.
4. Spanish basin is located between the mid- Atlantic Ridge and Iberian Peninsula. It is bordered by Azores Rise in the south and extends upto 50°N lati-tude. The average depth is 5,000m.
5. North and South Canary basin is comprised of two almost circular basins and is 5,000m deep.
6. Cape Verde basin is located between the mid- Altlantic Ridge and west African coast and extends from 10° N to 23.° N. Average depth is 5000 m but at few places it becomes 5000 m or more.
7. Guinea basin extends from north-east to south-west in elongated shape between Guinea Ridge and Sierra Leone Rise and measures 4,000 to 5,000 m in depth.

8. Angola basin is located between the equator and 30°S latitude. It stretches from the African coast in the north-east to the knot of the mid-Atlantic Ridge and Walvis Ridge in the south-west. The basin is most extensive near the African coast and narrows down towards south-west. The average depth is 5,000m.
9. Cape Basin (25°S-45°S), Agulhas Basin (40°S- 50°S), Argentina Basin (35°S-50°S, depth 5,000m- 6,000m) and Atlantic-Antarctic Basin are the other significant basins of the Atlantic Ocean.

7.5 Ocean Deeps:

The number of deeps in the Atlantic Ocean is far less than in the Pacific Ocean because of the absence of the effects of Tertiary orogenic movements along the Atlantic coasts. Murray has identified 29 deeps upto the depth of 3,000 fathoms (5,486.4m) in the Atlantic Ocean. Nares Deep (6,000m), Pureto Rico Deep (8,385m), Hatteras Deep (5,445m), Columbia Deep (5,125m, south of Haiti), Valdivia Deep (3,134 fathoms), Tizard or Romanche Deep (9,370m), Buchanan Deep (3,063 fath-oms), Moseley Deep (3,309 fathoms), Vema Deep (4,900m) etc. are a few important ocean deeps of the Atlantic Ocean.

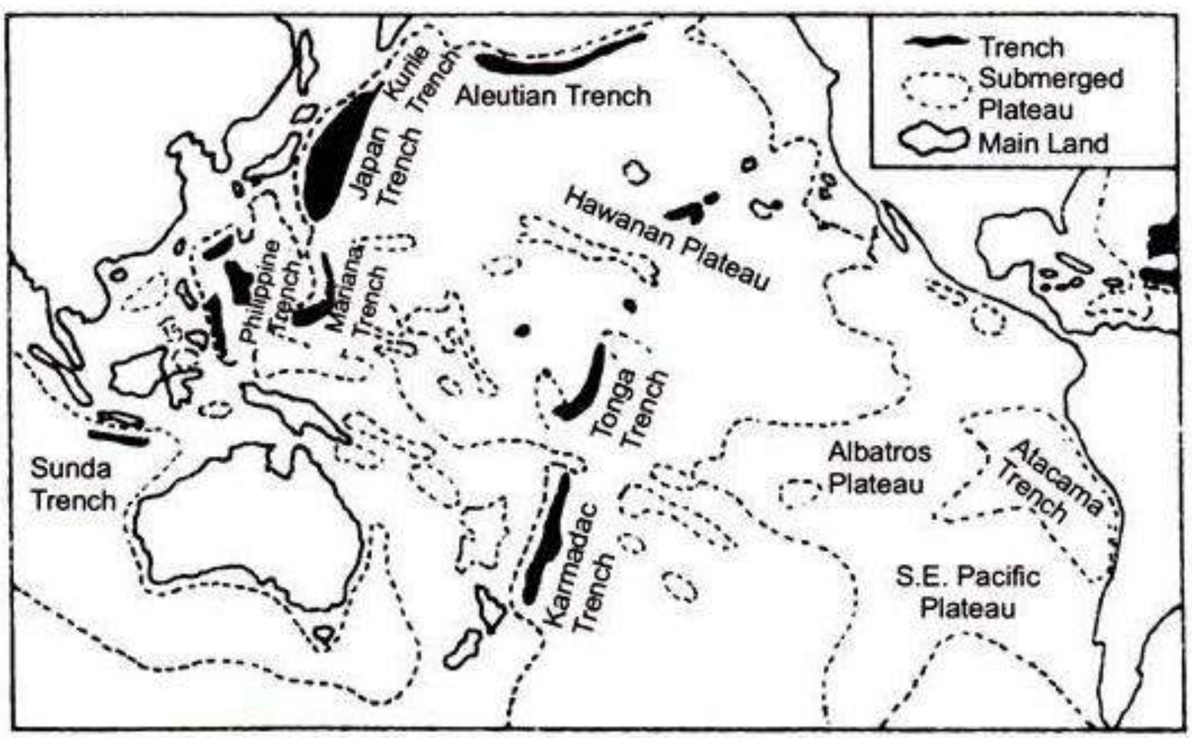
7.6 Marginal Seas

- The Mediterranean Sea, Caribbean Sea and Gulf of Mexico are significant marginal seas in the Atlantic Ocean.
- The Mediterranean Sea is divided into two major basins (East and West Basins) by 4,000m deep mid-sea ridge which runs from the southern Italian coast to the north African coast.
- The Gulf of Mexico and Caribbean Sea are separated by a 1,600 m deep ridge running between Yucatan Peninsula and Cuba Island.
- The prominent basins are Mexico basin and Caribbean basin.
- The latter is further divided into four sub-basins e.g. Yucatan basin, Cayman trough, Columbia basin and Venezuela basin.

8. Bottom Relief of the Pacific Oceans

8.1 Shape and Size

The Pacific Ocean covering one-third of the area of the earth, extends from the coast of Asia in the west to America in the east (16093 km) and rom Bering Strait in the north to the Cape Adare (Antarctica Continent) in the South (14966 km). The average depth of the Pacific is about 5000 m. Only 3.9 % of its area is less than 1000 m. deep whereas major portion (30.9 %) lies below 5000 m. excluding adjacent seas. The descent from the coast to the sea plain is very much steeper. The oceanic surface in general is uniform, with broad gentle swells and depressions. Maximum area of 37.7 % lies within 4000-5000 m. depth. It is the most unique ocean in many respects. It has a broad triangular shape. All along the coast for nearly 17700 km, the folded mountains are found parallel to it. In the north, it is completely blocked excepting a narrow Bering Sea passage into the Arctic Ocean.



Bottom configuration of the Pacific Ocean

8.2 Continental Shelf

The continental shelf surrounding the margin of the Pacific Ocean is controlled by the shape and structure of its coastline. On the eastern margin of this ocean the width of the shelf is rather narrow. Due to the presence of the Rockies and the Andes Mountains parallel to the west coasts of North and south Americas respectively the continental shelves have become very narrow. Their width is limited to only 80 km. However, on the western margin of this ocean, due to the absence of mountain chains or plateaus, the continental shelf is broad. The continental shelves adjoining the coasts of Australia, East Indies and East Asia are relatively much broader. Along these coasts the width of the shelves varies from 160 to 1600 km with their average depth hardly exceeding 1000 m. On these shelves are situated most of the islands and marginal seas.

8.3 Ridges

Pacific Ocean is different from the other oceans in the respect that it has no central ridge. Only a few submarine ridges can be located here and there, mostly on the eastern margin of the ocean, and the submarine swells are found in the middle of the Pacific. One of the most important ridges known as the East Pacific ridge or Albatross Plateau (3000-4000 m. deep) is quite extensive. The north-east projection of the plateau is known as Cocos ridge and extends from the coast of Central America towards south-west. It is about 1600 km broad and bifurcates into two near 2◦ S lat. The eastern part is a narrow ridge named San Felix-Juan Fernandez ridge, less than 2000 m. deep and runs parallel to the Chilean coast. The western ridge moves to the south and forms a wide plateau between 20◦-40◦S lat., known as SouthEastern Pacific plateau. The depth here is between 2000-4000m. Further south the same plateau narrows down in the form of a curved Pacific-Antarctic ridge where the depth is about 3500 m.

8.4 Basins

Many depressions and basins, separated by numerous swells, are also found in the Pacific Ocean.

1. Aleutian basin – north of the Aleutian island, this basin is 4000 m. deep.
2. Philippine basin – situated east of Philippine Islands, this basin extends up to 5◦ N. Its depth varies between 5000-6000 m. The western part of the basin is comparatively deeper than 6000m.

3. West Caroline basin. It is a 4000-5000 m. deep circular basin east of Philippine basin.

4. East Caroline basin – this basin is also 5000 m. deep. 5. Fiji basin – south of Fiji Island, Fiji basin is more than 4000 m.

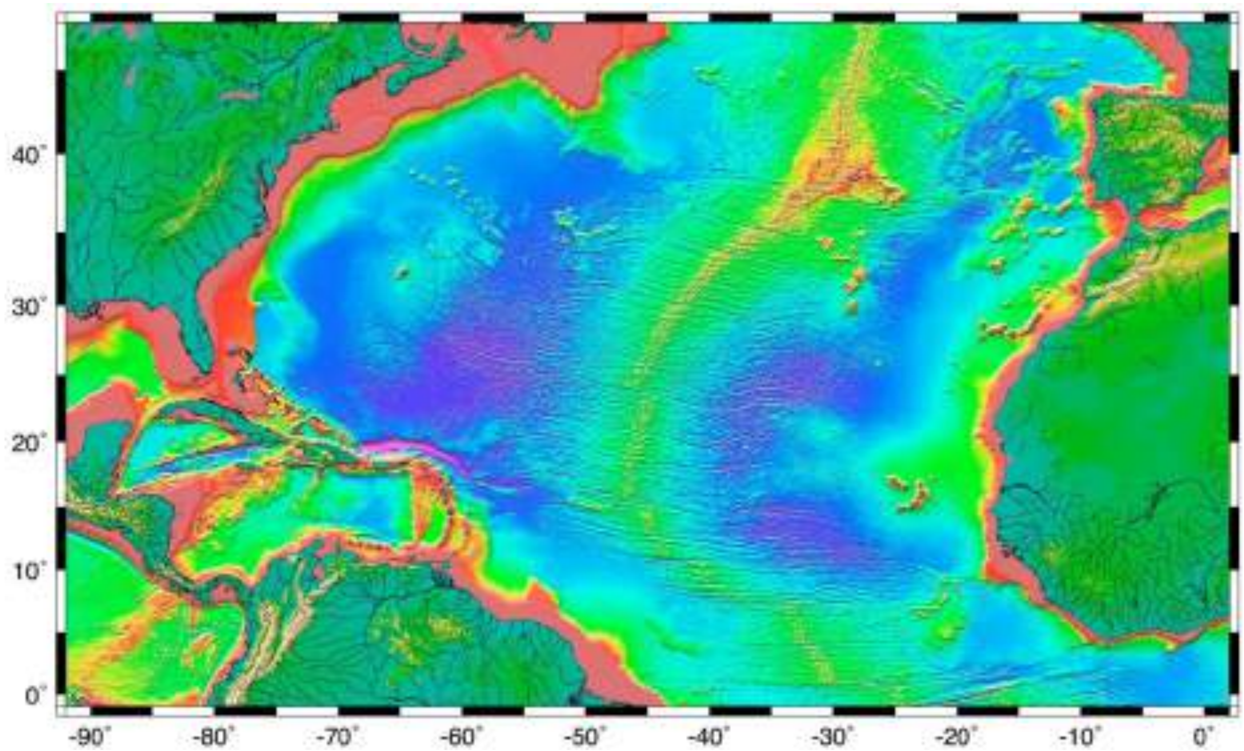
6. East Australian basin – a 4000 m. deep basin, compact and circular in form, extends east of Australia with areas deeper than 5000 m. found in the north.

7. South Australian or Jeffrey's basin – it is a 5000 m. longitudinal basin extending south of Australia.

8. South-western Pacific basin – it is a wide 6000 m. deep basin.

9. South-eastern Pacific basin – this 5000 m. deep and broad basin extends west of Peru and Chile with Baver deep of 5266 m. depth.

10. Pacific Antarctic basin. It extends south-west of Chile



8.5 Deeps

Total 32 deeps are recorded in the Pacific, out of which most of them ae in the trenches (longitudinal deep areas), parallel to the island arc or the mountain chain. These deeps are located mostly in the western part of the ocean. The following are some of the important deeps and trenches:

1. Aleutian trench – it is and arc like depression bordering Aleutian Islands; the average depth is about 6000 m. and the maximum recorded depth is 7679 m.

2. Kurile trench and Japan trench – lying parallel to the Japanese Islands, the 8000 m. deep trench extends for 2700 km, and seldom more than 160 km away from the land. In it are situated Vityez deep (10377 m) and Ramapo deep (10374 m).

3. Philippine trench. Extending 64 km along the eastern coast of Philippine Islands, this trench records the greatest depth (10497 m) off the island of Mindanao, known as Cape Johnson deep.

4. Mariana trench – the Challenger Deep, in the South Pacific's Marianas Trench, is the deepest known part of the Ocean. It's bottom lies 10,900 m below the sea level.

5. Tonga-Kermadec trench – it is trough like depression extending from north-east to south-west along the Tonga and KermadecIslands. They ae measured to be 8000 m. deep with 9428 m. Aldrich deep.

6. Peru-Chile trench – it is situated along the Andean coast in the form of broken trenches. Batholomew deep 7973 m. located near Antafogsta city..

8.6 Bottom Reliefs of the Atlantic Ocean

(1) Oman basin faces the Gulf of Oman and is spread over the extensive continental shelf with aver-age depth of 3,658 m.

(2) Arabian basin is located in almost circular shape between Laccadive-Chagos ridge and Socotra – Chagos Ridge with the depth of 3,600m – 5,486m.

(3) Somali basin is bordered by Socotra – Chagos ridge in the north-west. Central Ridge in the east, Seychelles – Mauritius Ridge in the south-west and African coast in the west. The average depth is 3,600m.

(4) Mauritius basin is located between S.W. Indian Ridge and South Madagascar Ridge and ex-tends from 20°S to 40°S latitude. The depth varies between 3,600m and 5,486 m. The deepest part measures 6,391 m depth.

(5) Mascarene basin of oval shape extends between Madagascar and Seychelles – Mauri-tius Ridge.

(6) Agulhas-Natal basin is an elongated basin which is bordered by Madagascar ridge in the north and north-east, Prince Edward Crozet Ridge in the east and the S.E. African coast in the west and north-west, Average depth is 3,600m.

(7) Atlantic- Indian – Antarctic basin is in fact the eastward continu-ation of Atlantic – Antarctic Basin. It stretches upto 70°E longitude and is bordered by Prince Edward Crozet Ridge in the north, Antarctica in the south and Kerguelen Gassberg Ridge in the north-east. Average depth is 3,600m.

(8) Eastern Indian-Antarctic basin is located between Amsterdam – St. Paul Plateau and Indian-Antarctic Ridge in the north and north-east and Antarctica in the south. The depth varies from 3,600m to 4,800m. Kerguelen – Gassberg Ridge separates the basin from the Atlantic – Indian-Antarctic Basin.

(9) West Australian basin is the most extensive basin and forms rectangular shape surrounded by S.E. Indian Ridge in the south – west, Ninety East Ridge in the west, continental shelves of Java-Sumatra in the north-east and the continental shelf of west Australia, Aver-age depth varies from 3,600m to 6,100m but the central part of the basin is 6,459 m deep.

(10) Mid-Indian basin is bordered by the central ridge in the west and the south-west, by Ninety East Ridge in the east and by the Bengal plateau in the north. The average depth of outer part ranges from 3,600m to 6,800m while the depth of the central part of the basin ranges between 4,800m and 6,100m.

8.7 Deeps and Trenches:

There are very few deeps and trenches in the Indian Ocean. About 60 per cent of the Ocean consists of deep sea plains with depth ranging from 3,600m to 5,487m. Important deep sea plains are Somali Abyssal plain. Ceylon (Sri Lanka) Abyssal plain, Indian Abyssal Plain, (4,380m) etc. Significant trenches are Java or Sunda Trench (7,450m deep), Ob Trench (6,875m deep), Mauritius Trench, Amirante Trench etc

9. Bottom Relief of the Indian Ocean

Shape and Size The Indian Ocean covers 20 % of the total area of all the oceans of the world. It is a warm ocean blocked on the three sides by the continents of Africa, Asia and Australia. Most of the coast is made up of hard block mountains of Gondwana remnant in Africa, Australia, Deccan Plateau of India and Western Australia, but folded ranges are also found along East Indies. The shape of the ocean is compact, with bold and regular coastlines. In the south it extends up to the Antarctica continent where it merges into the Atlantic and the Pacific. The average depth of the ocean is 4000 m., which is less varying and comparatively lesser than that of other oceans. Out of the total area, the deep-sea plain with a depth between 4000-6000 m. covers 58.8 % area.

9.1 Continental Shelf

The continental shelf surrounding this ocean varies in its width. The continental shelf of this ocean is generally narrow with the average width of about 96 km. However, in the Arabian Sea, the Bay of Bengal and the Andaman Sea the width of the shelf varies from 192 km to 208 km. On the seaward margin of the shelf, the depth of water lies between 50 and 200 meters. Between Australia and New Guinea Island the shelf is 960 km wide. Due to intense glaciation the structure of the shelf adjoining the Antarctica has become very complex. In such areas the landward margins of the shelf are 150-200 m deep, whereas the seaward margins register depth varying from 400 to 500 meters. In the tropical areas different types of coral reefs such as, fringing reef, barrier reef and atoll are found on the shelf. The continental slopes on the outer margins of the shelf are marked by the extreme steepness, angle of slope varying from 10◦ to 30◦. The continental shelves are characterized by many submarine valleys and canyons. The width of the shelf along the coast of Africa is just normal, but near Madagascar the shelf is relatively broader than elsewhere. The continental shelves of Java and Sumatra Islands are about 160 km. wide.

9.2 Ridges and Basins

The bottom relief of the Indian Ocean resembles that of the Atlantic Ocean. This ocean has a continuous central ridge, called the Arabic-Indian Ridge, together with its southern extension, the Kerguelen-Gaussberg Ridge, which connects with the Antarctic continent. The central ridge separates the eastern basin from the western basin. Remember that all the oceanic islands in this ocean are situated on the central ridge and on its cross ridges.

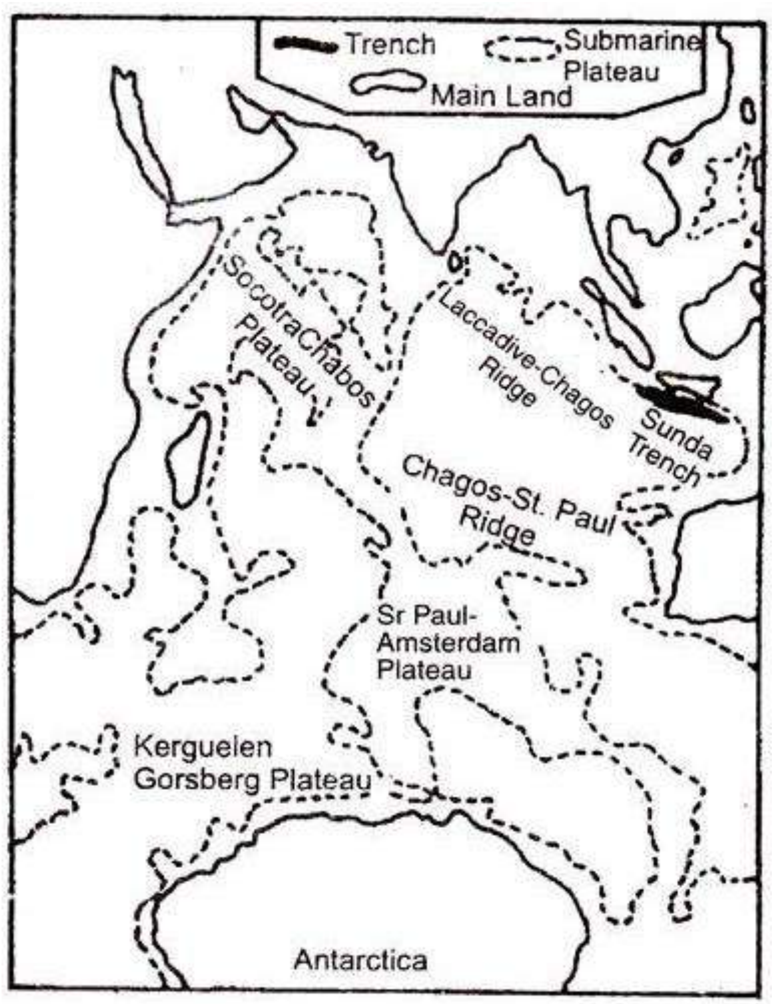
The Indian Ocean is characterized by having many broad submarine ridges, separating several individual basins of the abyssal plain. One of its most distinguishing features is the presence of the series of curving ridges in the north-west segment of the ocean.

The above-mentioned ridges divide the Indian Ocean into three distinct parts:

1. African part,

2. Australian part, and

3. The part adjoining the continent of Antarctica.



Bottom configuration of the Indian Ocean

Each one of these parts is further subdivided into several basins by ridges and submarine mountain chains, namely, Comoro and North Australian Basin extending up to 320 km. South Indian Basin and Australian-Antarctic Basin extend up to 9000 km. the Arabian Basin is surrounded by ridges. The East Indian Ridge, also called the Ninety

East Ridge, is 4000 km long and straight. The ridge joins the West Australian Ridge (the Broken Ridge) in the south.

It is interesting to note that the central ridge that runs from near the Cape Comorin to Antarctica has been given different names in its different sections. In the south the central ridge becomes wider, and there it is called the Amsterdam – St. Paul Plateau. A transverse branch goes towards the south-east from Cape Guardfui, the 'Eastern Horn' of Africa to join the main ridge and is named the Socotra-Chagos Ridge. Another transverse ridge called the Seychelles Ridge runs parallel to the Socotra-Madagascar trends southwards.

It is called the South Madagascar Ridge. Farther south it becomes wider and is known as the Prince Edward – Crozet Ridge. Thus, the submarine ridges rising from the coastal areas of Peninsular India, Madagascar and the eastern coast of Africa extend southwards. In the south the extensive plateau of Karguelen extends from north-west to south-east. There are numerous trenches beside the submarine ridges on the ocean floor, among which the East Indian, Chagos and Amerante trenches are very important.

9.3 Oceanic Deeps

Out of the total area of Indian Ocean, about 58.8 % forms deep sea plain between the depth of 4000-6000 m. Unlike the Pacific and Atlantic Oceans, the oceanic deeps with unfathomable depths are lacking. The Sunda Deep near Java is an exception. The depth of this oceanic deep is 7450 metres.

9.4 Islands

Relative to the Pacific and Atlantic Ocean, the number of islands in the Indian Ocean is far less. Some of the islands, however, are supposed to be parts of the main land. Out of these islands, Madagascar and Sri Lanka are the most prominent. Some of the smaller islands namely, Socotra, Zanzibar and Comoro situated off the Cape Guardafui fall into this category.

9.5 Marginal Seas

Since the coastal areas of the Indian Ocean are generally plateaus, the number of marginal seas is far less. In fact, there are only two real marginal seas in this ocean: the Red Sea and the

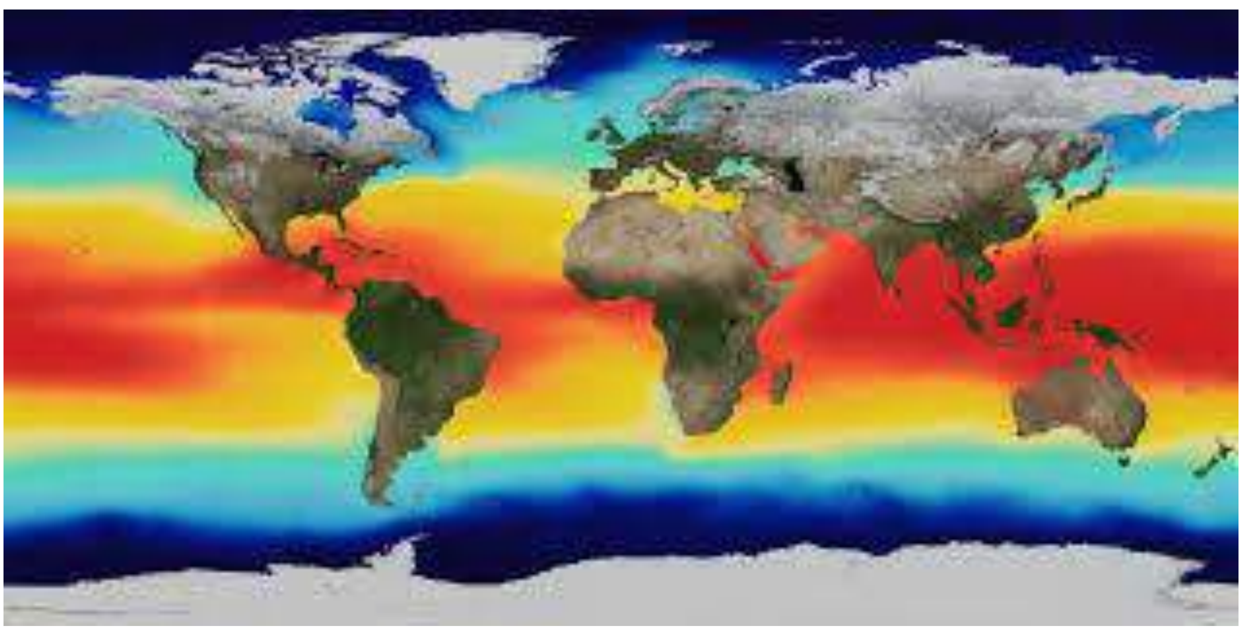
Persian Gulf. The Red Sea occupies a rift-valley between the continent of Africa and the Arabian Peninsula. The Red Sea is separated from the Indian Ocean by a submerged sill across the Strait of Bab-el-Mandeb. The depth of water over the sill is only 200 fathoms. The Persian Gulf represents a shallow trough. It is practically enclosed and separated from the open ocean by the northward projecting Oman Peninsula. Due to this peninsula, the Strait of Hurmuz has become very narrow, its width limited to only 80 km.

10. Temperature and salinity of the oceans; Heat and salt budgets

The study of the temperature of the oceans is important for determining the movement and characteristics of large volumes of water, the type and distribution of marine organisms at various depths of oceans, the climate of coastal lands, etc. Three types of instruments are used for recording ocean temperatures, viz. (i) standard- type thermometers are used to measure the surface temperature, (ii) the reversing thermometers are used to measure sub-surface temperature, and (iii) the thermographs. Nowadays, the automatic self-recording instruments are also used instead of the above-mentioned thermometers.

10.1 Source of Heat in Oceans

The sun is the principal source of energy for oceans, as for anything else on this earth. Apart from that, the ocean is also heated by the inner heat of the ocean itself.



Source: NASA Scientific Visualization Studio

The ocean water is heated by three processes:

1. Absorption of radiation from the sun is maximum over low latitude regions due to vertical insolation and longer duration of daylight, whereas it decreases steadily towards

poles. Even within the same latitude, the solar insolation received by the ocean varies due to factors such as currents and cloudiness.

2. The convectional currents in the water body also heat up the oceanic water. Since the temperature of the earth increases with increasing depth, the ocean water at great depths is heated faster than the upper water layers in the ocean. So, a convectional oceanic circulation at the bottom layers of ocean water takes place causing circulation of heat in water.

3. Kinetic energy is produced due to friction caused by the surface wind and the tidal currents which increase stress on the water body. Thus the ocean water is heated.

The ocean water is cooled by the processes mentioned below:

1. Back radiation from the sea surface takes place as the solar energy once received is re-radiated as long wave radiation from the seawater.

2. Exchange of heat between the sea and the atmosphere takes place, but only if the sea water is colder or warmer than the atmosphere.

3. Evaporation takes place when sea water is warm, surface is cold and atmospheric stratification is unstable.

10.2 Heat Budget of the Oceans

Heat budget, in general, suggests that the total supply of energy is balanced by the loss of equal amount of energy. Mosby viewed that the average annual surplus of insolation between the equator (0°) and 10°N latitude was about 0.170 gm cal/ cm2/min, while it is about 0.040 gm cal/cm2/min. between 60°N to 70°N. This difference of surplus of insolation completely disappears if we take all the latitudinal regions into consideration.

10.2.1 Distribution of Temperature of Oceans:

The distribution of temperature is guided by the following factors:

1. The average daily duration of insolation and its intensity.

2. The depletion of energy by insolation, reflection, scattering and absorption.

3. The albedo of the sea surface and its varying nature depending on the angle of sun rays.
4. The physical characteristics of the sea surface, e.g., the boiling point of the sea water is increased in the case of higher salinity and vice versa.
5. Transfer of heat by evaporation and condensation.
6. Prevalent winds; dragging warm or cold surface water to the cold or warm places of the world respectively: this phenomenon causes upwelling of cold water in the warm ocean current belts and vice versa; the foggy sea surface condition on the north-eastern coast of the USA is the result of the cold wind blowing from land to ocean.
7. Local weather conditions such as cyclones, storms and hurricanes.
8. The presence of submarine ridge; temperature is affected due to lesser mixing of , waters on one side of the ridge upto the bottom, while greater mixing of waters takes place on the other side of the ridge.
9. The shape of the ocean: the latitudinally extensive seas in low latitude regions have warmer surface water than longitudinally extensive sea; e.g., the latitudinally extensive Mediterranean Sea records higher temperature than the longitudinally extensive Gulf of California.

10.2.2 Range of Ocean Temperature:

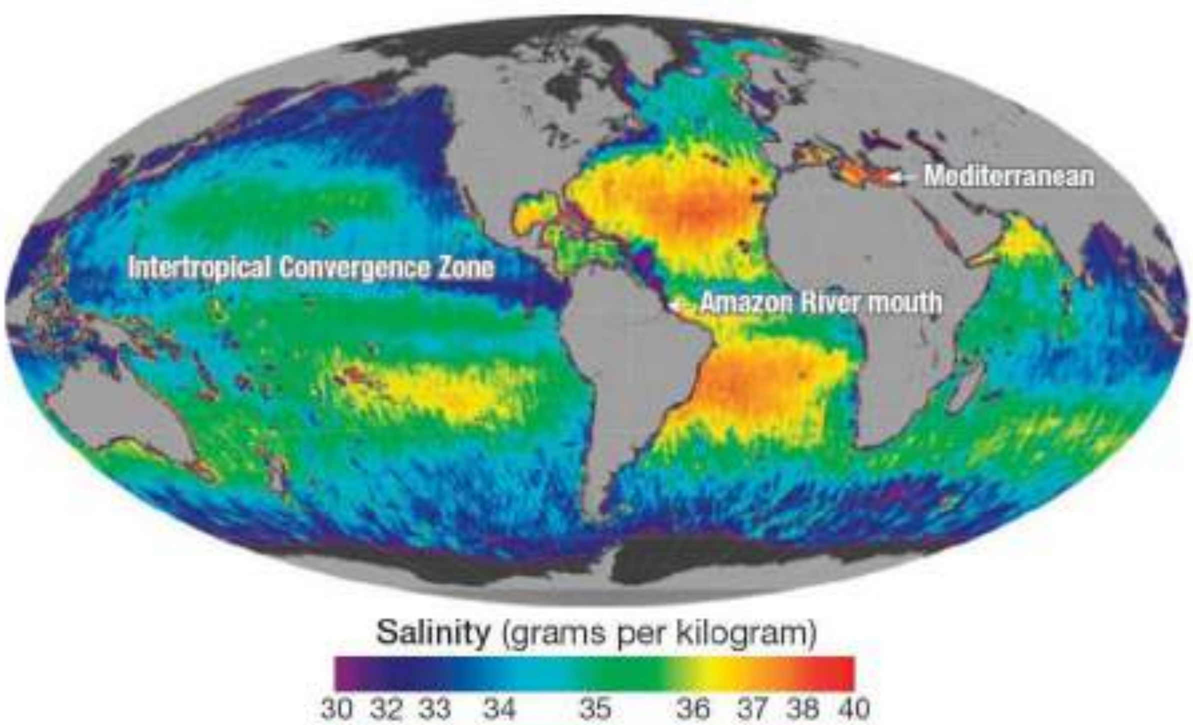
The oceans and seas get heated and cooled slower than the land surfaces. Therefore, even if the solar insolation is maximum at 12 noon, the ocean surface temperature is highest at 2 p.m.The average diurnal or daily range of temperature is barely 1 degree in oceans and seas. The highest temperature in surface water is attained at 2 p.m. and the lowest, at 5 a.m. The diurnal range of temperature is highest in oceans if the sky is free of clouds and the atmosphere is calm.

The annual range of temperature is influenced by the annual variation of insolation, the nature of ocean currents and the prevailing winds. The maximum and the minimum temperatures in oceans are slightly delayed than those of land areas (the maximum being in August and the minimum in February). The northern Pacific and northern Atlantic oceans have a greater range of temperature than their southern parts due to a difference in the force of prevailing winds from the land and more extensive ocean currents in the southern parts of oceans. Besides annual and diurnal ranges of temperature, there are periodic fluctuations of sea temperature also. For example, the 11-year sunspot cycle causes sea temperatures to rise after an 11- year gap.

10.3 Sea Surface Temperature:

The surface temperature of the oceans is depicted graphically by isotherms. The temperature decreases from the equator to the poles. However, the highest sea surface temperature is observed not exactly on the equator but slightly towards north of equator: this is due to the presence of maximum land area north of 0° latitude.

The water bodies of the southern hemisphere, as a whole, display higher average temperature than those in the northern hemisphere because the greater proportion of land area in the northern hemisphere absorbs more solar energy than does the water. Moreover, due to the presence of continents in the northern hemisphere, the circulation of water and the transport of heat is not efficient in this hemisphere, while in the southern hemisphere it is just the opposite.



IIPA2022

Indian & World Geography Chapter 10

Short Answers

CSM-03 Compillled by Dr Amit Kumar Singh

2022

This Chapter Contains

- Salinity Distribution in the Ocean
- Waves, currents and tides: Major Ocean Currents
- Ocean Currents
- Marine resources
- Ocean thermal energy conversion (OTEC)
- Composition and Structure of Atmosphere
- Insolation and Heat Balance
- Heat Budget of the Earth
- Atmospheric Circulation and Weather System
- Air masses: Origin and Classification
- Urban Heat Islands
- Climate Change and Global Warming

Contents

1. Salinity Distribution in the Ocean

The salinity of surface seawater is controlled primarily by the balance between evaporation and precipitation. As a result the highest salinities are found in the so-called sub-tropical central gyre regions centered at about 20° to 3° North and South, where evaporation is extensive but rainfall is minimal. The highest surface salinities, other than evaporite basins, are found in the Red Sea.

Salinity (S) conceptually grams of dissolved (grams of dissolved (<0.5µm) inorganic ions per kg of seawater

The average salinity of seawater is S = 35 which means that SW is 3.5% salt and 96.5% H_2O by weight.

1.1 Why is salinity important?

1. Salinity, along with temperature, determines the density of seawater, and hence its vertical flow patterns in thermohaline circulation.

2. Salinity records the physical processes affecting a water mass when it was last at the surface.

   a. precipitation/evaporation – salts excluded from vapor

   b. freezing/thawing – salts excluded from ice

3. Salinity can be used as a conservative (unchanging) tracer for determining the origin and mixing of water types.

1.2 Determination of Salinity

Surface seawater salinities largely reflect the local balance between evaporation and precipitation.

a. Low salinities occur near the equator due to rain from rising atmospheric circulation.

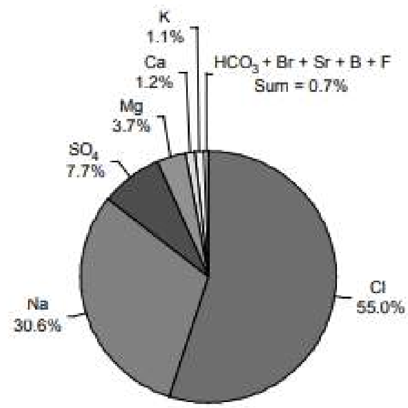
b. High salinities are typical of the hot dry gyres flanking the equator (20-30 º degrees latitude) where atmospheric circulation cells descend.

c. Salinity can also be affected by sea ice formation/melting (e.g. around Antarctica)

d. The surface N. Atlantic is saltier than the surface N. Pacific, making surface water denser in the N. Atlantic at the same temperature and leading to down-welling of water in this region this difference is because on average N. Atlantic is warmer (10.0º C) than N. Pacific (6.7 º C). This is mostly because of the greater local heating effect of the Gulf Stream, as compared to the Kuroshio Current. Warmer water evaporates more rapidly, creating a higher residual salt content

The **major ions** (>1mg/kg seawater) at S = 35.000 (from Pilson)

Ion	Formula	g/Kg	mmol/Kg
Sodium	Na^+	10.781	468.96
Magnesium	Mg^{2+}	1.284	52.83
Calcium	Ca^{2+}	0.4119	10.28
Potassium	K^+	0.399	10.21
Strontium	Sr^{2+}	0.00794	0.0906
Chloride	Cl^-	19.353	545.88
Sulfate	SO_4^{2-}	2.712	28.23
Bicarbonate	HCO_3^-	0.126	2.06
Bromide	Br^-	0.067	0.844
Borate	$H_3BO_4^-$	0.0257	0.416
Fluoride	F^-	0.00130	0.068
Totals	11	35.169	1119.87



Weight% of Major Ions

- The influence of surface fluctuations in salinity due to changes in evaporation and precipitation is generally small below 1000 m, where salinities are mostly between about 34.5 and 35.0 at all latitudes.
- Zones where salinity decreases with depth are typically found occur at low latitudes and mid latitudes, between the mixed surface layer and the deep ocean. These zones are known as **haloclines.**
- As seawater mixes with river water in estuaries, a conservative seawater component (e.g. a major ion) will co-vary directly in concentration with salinity. A component that is added during mixing will curve up in concentration versus a conservative mixing line
- Temperatures of seawater vary widely (-1 to 30 º C), whereas the salinity range is small (35.0 º 2.0). The North Atlantic contains the warmest and saltiest water of the major oceans, the Southern Ocean (the region around Antarctica) is the coldest, and the North Pacific has the lowest average salinity.

2. Waves, currents and tides: Major Ocean Currents

Waves, tides and currents are three types of natural phenomena that occur on water and whilst they are similar in nature, they are not the same thing. While all three are related to bodies of water, they differ based on their causes, intensity and frequency among other factors. Another common misconception is that while these phenomena are known to drive the sea, the ocean itself is not responsible for the generation of waves, tides and currents. Waves for example are influenced by the action of wind on the surface of the ocean while currents are influenced by the heat from the sun on the equator and cooler poles. Tides on the other hand are caused by gravitational forces from the moon and sun. All three contain some form of moving and potential energy and slight changes can lead to much larger downstream effects that affect nearby communities and recreational users.

2.1 Waves

- Waves are nothing but the **oscillatory movements** that result in the rise and fall of water surface.
- Waves are a kind of horizontal movements of the ocean water.
- They are actually the energy, not the water as such, which moves across the ocean surface.
- This energy for the waves is provided by the **wind**.
- In a wave, the movement of each water particle is in a circular manner.
- A wave has two major parts: the raised part is called as the **crest** while the low-point is called as the **trough**.

2.2 Tides

- Tide are the periodical rise and fall of the sea levels, once or twice a day, caused by the combined effects of the gravitational forces exerted by the sun, the moon and the rotation of the earth.
- They are a vertical movement of waters and are different from movements of ocean water caused by meteorological effects like the winds and atmospheric pressure changes.

- Note: The water movements which are caused by the meteorological effects like the said above are called as surges and they are not regular like tides.
- The moon's gravitational pull to a great extent is the major cause of the occurrence of tides (the moon's gravitational attraction is more effective on the earth than that of the sun).
- Sun's gravitational pull and the centrifugal force due to the rotation of earth are the other forces which act along with the moon's gravitational pull.
- The highest tides in the world occur in the Bay of Fundi in Canada.
- When the tide is channeled between islands or into bays and estuaries, they are termed as Tidal Currents.
- The regular interval between two high or two low tides is 12 hours 25 minutes.

Flow Tide and Ebb Tide

A flow tide or a flood tide is a rising tide or incoming tide which results in a high tide. It is thus the time period between a low tide and a high tide (i.e., the rising time). Ebb Tide is the receding or outgoing tide. It is the period between high tide and low tide during which water flows away from the shore.

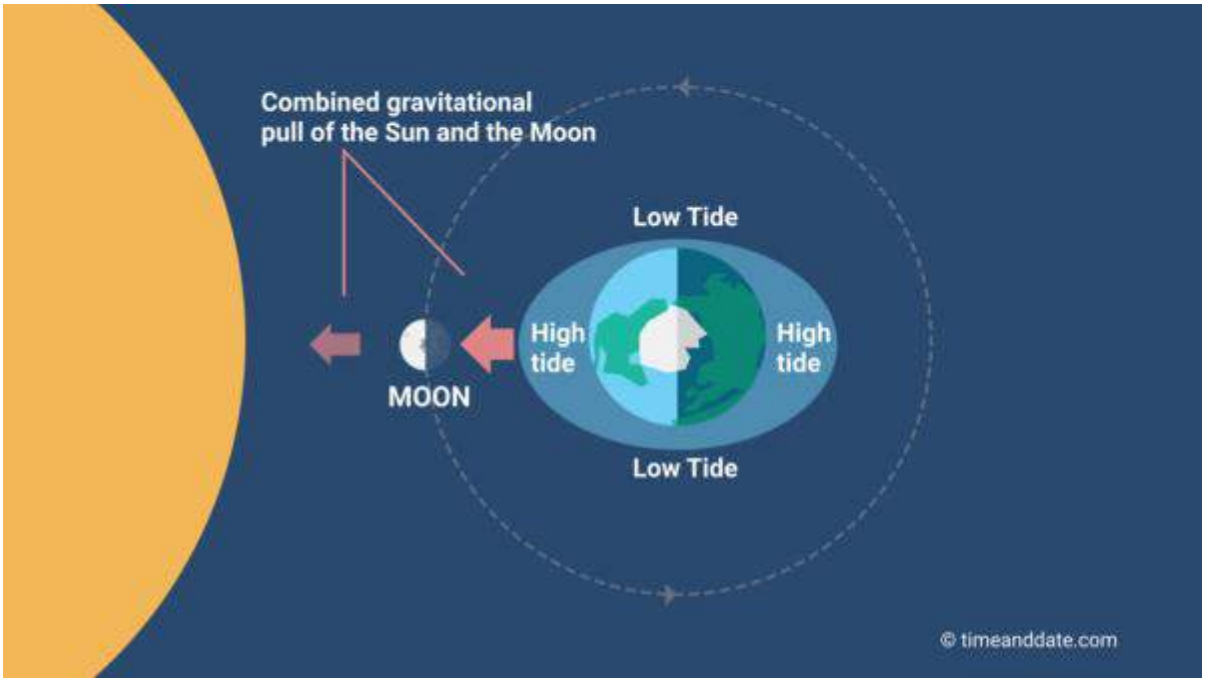
2.3 Types of Tides

2.3.1 A. Tides based on the Frequency

1. **Semi-diurnal Tide**: They are the most common tidal pattern, featuring two high tides and two low tides each day.
2. **Diurnal Tides**: Only one high tide and one low tide each day.
3. **Mixed Tide**: Tides having variations in heights are known as mixed tides. They generally occur along the west coast of North America.

2.3.2 B. Tides based on the Sun, the Moon, and the Earth's Positions

1. **Spring Tides:** When the sun, the moon, and the earth are in a straight line, the height of the tide will be higher than normal. These are called as a spring tides. They occur twice in a month-one on the full moon (Poornima) and the other on the new moon (Amavasya).



2. **Neap Tides**: Normally after seven days of a spring tide, the sun and the moon become at a right angle to each other with respect to the earth. Thus, the gravitational forces of the sun and the moon tend to counteract one another. The tides during this period will be lower than the normal which are called as the neap tides. They also occur twice in a month- during the first quarter moon and the last quarter moon.

2.4 Role of Moon

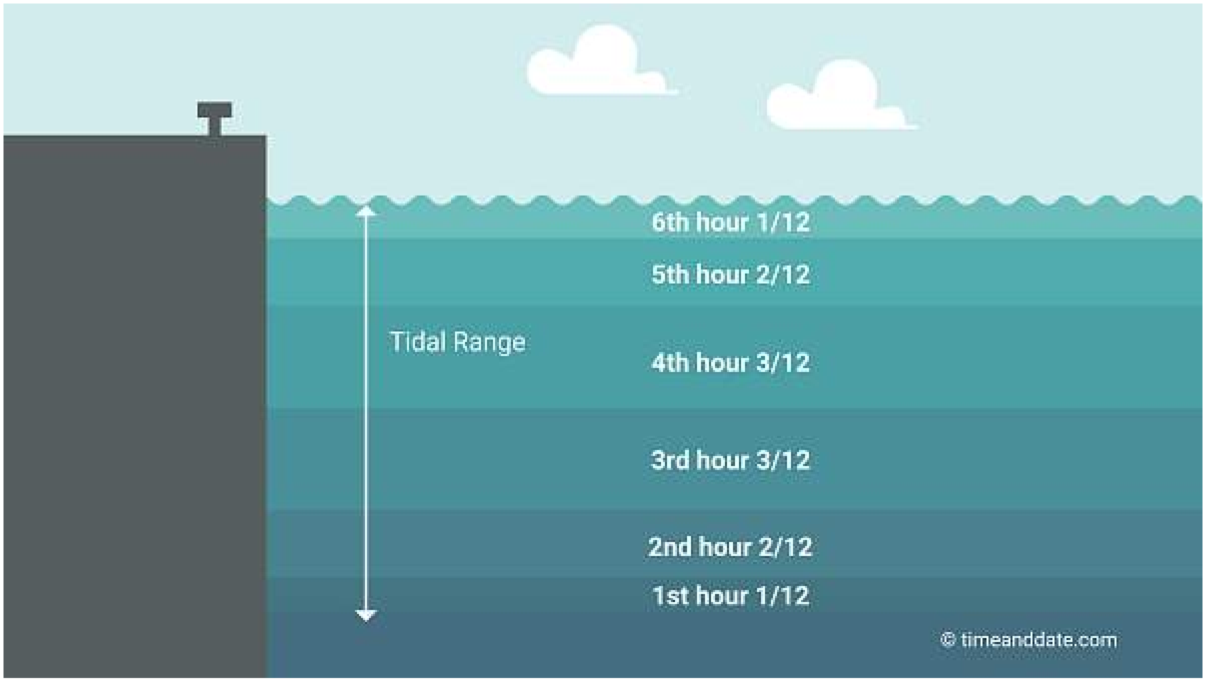
While both the Moon and the Sun influence the ocean tides, the Moon plays the biggest role. Although the Sun's gravitational pull on the Earth is 178 times stronger than the Moon's, the tidal bulges it causes are much smaller.

This is because, contrary to common belief, tides are not caused by the gravitational forces of the Moon or the Sun lifting up the oceans—their gravitational pull is much too weak for that. Rather, tides are created because the strength and direction of the gravitational pull *varies* depending on where on Earth you are. This variation creates the differential forces *or* tidal forces that in turn cause tides.

The tidal forces of the Moon are much stronger than the Sun's because it is so much closer to our planet, causing a much greater variation in the gravitational force from one location to another. The Sun's gravitational force, on the other hand, varies much less because the Sun is so far away.

The Rule of 12ths

People who have to consider the tides in their daily life, like sailors, fishers, and surfers, often use what is called the rule of 12ths to calculate the expected water level.



The water level changes gradually.

This rule states that in the 1st hour after low tide the water level will rise by 1/12 of the predicted tidal range in any given area. In the 2nd hour, it will rise 2/12, and in the 3rd hour, it will rise 3/12. In the 4th hour, it will also rise 3/12, in the 5th, it will rise 2/12, and in the 6th hour, it will rise 1/12.

The sequence to remember is 1-2-3-3-2-1.

So, let’s say the predicted tidal range is 12 feet. In the 1st hour, the tide would rise 1 foot. In the 2nd hour, it would rise 2 feet. In the 3rd and 4th hours, it would rise 3 feet. In the 5th hour, the tide would rise 2 feet, and in the 6th hour, 1 foot.

3. Ocean Currents

Ocean water is on the move, affecting your climate, your local ecosystem, and the seafood that you eat. Ocean currents, abiotic features of the environment, are continuous and directed movements of ocean water. These currents are on the ocean’s surface and in its depths, flowing both locally and globally.

Winds, water density, and tides all drive ocean currents. Coastal and sea floor features influence their location, direction, and speed. Earth’s rotation results in the **Coriolis Effect** which also influences ocean currents. Similar to a person trying to walk in a straight line across a spinning merry-go-round, winds and ocean waters get deflected from a straight line path as they travel across the rotating Earth.

The winds majorly responsible for creating ocean currents are the Westerlies and the Trade winds. Owing to the earth's rotation, winds blow anti-clockwise in the northern hemisphere and clockwise in the southern hemisphere. This pattern of blowing winds is called the Coriolis effect.

Ocean currents also move in the same pattern as winds i.e. anit-clockwise in the northern hemisphere and clockwise in the southern hemisphere. The ocean currents can be warm or cold, depending on their origin. Warm ocean currents originate near the equator and move towards the poles or higher latitudes while cold currents originate near the poles or higher latitudes and move towards the tropics or lower latitude.

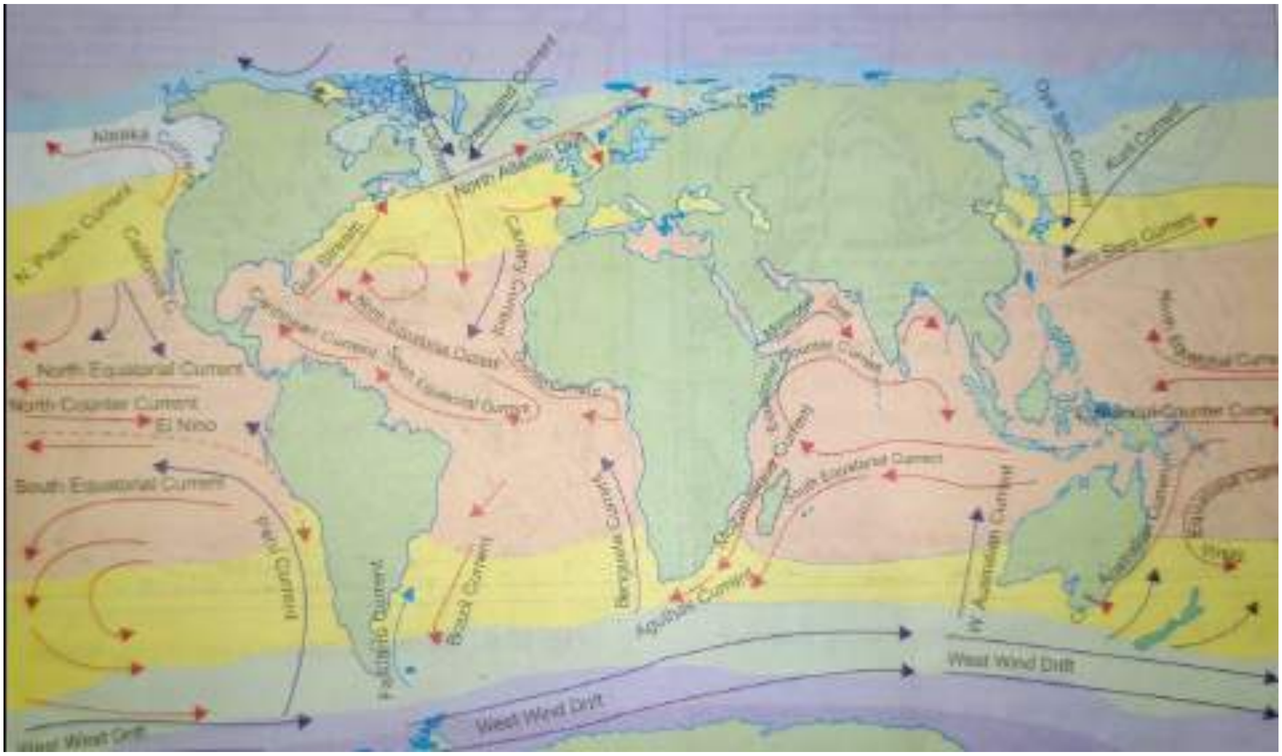
The ocean currents greatly influence the temperature of an area. In areas where warm and cold currents meet, the temperature falls, giving rise to foggy conditions. Whoever, mixing of warm and cold currents supports a rich marine life.

3.1 Types of Ocean Currents

3.1.1 Warm Ocean Currents:

- Those currents which flow from equatorial regions towards poles which have a higher surface temperature and are called warm current.
- They bring warm waters to the cold regions.

- They are usually observed on the east coast of the continents in the lower and middle latitudes of both hemispheres.
- In the northern hemisphere, they are also found on the west coast of the continents in the higher latitudes (E.g. Alaska and Norwegian Currents).



3.1.2 Cold Ocean Currents:

- Those currents which flow from polar regions towards equator have a lower surface temperature and are called cold currents.
- They bring cold waters into warm areas.
- These currents are usually found on the west coast of the continents in low and middle latitudes of both hemispheres.
- In the northern hemisphere, they are also found on the east coast in the higher latitudes (E.g. Labrador, East Greenland and Oyashio currents).

3.2 Classification of Ocean Currents

1. **Surface Currents:** They constitute about 10% of all the waters in an ocean. These waters are occupied at the upper 400m of an ocean or the Ekman Layer. It is the layer of the ocean

water which moves due to the stress of blowing the wind and this motion is thus called as Ekman Transport.

2. **Deep Water Currents:** They constitute about 90% of the ocean water. They move around the ocean basin due to variations in the density and gravity.

The Gulf Stream is a strong ocean current that brings warm water from the Gulf of Mexico into the Atlantic Ocean. It extends all the way up the eastern coast of the United States and Canada. The Gulf Stream is a strong ocean current that brings warm water from the Gulf of Mexico into the Atlantic Ocean.

Effects of ocean currents on climate :-The ocean currents mitigate the air temperatures and help in the regulation of air routes. Warm and cold currents affect the rainfall as winds passing over the warm current pick up the moisture and give extra rains to British Columbia, British Isles, Japan and Queensland. Eastern margins of Australia and Africa have heavy rainfall due to the same reason.

Effects of ocean currents on economy:-Knowledge of surface ocean currents is essential in reducing costs of shipping, since traveling with them reduces fuel costs. In the wind powered sailing-ship era, knowledge of wind patterns and ocean currents was even more essential. A good example of this is the Agulhas Current (down along eastern Africa), which long prevented sailors from reaching India. In recent times, around-the-world sailing competitors make good use of surface currents to build and maintain speed. Ocean currents can also be used for marine power generation, with areas off of Japan, Florida and Hawaii being considered for test projects

Effects of ocean currents on fishing:-The mixing of the cold and warm currents provides ideal temperature conditions for the life of fish. The chief food of fish (plankton) is found in abundance in cold water. For example, off Newfoundland where Gulf Stream and Labrador (cold and warm currents) meet upwelling water brings in nutrient salts to the surface of the sea.

4. Marine resources; biotic, mineral and energy resources

Marine resources are materials found in the ocean such as biological diversity, oil, sand, and coral reefs. Explore the characteristics, formation, and management of marine resources. **Marine resources** are materials and attributes found in the ocean that are considered to have value. That value can be intrinsic, or monetary. They include a huge number of things: biological diversity, fish and seafood supplies, oil and gas, minerals, sand and gravel, renewable energy resources, tourism potential, and unique ecosystems like coral reefs. These resources can have great monetary value, and even when they don't, the uniqueness and opportunity for education and human enrichment cannot be quantified. The way we manage and use these resources is therefore of great importance.

Typically **Ocean Resources can be classified in to two** broad categories –

1. **Biotic Resources**
    - Planktons
    - Nektons
    - Benthos
2. **Abiotic Resources**
    - Mineral
    - Energy

4.1 Biotic Resources

- **Biotic means alive** and **Abiotic means nonliving**.
- Biotic resources of the seas include **fishes, crustaceans, molluscs, corals, reptiles and mammals etc.**

Planktons

Plankton are the diverse collection of organisms found in water that are unable to propel themselves against a current.

- **Phytoplanktons**– floating and drifting micro plants.
- Autotrophs

- Eg- algae and diatoms
- **Zooplanktons**– floating and drifting micro animals.

Nektons

Nekton (or swimmers) are living organisms that are able to swim and move independently of currents at various depths of seas and oceans.

Nektons –

1. fishes
   - pelagic
   - demersal
2. mammals
   - dolphin
   - Blue
   - Whale

Fishes

Pelagic fish live in the pelagic zone of ocean or lake waters – being neither close to the bottom nor near the shore Demersal fish that live on or near the bottom.

Benthos

Benthos is the community of organisms that live on, in, or **near the seabed**, also known as the benthic zone. This community lives in from tidal pools along the foreshore, out to the continental shelf, and then down to the abyssal depths.

Benthos –

1. mobile
2. immobile

4.2 Mineral Reserves

1. Mineral dissolved in seawater
2. Continental Shelf and Slope Deposits
3. Deep ocean bottom deposits

Mineral dissolved in sea-water

1. Salt
2. Bromine
3. Magnesium
4. Gold
5. Zinc
6. Uranium
7. Thorium

Continental Shelf and Slope Deposits

- Sulfur – associated with marine volcanism.
- Ex. Gulf of Mexico – a rich source of sulfur

Magnetite reserves are found along the **circum pacific volcanic belt.**

- Monazite sand (source of thorium) at Kerala coast
- Gold (Alaska)
- Zircon (Brazil, Australia)
- Diamond (SouthAfrica)
- Calcium-– Peruvian coast rich deposits of calcium and phosphate
- Sand and gravel – significant building materials widely found on beds of continental shelves
- Fishes are rich in nitrate and phosphate, high protein, medicinal use
- Pearls

4.3 Deep ocean bottom deposits

- **Manganese nodules**– It comprises several minerals like nickel, copper, cobalt, lead, zinc, etc.
- The maximum percentage of Iron and Manganese.
- **Cobalt-rich marine deposits** associated with seamounts and guyots.
- **Phosphate-in form of phosphoritic modules** on shallow seabeds.
- **Polymetallic nodules**
    - **Polymetallic nodules are rounded accretions of manganese and iron hydroxides** that cover vast areas of the **seafloor** but are **most abundant on abyssal plains.**

5. Ocean thermal energy conversion (OTEC)

Ocean thermal energy conversion (OTEC) uses the temperature difference between a cooler deep and warmer shallow or surface seawaters to run a heat engine and produce useful work, usually in the form of electricity.

However, since the temperature differential is small, the thermal efficiency is low, making its economic feasibility a challenge.

5.1 Wave Energy –

Wave energy is produced when electricity generators are placed on the surface of the ocean. The energy provided is most often used in desalination plants, power plants, and water pumps. Energy output is determined by wave height, wave speed, wavelength, and water density.

5.2 Tidal energy –

- Tidal energy is produced through the use of tidal energy generators.
- Large underwater turbines are placed in areas with high tidal movements and are designed to capture the kinetic motion of ocean tides in order to produce electricity.

5.3 Offshore Wind energy –

Offshore wind power or offshore wind energy refers to the construction of wind farms in bodies of water to generate electricity from wind. Stronger wind speeds are available offshore compared to on land, so offshore wind power's contribution in terms of electricity supplied is higher.

5.4 Blue Economy

- The concept was introduced by **Gunter Pauli** in his 2010 book- "The Blue Economy: 10 years, 100 innovations, 100 million jobs".
- It is the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health.
- It advocates the greening of ocean development strategies for higher productivity and conservation of the ocean's health.

- It encompasses–
    - Renewable Energy: Sustainable marine energy can play a vital role in social and economic development.
    - Fisheries: Sustainable fisheries can generate more revenue, more fish, and help restore fish stocks.
    - Maritime Transport: Over 80% of international goods traded are transported by sea.
    - Tourism: Ocean and coastal tourism can bring jobs and economic growth.
    - Climate Change: Oceans are an important carbon sink (blue carbon) and help mitigate climate change.
    - Waste Management: Better waste management on land can help oceans recover.
- Blue Economy emphasizes on integration of the development of ocean economy with social inclusion, environmental sustainability, combined with an innovative business model.
- This is reflected in **Sustainable Development Goal (SDG 14),** which calls to conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

5.5 Need for Blue Economy

- Oceans cover three-quarters of the Earth's surface, contain 97% of the Earth's water, and represent 99% of the living area on the planet.
- Oceans protect biodiversity, keep the planet cool, and absorb about 30% of global CO_2 emissions.
- At least 3-5% of global GDP is derived from oceans.
- Blue economy, through sustainable use of oceans, has great potential for boosting economic growth by providing opportunities for income generation and jobs, etc.
- It can support food security, and diversification to address new resources for energy, new drugs valuable chemicals, protein food, deep-sea minerals, security, etc.
- It is the next **sunrise sector**.

5.6 Challenges

- **The threat of sea-borne terror –** piracy and armed robbery, maritime terrorism, illicit trade in crude oil, arms, drug and human trafficking and smuggling of contraband, etc.
- **Natural Disasters –** every year tsunamis, cyclones, hurricanes typhoons, etc leave thousands of people stranded and property worth millions destroyed.
- **Man-Made problems –** Oil spills, climate change continue to risk the stability of the maritime domain.
- **Impact of climate change –** changes in sea temperature, acidity, threaten marine life, habitats, and the communities that depend on them.
- **Marine pollution –** in form of excess nutrients from untreated sewerage, agricultural runoff, and marine debris such as plastics
- **Overexploitation of marine resources –** illegal, unreported, and unregulated extraction of marine resources.

6. Composition and Structure of Atmosphere

6.1 Composition

The atmosphere is composed of gases, water vapour and dust particles. Table below shows details of various gases in the air, particularly in the lower atmosphere. 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 surface of the earth.

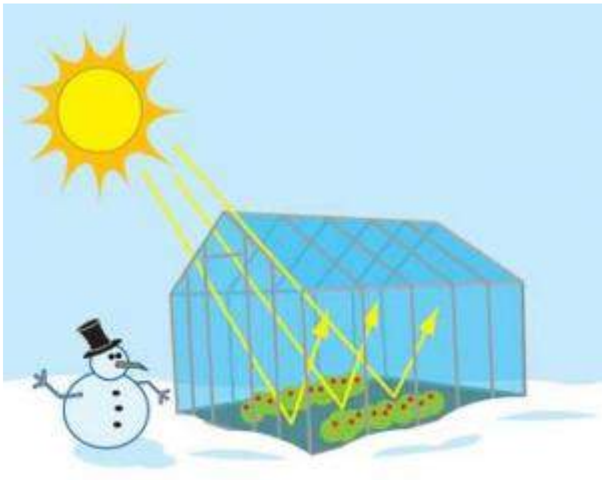
Constituent	*Formula*	*Percentage by Volume*
Nitrogen	N_2	78.08
Oxygen	O_2	20.95
Argon	Ar	0.93
Carbon dioxide	CO_2	0.036
Neon	Ne	0.002
Helium	He	0.0005
Krypto	Kr	0.001
Xenon	Xe	0.00009
Hydrogen	H_2	0.00005

6.1.1 Gases

The two most abundant gases in the Earth's atmosphere are nitrogen (N_2), which makes up 78% of the volume of the atmosphere, and oxygen (O_2), which makes up 21%. Although nitrogen and oxygen together with the other permanent gases account for nearly the entire atmosphere (>99%), and are crucial for life on Earth, they have little to no impact on weather and climate. It is the scarce variable components, like **water vapor** (H_2O), **carbon dioxide** (CO_2), **methane** (CH_4), and **nitrous oxide** (N_2O) that influence weather and climate.

Carbon dioxide is meteorologically a very 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 green house effect. The volume of other gases is constant but the volume of carbon dioxide has been rising in the past few decades mainly because of the burning of fossil fuels. This has also increased the temperature of the air. 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 and prevents them from reaching the surface of the earth.

6.1.2 Water vapor



Water vapor is the most abundant of the atmosphere's variable components. Its concentration changes from time to time and from place to place. On average, water vapor comprises 0.25% of the atmosphere. As discussed in the Water Chapter, the hydrologic cycle forms clouds from water vapor and produces precipitation that replenishes water in soils, lakes, and rivers. This **condensation** process (the cooling of water vapor to form liquid water) also releases stored heat, which plays an important role in the development of storms. In these ways, water vapor plays a critical role in weather.

As per the abobe figure A greenhouse is made of glass or plastic windows. Sunlight passes through the windows but heat is trapped inside. Vegetables and flowers can grow even during colder months.__

Other gases among the atmosphere's variable components are present in very small amounts, yet can have a powerful influence on weather. In some cases these trace variable gases are also extremely important to life on Earth.

Looking Ahead

In the Global Climate Change and Spirituality section you will learn that spiritual traditions such as Hinduism and Islam believe that the interdependent relationship between the atmosphere, plants, animals, water, and soil is a sacred balance.

For example, **ozone**, which naturally occurs in the **stratosphere** (10-50 km altitude in the atmosphere) screens out the sun's ultraviolet radiation (UV) which would otherwise reach the Earth's surface at levels damaging to living organisms. The screening of UV radiation occurs at very low concentrations of ozone (0.000004%). Ozone is also one of the **greenhouse gases** (GHGs), and has a strong influence on global warming.

Similarly, carbon dioxide makes up only 0.04% of the atmosphere, but is an important greenhouse gas that contributes to the warming of the Earth, and is also essential for **photosynthesis**, supplying plants and animals with their ultimate source of **carbon**

6.1.3 Dust Particle

Atmosphere has a sufficient capacity to keep small solid particles, which may originate from different sources and include sea salts, fine soil, smoke-soot, ash, pollen, dust and disintegrated particles of meteors. 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.

6.2 Layers of Earth Atmoshpheres

The atmosphere of Earth is divided into several different layers. The easiest way to think about the atmosphere above our planet is to imagine an invisible shield that protects our planet from all the bad stuff that floats around in the universe. Each layer has its own properties, depending on how far you are from the surface of the planet.

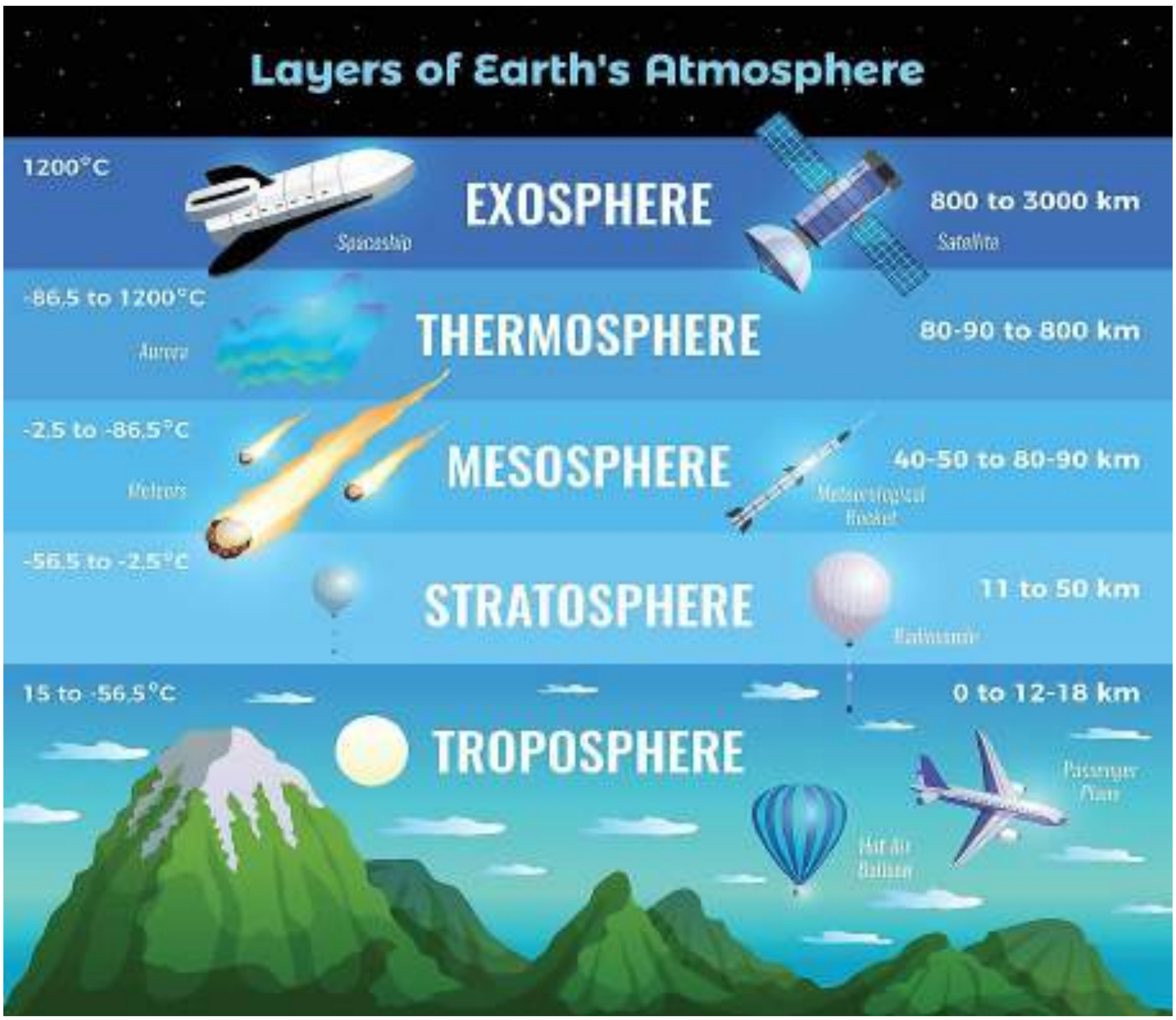
6.2.1. Troposphere

This is the first and the lowest layer of Earth's atmosphere. All life on this planet is affected by the changes that happen in this layer, as all the weather changes take place in **the troposphere**. It starts from the ground (or sea level) of our planet and expands up to 10 km up in the sky.

6.2.2. Stratosphere

If we start from the top of the troposphere and go further into the sky, we reach the layer known as the stratosphere. This layer goes up around 50 km above the Earth's ground. In this layer, the temperature rises as you go further up, and it has something to do with the ozone layer that is found inside the stratosphere.

The ozone layer serves a vital role in the protection of our planet, as the molecules of ozone prevent **ultraviolet light from the Sun** to hit our planet without stopping. The UV light is not technically stopped, but the conversion from UV light to heat happens (which is why holes in the ozone layer are so dangerous).



Source: https://www.worldatlas.com/

6.2.3. Mesosphere

As the name suggests, we are halfway up our atmosphere layers when we reach this part. **The mesosphere** goes up to 85 km above the surface of our planet, and the temperatures here behave as they do in the troposphere. In essence, the higher you go, the colder it gets. The air in this layer is absolutely not friendly for us, as it would be impossible to breathe in the mesosphere because of too low oxygen levels. Also, this layer of the atmosphere has the lowest temperature of all layers, and they drop down to -90° C.

6.2.4. Thermosphere

The layer that is located between 500 and 1000 km above the Earth's level is known as the thermosphere. You have guessed it, high temperatures are the name of the game here. This layer is under constant attack from the X-rays and **UV radiation** coming from the Sun and the space around us. Because of this, the temperatures in this layer can even reach 2,000° C!

6.2.5. Exosphere

Unlike other layers, which are mostly distinguishable from one another, it is hard to say how far **the exosphere** is from the surface of the planet. Somewhere it is around 100,000 km, but it can expand up to 190,000 km above sea level. The air here is extremely thin, and the conditions here are more similar to the ones we find when we leave the Earth's atmosphere entirely.

7. Insolation and Heat Balance of the Earth

The atmosphere is essential for the survival of plant and animal life. They also require the optimum temperature to keep themselves warm and grow. In this article, we are going to discuss in details about some of the topics like insolation, terrestrial radiation, heat budget of the earth, albedo, etc.

7.1 Insolation or Incoming Solar Radiation

- As we all know, the sun is the primary source of energy for the earth. The sun radiates its energy in all directions into space in short wavelengths, which is known as **solar radiation**.
- The earth's surface receives only a part of this radiated energy (2 units out of 1,00,00,00,000 units of energy radiated by the sun).
- The energy received by the earth's surface **in the form of short waves** is termed as **Incoming Solar Radiation or Insolation**.
- The amount of insolation received on the earth's surface is far less than that is radiated from the sun because of the small size of the earth and its distance from the sun.
- Moreover, water vapour, dust particles, ozone and other gases present in the atmosphere absorb a small amount of solar radiation.
- The solar radiation received at the top of the atmosphere varies slightly in a year due to the variations in the distance between the earth and the sun.
- During the earth's 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 nearest to the sun. This position is called **perihelion**.
- Due to this variation in the distance between the earth and the sun, the annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July.
- However, the effect of this variation is masked by some other factors like the distribution of land and sea and the atmospheric circulation. Hence the variation does not have a greater effect on daily weather changes on the surface of the earth.

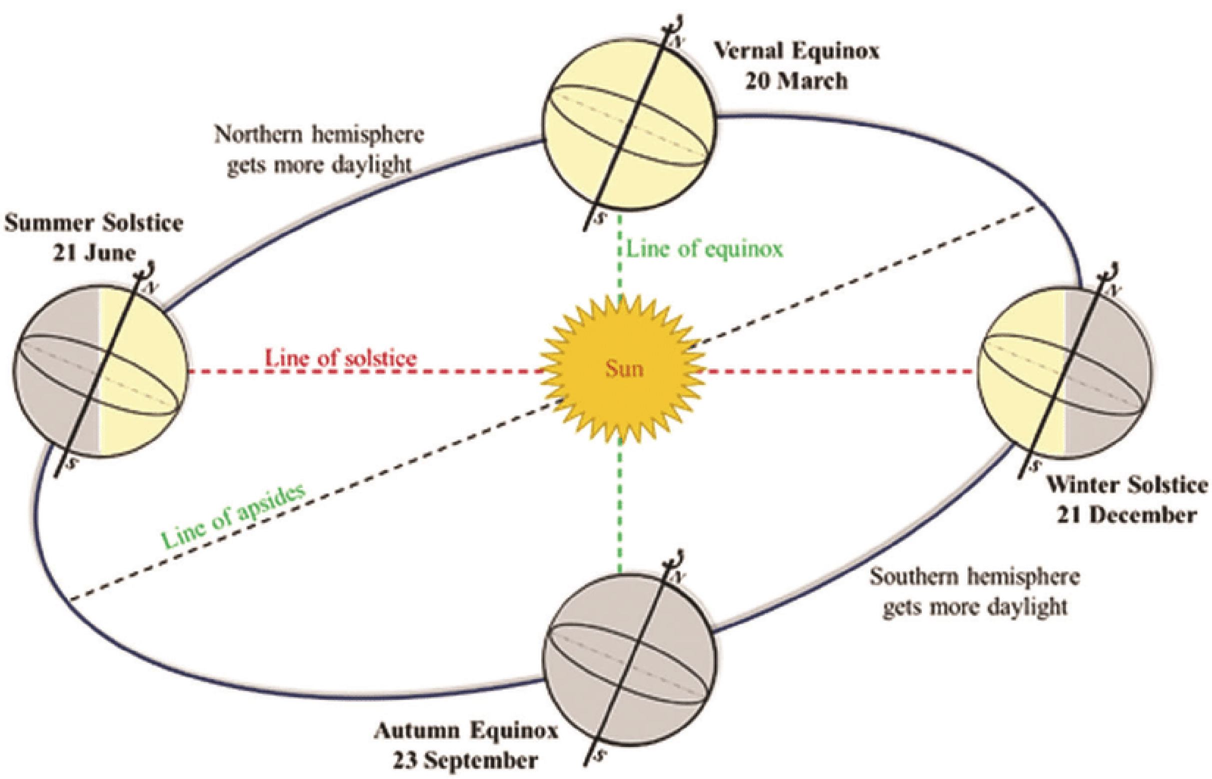
7.2 Factors influencing Insolation

- The amount of insolation received on the earth's surface is not uniform everywhere. It varies according to the place and time. When the tropical regions receive maximum annual insolation, it gradually decreases towards the poles. Insolation is more in summers and less in winters. The major factors which influence the amount of insolation received are:

  - Rotation of the earth on its axis
  - The angle of incidence of the sun's rays
  - Duration of the day
  - Transparency of the atmosphere

7.2.1. Rotation of the earth on its axis

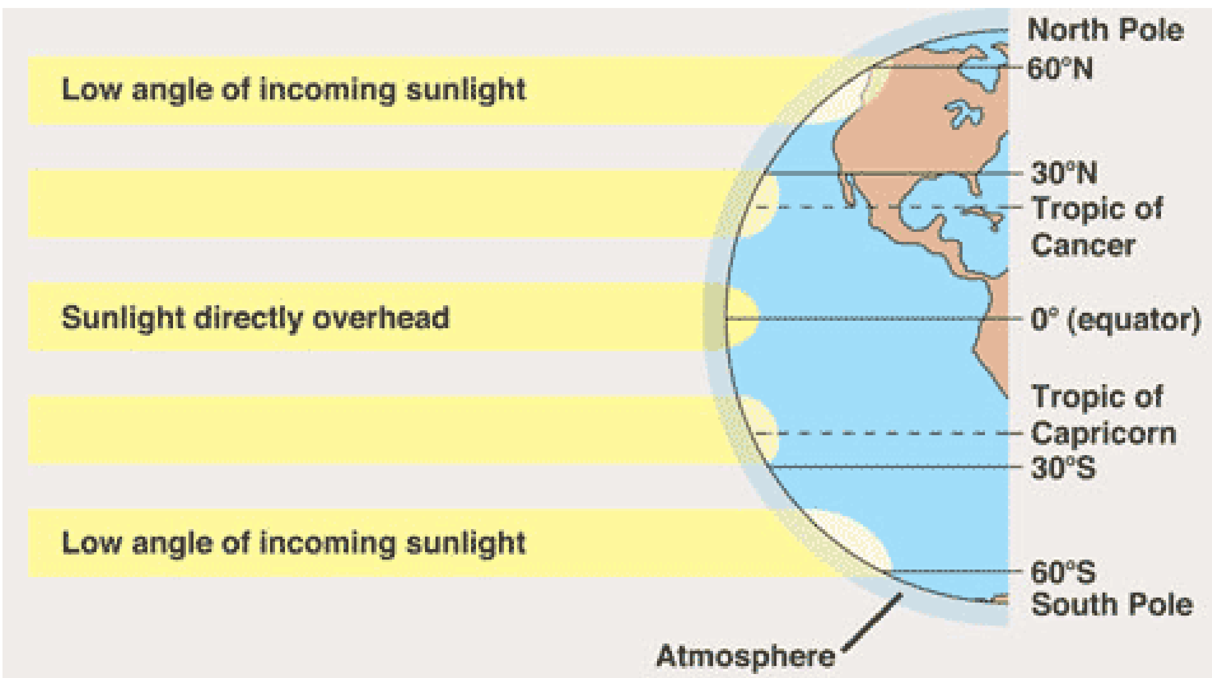
- The earth rotates on its own axis which makes an angle of 66.5 with the plane of its orbit around the sun.



- The rotation of the earth on this inclined axis has a greater influence on the amount of insolation received at different latitudes.

7.2.2. The angle of incidence of the sun’s rays

- Since the earth is a geoid resembling a sphere, the sun’s rays strike the surface at different angles at different places. This depends on the latitude of the place.
- The higher the latitude, the less is the angle they make with the surface of the earth.
- The area covered by the vertical rays is always less than the slant rays. If more area is covered, the energy gets distributed and the net energy received per unit area decreases.
- Moreover, the sun’s rays with small angle traverse more of the atmosphere than rays striking at a large angle.
- Longer the path of the sun’s rays, greater is the amount of reflection and absorption of heat by the atmosphere. As a result, the intensity of insolation is less.



Source: https://www.quora.com/Which-zone-receives-the-slanting-rays-of-the-sun

7.2.3. Duration of the day

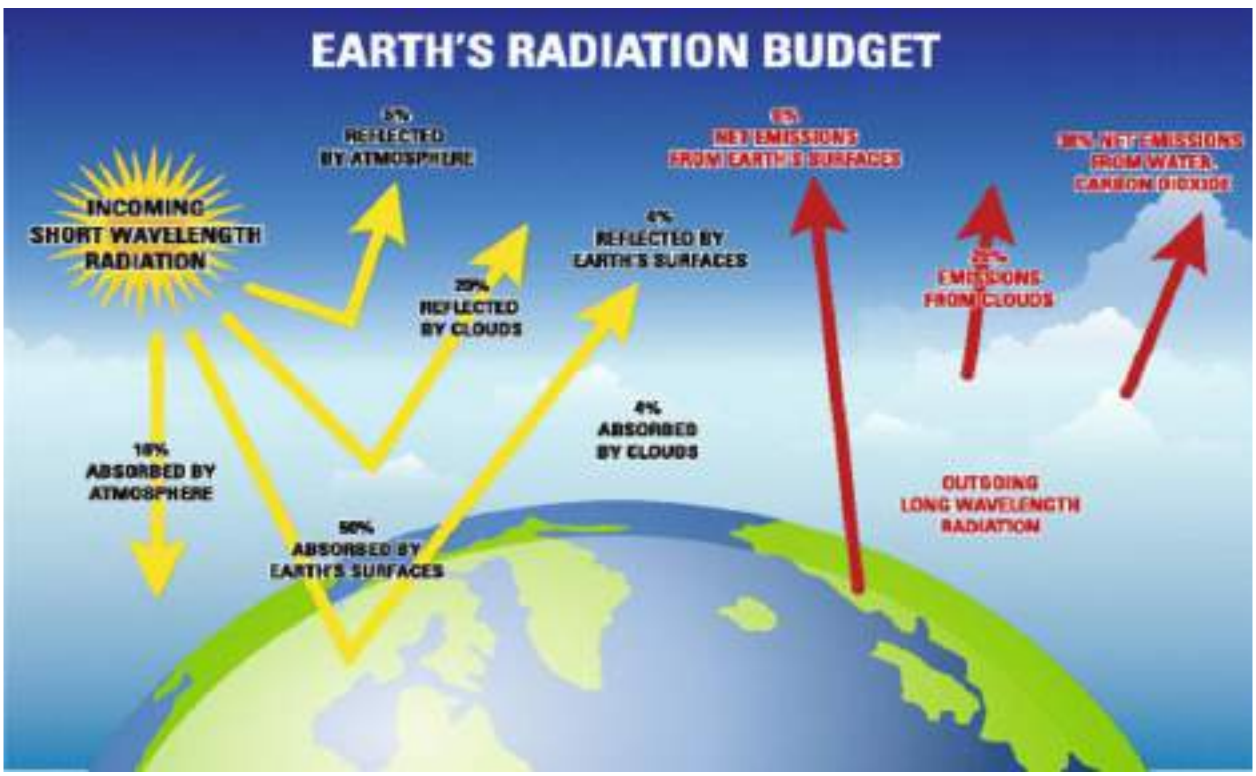
- Duration of the day varies from place to place and season to season. It decides the amount of insolation received on the earth's surface.

- The longer the duration of the day, the greater is the amount of insolation received. Conversely shorter the duration of the day leads to receipt of less insolation.

7.2.4. Transparency of the atmosphere

- The transparency of the atmosphere depends upon the cloud cover and its thickness, dust particles, water vapour, etc. They reflect, absorb or transmit insolation.

- Thick cloud hinders the solar radiation to reach the earth's surface. Similarly, water vapour absorbs solar radiation resulting in less amount of insolation reaching the surface.



Source: https://www.researchgate.net/figure/Components-of-the-earths-radiation-budget-adapted-from-NASA_fig1_291186092

- When the solar radiation passes through the atmosphere, water vapour, ozone and other gases absorb much of the near infrared radiation (mainly in the troposphere).

- Very small suspended particles in the troposphere scatter visible spectrum both to space and towards the earth's surface. This process adds colour to the sky.

- The red colour of the rising and the setting sun and the blue colour of the sky are the results of scattering of the light within the atmosphere.

Note: Maximum insolation is received over the subtropical desert, where the cloudiness is the least. The 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.

7.3 Heating and Cooling of the Atmosphere

The sun is the ultimate source of atmospheric heat and energy. There are different ways of heating and cooling of the atmosphere. They are:

1. Terrestrial Radiation
2. Conduction
3. Convection
4. Advection

7.3.1. Terrestrial Radiation

Before discussing terrestrial radiation, the following facts about radiation are worth noting.

i) All objects whether hot or cold emit radiant energy continuously.

ii) Hotter objects emit more energy per unit area than colder objects.

iii) The temperature of an object determines the wavelength of radiation. Temperature and wavelength are inversely proportional. Hotter the object, shorter is the length of the wave.

- So, when the earth's surface after being heated up by the insolation (in the form of short waves), it becomes a radiating body.

- The earth's surface starts to radiate energy to the atmosphere in the form of **long waves**.

- This is what we call as **terrestrial radiation**. This energy heats up the atmosphere from bottom to top.

- It should be noted that the **atmosphere is transparent to short waves and opaque to long waves**.

- The long-wave radiation is absorbed by the atmospheric gases particularly by carbon dioxide and other greenhouse gases. Thus, the atmosphere is indirectly heated by the terrestrial radiation.

- The atmosphere, in turn, radiates and transmits heat to space. Finally, the amount of heat received from the sun is returned to space, thereby maintaining a constant temperature at the earth's surface and in the atmosphere.

7.3.2. Conduction (transfer of heat by contact)

- Conduction is the process of heat transfer from a warmer object to a cooler object when they come in contact with each other.

- The flow of heat energy continues till the temperature of both the objects become equal or the contact is broken.

- The conduction in the atmosphere occurs at the zone of contact between the atmosphere and the earth's surface.

- Conduction is important in heating the lower layers of the atmosphere.

7.3.3. Convection (vertical transfer of heat)

- Transfer of heat by the movement of a mass or substance from one place to another, generally vertical, is called convection.

- The air of the lower layers of the atmosphere gets heated either by the earth's radiation or by conduction. The heating of the air leads to its expansion. Its density decreases and it moves upwards.

- The continuous ascent of heated air creates a vacuum in the lower layers of the atmosphere. As a consequence, cooler air comes down to fill the vacuum, leading to convection.

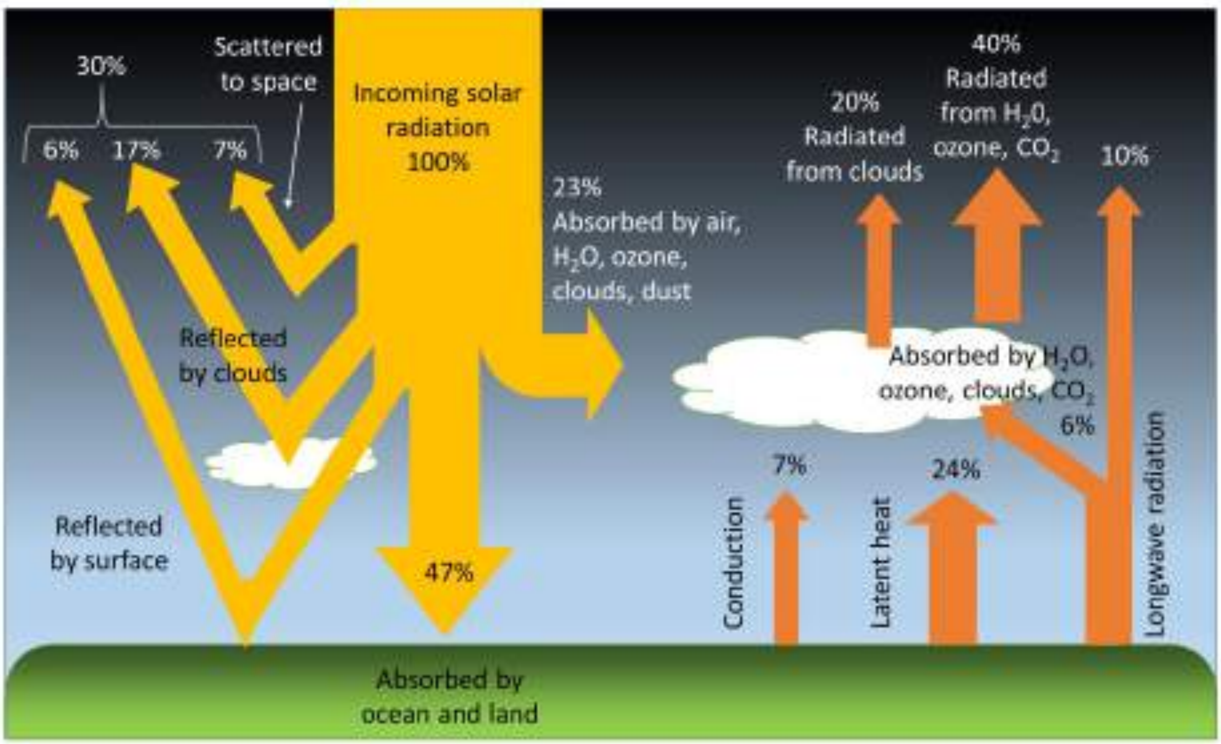
- The cyclic movement associated with the convectional process in the atmosphere transfer heat from the lower layer to the upper layer and heats up the atmosphere.
- The convection transfer of energy is confined only to the troposphere.

7.2.4. Advection (horizontal transfer of heat)

- The transfer of heat through horizontal movement of air (wind) is called advection.
- Winds carry the temperature of one place to another. The temperature of a place will rise if it lies in the path of winds coming from warmer regions. The temperature will fall if the place lies in the path of the winds blowing from cold regions.
- Horizontal movement of the air is relatively more important than the vertical movement. In the middle latitudes, most of diurnal (day and night) variations in daily weather are caused by advection alone.
- In tropical regions particularly in northern India during the summer season, local winds called **'Loo'** is the outcome of advection process.

8. Heat Budget of the Earth

- The earth as a whole does not accumulate or lose heat. It maintains its temperature.
- 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.
- This balance between the insolation and the terrestrial radiation is termed as the **heat budget or heat balance of the earth**.



Source: https://rwu.pressbooks.pub/webboceanography/chapter/8-1-earths-heat-budget/

- This is why the earth neither warms up nor cools down despite the huge transfer of heat that takes place.

8.1 Albedo

- Albedo can be simply defined as a measure of how much light that hits a surface is reflected back without being absorbed.

- It is a reflection coefficient and has a value less than one.
- When the solar radiation passes through the atmosphere, some amount of it is reflected, scattered and absorbed.
- The reflected amount of radiation is called as the albedo of the earth.
- The value of albedo will be different for different surfaces.
- Because of the effect of albedo, highly developed areas such as urban cities can experience higher average temperatures than the surrounding suburban or rural areas, a phenomenon known as the "Urban Heat Island Effect".
- The higher average temperature can be attributed to less vegetation, higher population densities, and more infrastructures with dark surfaces (asphalt roads, brick buildings, etc.).

Surface	Albedo
Soil	0.05 - 0.40
Sand	0.15 - 0.45
Grass	0.16 - 0.26
Agricultural Crops	0.18 - 0.25
Tundra	0.18 - 0.25
Forest	0.05 - 0.20
Water	0.03 - 1.00
Snow	0.40 - 0.95
Ice	0.20 - 0.45
Clouds	0.30 - 0.90

Figure 2 *Albedo values for various Earth surfaces. Adapted from www.eoearth.org.*

8.2 Variation in the net budget at the earth's surface

- Although the earth as a whole maintains a balance between the insolation and the terrestrial radiation, this is not true what we observe at different latitudes.
- As we have discussed earlier, there are variations in the amount of insolation received at different latitudes.

- In the tropical region, the amount of insolation is higher than the amount of terrestrial radiation. Hence it is a region of surplus heat. In the polar region, the heat gain is less than the heat loss. Hence it is a region of deficit heat.
- Thus the insolation creates an imbalance of heat at different latitudes.
- This imbalance is nullified to some extent by winds and ocean currents, which transfer heat from surplus heat regions to deficit heat regions.
- This process of redistribution and balancing of latitudinal heat is commonly known as **Latitudinal Heat Balance**.

Note: Topics like Temperature, Factors controlling Temperature and Distribution of Temperature will be covered in the next article.

9. Atmospheric Circulation and Weather System

Variying temperature on earth plays an important role in the uneven distribution over the surface of the earth. Air expands when heated and gets compressed when cooled. This results in variations in the atmospheric pressure. The result is that it causes the movement of air from high pressure to low pressure, setting the air in motion. You already know that air in horizontal motion is wind. Atmospheric pressure 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.

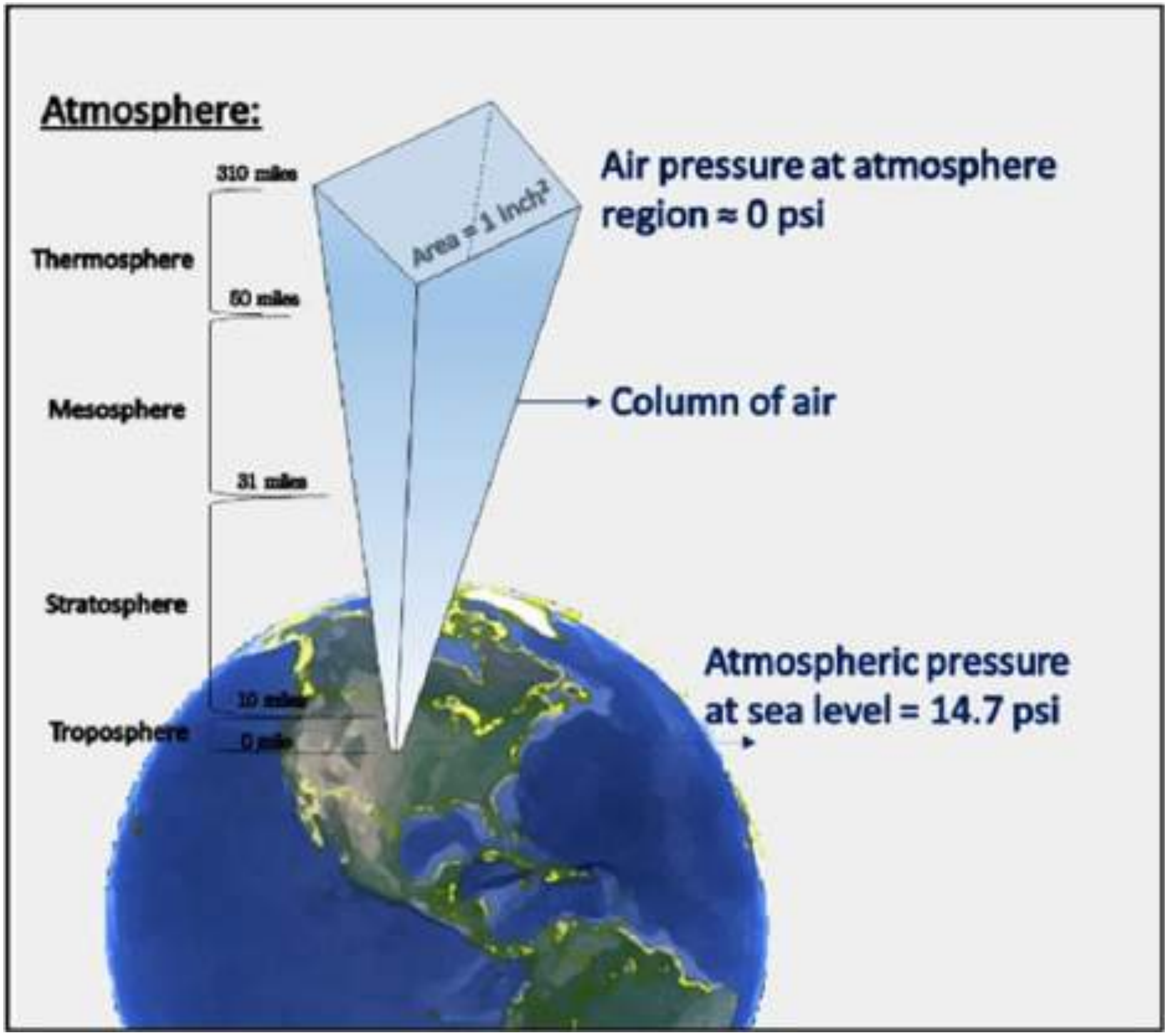
9.1 Atmospheric Pressure

Atmospheric pressure 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

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 atmospheric pressure is expressed in units of milibar. At sea level the average atmospheric pressure is 1,013.2 milibar.

Due to gravity the air at the surface is denser and hence has higher pressure. Air pressure is measured with the help of a mercury barometer or the aneroid barometer.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.



Source: https://www.researchgate.net/figure/Visual-representation-of-air-pressure-within-the-atmosphere-region_fig4_317240269

Vertical Variation of Pressure

In the lower atmosphere the pressure decreases rapidly with height. The decrease amounts to about 1 mb for each 10 m increase in elevation. It does not always decrease at the same rate.. 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

Small differences in pressure are highly significant in terms of the wind direction and velocity. Horizontal distribution of pressure is studied by drawing isobars at constant levels. Isobars are lines connecting places having equal pressure. In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level for purposes of comparison. 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. They oscillate with the apparent movement of the sun. In the northern hemisphere in winter they move southwards and in the summer northwards.

9.2 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. In addition, the gravitational force acts downward.

Pressure Gradient Force

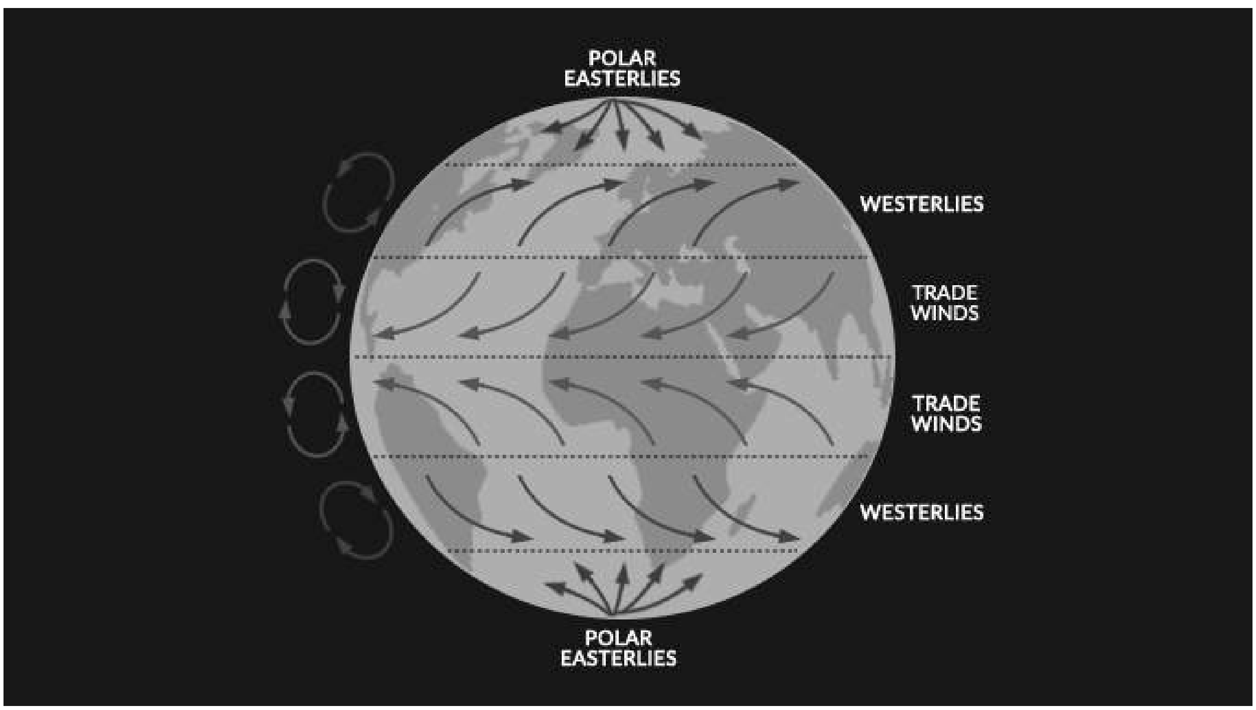
The differences in atmospheric pressure produces a force. The rate of change of pressure with respect to distance is the pressure gradient. The pressure gradient is strong where the isobars are close to each other and is weak where the isobars are apart.

Frictional Force

It affects the speed of the wind. It is greatest at the surface and its influence generally extends upto 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. This force is called the Coriolis force after the French physicist who described it in 1844. 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.

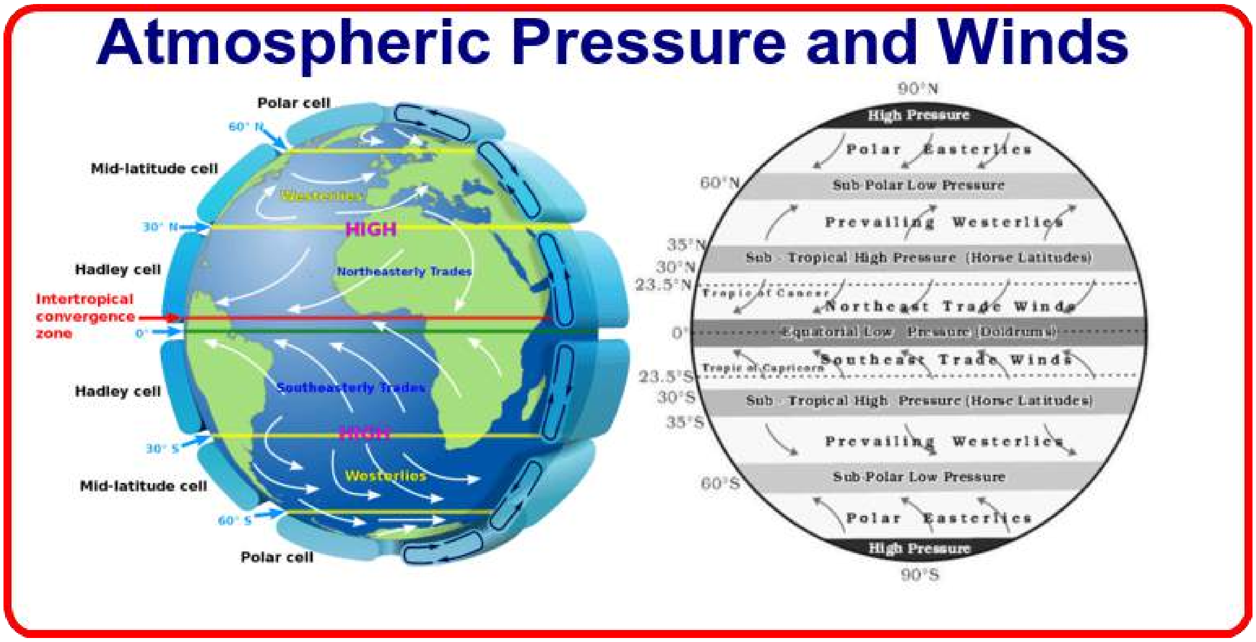


Source: https://earthhow.com/coriolis-effect-air-circulation/

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 lowpressure 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.(important need more point)

Pressure and Wind

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. Liked this document? Please rate to help us maintain content quality Excellent Average Poor 4/24/22, 1:05 PM Revision Not



Source: https://www.jkosm.in/atmospheric-pressure-and-winds/

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 (Figure 10.4). The wind circulation around a low is called cyclonic circulation. Around a high it is called anti cyclonic circulation. The direction of winds around such systems changes according to their location in different hemispheres 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. Generally, over low pressure area the air will converge and rise. Over high pressure area the air will subside from above and diverge at the surface Apart from convergence, some eddies, convection currents, orographic uplift and uplift along fronts cause the rising of air, which is essential for the formation of clouds and precipitation

9.3 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 30 N and S. Another reason for sinking is the cooling of air when it reaches 30 N 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. General Atmospheric Circulation and its Effects on Oceans Warming and cooling of the Pacific Ocean is most important in terms of general atmospheric circulation.

- The warm water of the central Pacific Ocean slowly drifts towards South American coast and replaces the cool Peruvian current. Such appearance of warm water off the coast of Peru is known as the El Nino. The El Nino event is closely associated with the pressure changes in the Central Pacific and Australia. This change in pressure condition over Pacific is known as the southern oscillation.
- The combined phenomenon of southern oscillation and El Nino is known as ENSO. In the years when the ENSO is strong, large-scale variations in weather occur over the world.

10. Air masses: Origin and Classification

Air Mass is defined as a large body of air having little horizontal variation in temperature and moisture. The air masses have a relatively uniform distribution of vertical gradients in their physical properties like temperature, pressure, and humidity.

10.1 Formation of Air Masses

Air masses are formed in very particular surface and atmospheric conditions which are found only in a few areas of the world. These preconditions are:

1. Physiographic homogeneity – surface should be either an oceanic surface or a plane on a continental surface.
2. Atmospheric conditions must be stable for the origin of air masses. There should not be any major movement in the air. This is important for air to maintain contact with uniform surface area for a long duration of time.
3. The air should rest on the given surface for 2 to 3 days to absorb the properties of the given surface.

Such atmospheric conditions are found in very restricted areas on the globe where the air is sinking slowly and gradually over the uniform surface, such areas are:

- Polar and subpolar regions (due to the presence of polar high-pressure belts and related sinking of air)
- Subtropical high-pressure belts (due to subsidence of air from the upper troposphere to lower troposphere)

Source regions

The homogenous surfaces, over which air masses form, are called the source regions. The source region should be extensive with gentle, divergent air circulation. Areas with high pressure but little pressure difference or pressure gradient are ideal source regions. There are no major source regions in the mid-latitudes as these regions are dominated by cyclonic and other disturbances.

- The main source regions are the high-pressure belts in the sub-tropics (giving rise to tropical air masses) and around the poles (giving rise to polar air masses).
- Source Region establishes heat and moisture equilibrium.
- When an air mass moves away from a source region, the upper level maintains the physical characteristics for a longer period. This is possible because they are stable with stagnant air which does not facilitate convection.

Movement of air masses

Once they are formed they start moving away from the source regions due to gravity.

Usually, they follow the path provided by the permanent winds system prevailing in that area which are polar winds, westerly winds, and trade winds.

10.2 Types of air masses

Classification of air masses is done based on a variety of parameters. In total there are 16 kinds and each has been denoted by a symbol for identification. However, for understanding fronts and cyclones further, only two types of classification are required.

They are classified based on the nature of the surface from which they originate. On this basis they are classified as:

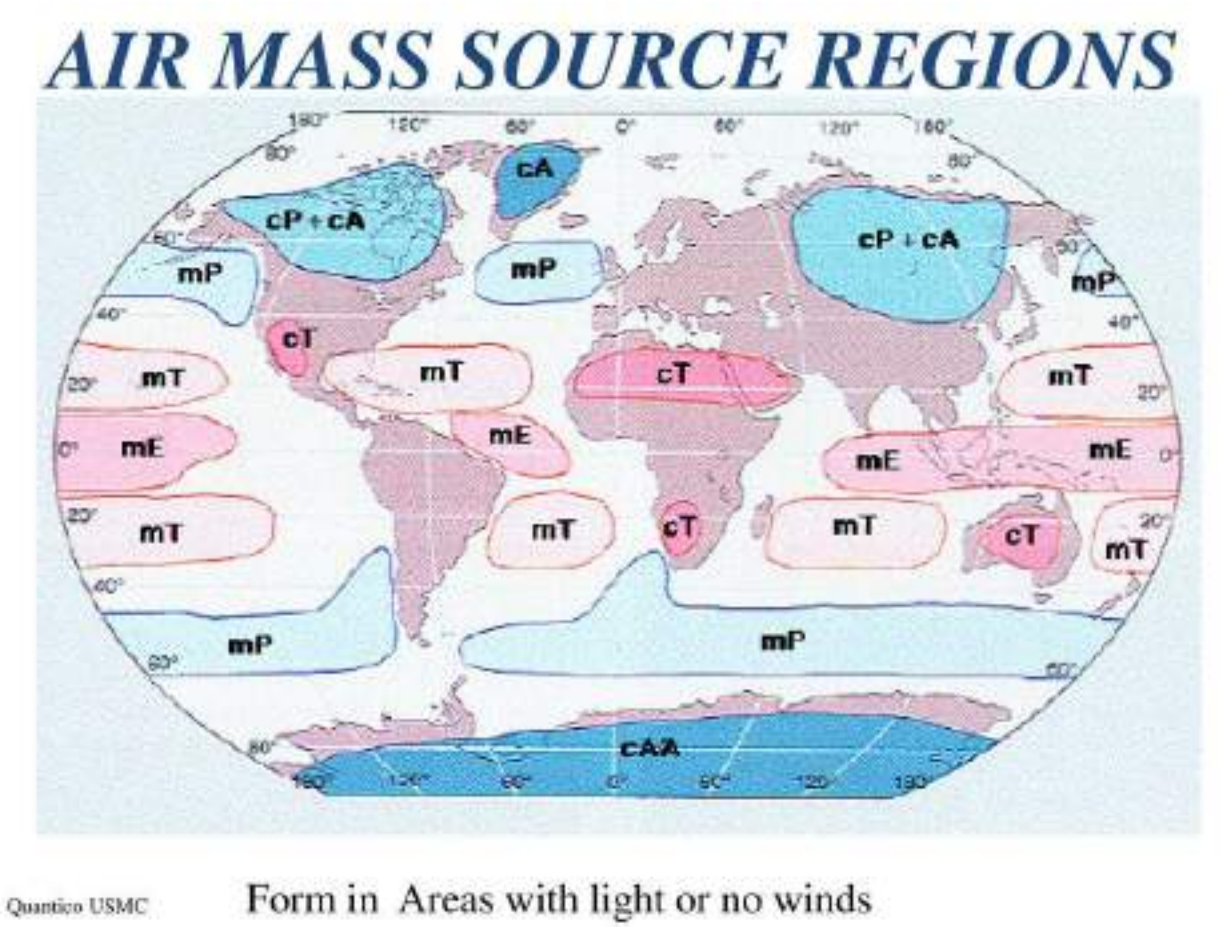
- Continental – originating from the homogeneous continental surface
- Maritime – originating from homogeneous oceanic surface

Therefore the classification is done based on their latitudinal position. On this basis both the above-mentioned they have been further classified into two kinds of each:

10.2.1 Continental Air mass

1. Continental tropical air mass

- The source regions include tropical and subtropical deserts of the Sahara in Africa, West Asia, and Australia.
- These are dry, hot, and stable and do not extend beyond the source.



Source: https://slideplayer.com/slide/17332630/

10.2.2. Continental polar air mass

- Source regions of these are the Arctic basin, northern North America, Eurasia, and Antarctica.
- These are characterized by dry, cold, and stable conditions**.**
- The weather during winter is frigid, clear, and stable.
- During summer, the weather is less stable with the lesser prevalence of anticyclonic winds, warmer land, and lesser snow.

10.2.3 Maritime air mass

1. Maritime tropical air mass

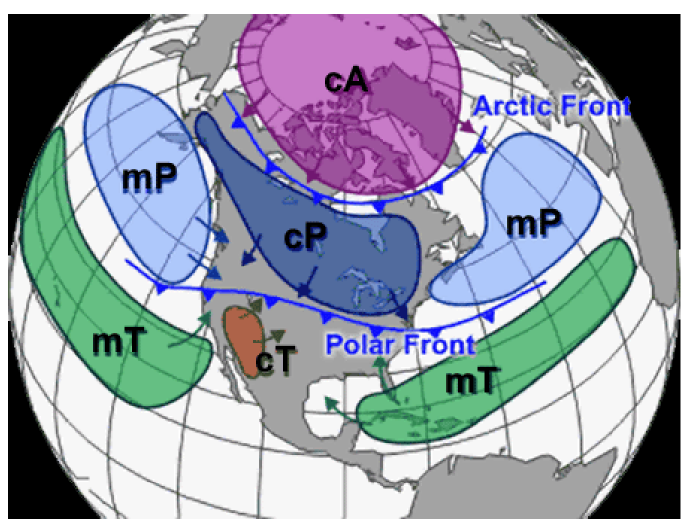
- The source regions of these include the oceans in the tropics and sub-tropics such as Mexican Gulf, the Pacific, and the Atlantic oceans.
- These are warm, humid, and unstable.
- The weather during winter has mild temperatures, overcast skies with fog.
- During summer, the weather is characterized by high temperatures, high humidity, cumulous clouds, and convectional rainfall.

2. Maritime polar air mass

- The source region of these is the oceans between 40° and 60° latitudes.
- These are those continental polar air masses that have moved over the warmer oceans, got heated up, and have collected moisture.
- The conditions over the source regions are cool, moist, and unstable. These are the regions that cannot lie stagnant for long.
- The weather during winters is characterized by high humidity, overcast skies, and occasional fog and precipitation.
- During summer, the weather is clear, fair, and stable.

They are also denoted by symbols as follows:

1. Maritime tropical (mT)
2. Continental tropical (cT)
3. Maritime polar (mP)
4. Continental polar (cP)
5. Continental arctic (cA)



10.3 Affect on global climate

- These have a deep impact on their areas of influence. For example, the Western European type of climate is fully developed by subtropical Marine Air masses.
- The origin of temperate cyclones is dependent on the convergence of two contrasting air mass that are continental polar and Maritime tropical air mass.
- The monsoon which is the backbone of Indian agriculture is also an example of tropical Marine Air mass

11. Urban Heat Islands

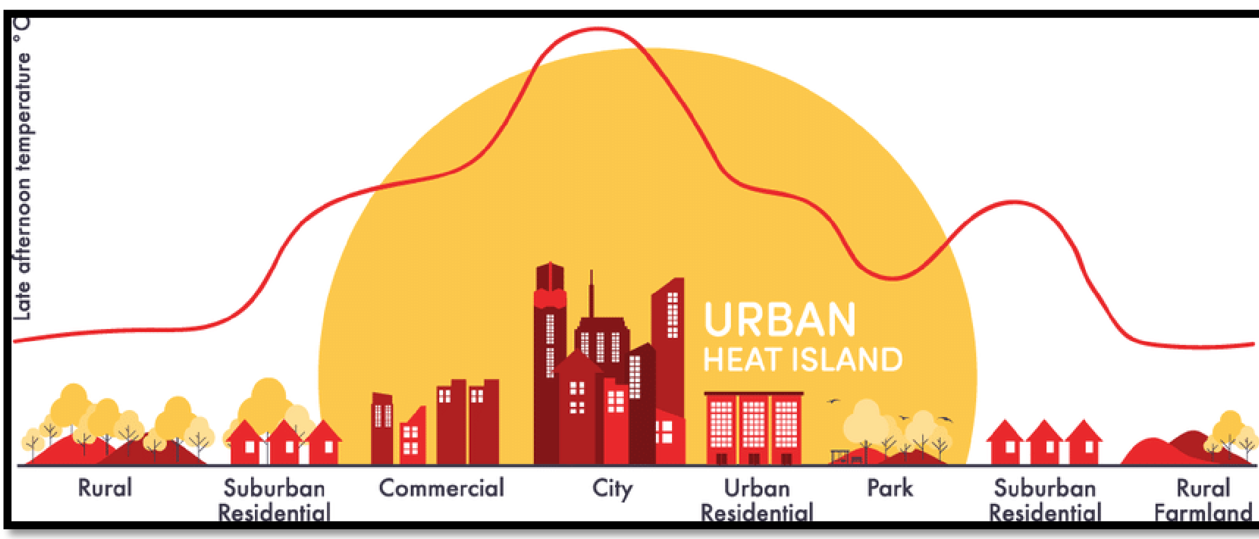
In large urban settlements, human activities greatly modify the environment, creating unique meteorological and climatological characteristics. The agglomeration of tall buildings, roadways, green spaces, and concrete surfaces produces intricate rain, wind, heat, and air-quality patterns. The hard surfaces can shape water flow and aggravate flood risks. The alignment of buildings can create local wind tunnels. Tiny particles emitted by traffic and industry can reduce air quality. The urban heat-island effect can raise temperatures by 5^{o}C to 10^{o}C, exacerbating heat waves.

Urban Heat Islands (UHI) are significantly warmer urban areas than its surrounding rural areas due to human activities. Urban Heat Island is a major problem associated with rapid urbanisation.

The temperature increase is attributed to deforestation and the construction materials adopted for city building. Usually, under the urban heat island phenomenon, the central regions of urban centres exhibit higher mean temperatures than the surrounding areas.

The heat island effect has corresponding ecological consequences on resident species.

The phenomenon, ‘Urban Heat Island’ was first investigated and described by Luke Howard in the 1810s.



Source: https://community.wmo.int/activity-areas/urban/urban-heat-island

11.1 Causes for the formation of heat islands in the urban habitat of the world

7 Key Factors contributing to the creation of “Urban Heat Island”

Insufficient Greenery

Buildings and skyscrapers tend to neglect the need for planting trees and plants on their premises. The designers, architects, and engineers fail to realize the benefits of greenery that create shade and a cooling effect in the air. Besides plantations inside the buildings purify the air and enhance the oxygen level. The open spaces are categorically replaced with stones, pavements, and concrete flooring. Instead of beautifying the apartments with green plants and flowers, the builders focus more on tiles and flooring. Seldom do they perceive the harm they are causing to the environment as well as to humanity.

Dark and Dull Coloured Roofs

Buildings are often roofed with dark and dull coloured tiles due to the dirt and dust outside. But little do we realize the amount of heat absorbed by such a roof tends to intensify the heat inside the building. It is one of the potential and serious causes of the urban heat island effect. On the contrary, light-colored roofs reflect the solar radiation and create a cooling sensation within the building interiors. The increase in temperature results in discomfort and health hazards for the people residing in the buildings and the apartments. The dark and dull roofs sadly create a heated canopy over the buildings that prevent the escape of the surface temperature.

Paved Surfaces

It is a common practice while constructing buildings, to introduce paved and impermeable surfaces around the compound for a fancy look and feel. But the architects remain ignorant of the fact that it eventually surges the urban heat island phenomenon. Parking lots and the walking trails in the building premises are covered with paved surfaces which are incapable to absorb the rainwater. The water flows away to the drainage system instead of being soaked inside the soil for the survival of the plants and trees.

Thermal Mass

Planning to establish and construct buildings in close proximity is another vital cause of the urban heat island effect. The wind is blocked, thus preventing the cooling effect due to convection. Besides it also prevents the pollutants from being dispersed. Buildings in urban areas accumulate a considerable amount of heat throughout the day from the solar power of the sun's heat radiations. At night though the temperature cools down yet the buildings are slow in releasing the heat at the same pace the way they absorb the heat. The result adverse effects of overheating inside the buildings.

Air Conditioning

The usage of air conditioning in urban areas is increasing at an exponential rate. While it reduces the temperature inside the buildings and creates a cooling effect, it releases heat into the outside environment. The heat is called "waste heat" which warms and increases the temperature; inappropriate for living beings. Several studies and analyses have proved that the use of air conditioning increases the air temperatures of the streets. Besides the effect is more at night since the atmospheric boundary is shallower at night compared to the daytime. The temperature in the outdoors has been deciphered to enhance more than 0.8K to 1K at night.

Improper air circulation

Narrow streets, gigantic skyscrapers and buildings, inadequate ventilation, and lack of appropriate spacing between the buildings are responsible for poor air circulation in the adjacent surroundings. It further aggravates the temperature stability of the environment. This results in high surface and air temperatures leading to the urban heat island effect. In other words, it acts as a hindrance to the concept called evapotranspiration; a process by which water is evaporated from the hot surfaces and transpired from the plant leaves to the atmosphere. Besides improper air circulation causes air pollution, breathing difficulties, and asthmatic traumas.

Ignorance of rainwater harvest

After the hot scorching heat of the summers, rains are welcomed gleefully. But in our enjoyment, we forget to preserve the rainwater for future use especially to reuse water in our daily chores. We neglect and ignore the phenomenon of rainwater harvest which brings in immense benefits.

In situations like drought and water shortage, the stored rainwater can be reused. Even the water can be utilized for cooling the surface temperatures thus preventing the occurrence of the urban heat island.

11.2 How to reduce urban heat?

Illustrated below are some of the important tips and recommendations on how to reduce urban heat:

- Opt for light coloured reflective roofing in the buildings and skyscrapers.
- Invest in landscape gardening within the building premises with annual maintenance to promote a green environment.
- Have a rooftop garden for reducing the surface temperature and allow evapotranspiration.
- Use energy-efficient electric equipment and appliances to reduce the burden of electricity thus supporting the lowering of heatwaves.
- Avoid unnecessary usage of air conditioning or coolers.
- While planning, designing, and architecting new building complexes, select eco-friendly building materials like Porotherm Smart Bricks, Clay Roof tiles, and Clay Façade Systems.
- Ensure proper spacing and allowance of air circulation in the building structure.
- Try to keep a balance between the paved surfaces and green surfaces.

Remedies :

Cooler, shaded spaces in our parks, near buildings, in streetscapes and alongside homes can reduce heat stress, particularly for those in our community who are most vulnerable to high temperatures.

Note: Cities in desert environments show a different trend known as the “urban oasis effect”. This effect is characterised by a cooler city centre compared to the surrounding environments

12. Climate Change and Global Warming

12.1 Climate Change:

Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle. But since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil and gas.

Burning fossil fuels generates greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun’s heat and raising temperatures.

Examples of greenhouse gas emissions that are causing climate change include carbon dioxide and methane. These come from using gasoline for driving a car or coal for heating a building, for example. Clearing land and forests can also release carbon dioxide. Landfills for garbage are a major source of methane emissions. Energy, industry, transport, buildings, agriculture and land use are among the main emitters.

12.1.1 Evidences of Climate Change

The planet earth has witnessed many variations in climate since the beginning. Geological records show alteration of glacial and inter-glacial periods. The geomorphological features, especially in high altitudes and high latitudes, exhibit traces of advances and retreats of glaciers. The sediment deposits in glacial lakes also reveal the occurrence of warm and cold periods. The rings in the trees provide clues about wet and dry periods. Historical records describe the vagaries in climate. All these evidences indicate that change in climate is a natural and continuous process. India also witnessed alternate wet and dry periods.

Archaeological findings show that the Rajasthan desert experienced wet and cool climate around 8,000 B.C. The period 3,000- 1,700 B.C. had higher rainfall. From about 2,000-1,700 B.C., this region was the centre of the Harappan civilisation. Dry conditions accentuated since then. In the geological past, the earth was warm some 500-300 million years ago, through the Cambrian, Ordovician and Silurian periods. During the Pleistocene epoch, glacial and inter-glacial periods occurred, the last major peak glacial period was about 18,000 years ago. The present inter-glacial period started 10,000 years ago.

12.1.2 Climate in the recent past

Variability in climate occurs all the time. The nineties decade of the last century witnessed extreme weather events. The 1990s recorded the warmest temperature of the century and some of the worst floods around the world. The worst devastating drought in the Sahel region, south of the Sahara desert, from 1967-1977 is one such variability. During the 1930s, severe drought occurred in southwestern Great Plains of the United States, described as the dust bowl. Historical records of crop yield or crop failures, of floods and migration of people tell about the effects of changing climate. A number of times Europe witnessed warm, wet, cold and dry periods, the significant episodes were the warm and dry conditions in the tenth and eleventh centuries, when the Vikings settled in Greenland. Europe witnessed "Little Ice Age" from 1550 to about 1850. From about 1885-1940 world temperature showed an upward trend. After 1940, the rate of increase in temperature slowed down.

12.2 Causes of Climate Change

The climate on Earth has been changing since it formed 4.5 billion years ago. Until recently, natural factors have been the cause of these changes. Natural influences on the climate include volcanic eruptions, changes in the orbit of the Earth, and shifts in the Earth's crust (known as plate tectonics).

Over the past one million years, the Earth has experienced a series of ice ages, including cooler periods (glacials) and warmer periods (interglacials). Glacial and interglacial periods cycle roughly every 100,000 years, caused by changes in Earth's orbit around the sun. For the past few thousand years, Earth has been in an interglacial period with a constant temperature.

However, since the Industrial Revolution in the 1800s, the global temperature has increased at a much faster rate. By burning fossil fuels and changing how we use the land, human activity has quickly become the leading cause of changes to our climate.

12.3 Greenhouse gases and the greenhouse effect

Some gases in the Earth's atmosphere trap heat and stop it escaping into space. We call these 'greenhouse gases'. These gases act as a warming blanket around the Earth, known as the 'greenhouse effect'.

Greenhouse gases come from both human and natural sources. Gases like carbon dioxide, methane, and nitrous oxide naturally occur in the atmosphere. Others, such as chlorofluorocarbons (CFCs), are only produced by human activity.

When short-wave radiation from the sun reaches Earth, most of it passes straight through and hits the surface. The Earth absorbs most of this radiation and gives off longer-wavelength infrared radiation.

The greenhouse gases absorb some of this infrared radiation, instead of it passing straight out into space. The atmosphere then emits radiation in all directions, sending some of it back to the surface, causing the planet to heat up. This process is known as the 'greenhouse effect'.

The greenhouse effect is critical to our survival. In fact, without greenhouse gases, Earth would be about 30 degrees colder than it is today. Without greenhouse gases and their warming effect, we wouldn't be able to survive.

However, since the Industrial Revolution, we've been adding more and more greenhouse gases into the air, trapping even more heat. Instead of keeping Earth at a warm, stable temperature, the greenhouse effect is heating the planet at a much faster rate. We call this the 'enhanced greenhouse effect' and it's the main cause of climate change.

12.4 Human causes of climate change

Humans cause climate change by releasing carbon dioxide and other greenhouse gases into the air. Today, there is more carbon dioxide in the atmosphere than there ever has been in at least the past 2 million years. During the 20th and 21st century, the level of carbon dioxide rose by 40%.

We produce greenhouse gases in lots of different ways:

- **Burning fossil fuels** – Fossil fuels such as oil, gas, and coal contain carbon dioxide that has been 'locked away' in the ground for thousands of years. When we take these out of the land and burn them, we release the stored carbon dioxide into the air.

- **Deforestation** – Forests remove and store carbon dioxide from the atmosphere. Cutting them down means that carbon dioxide builds up quicker since there are no trees to absorb it. Not only that, trees release the carbon they stored when we burn them.

- **Agriculture** – Planting crops and rearing animals releases many different types of greenhouse gases into the air. For example, animals produce methane, which is 30 times more powerful than carbon dioxide as a greenhouse gas. The nitrous oxide used for fertilisers is ten times worse and is nearly 300 times more potent than carbon dioxide!
- **Cement** – Producing cement is another contributor to climate change, causing 2% of our entire carbon dioxide emissions.

12.5 Natural changes to the climate

The leading cause of climate change is human activity and the release of greenhouse gases. However, there are lots of natural causes that also lead to changes in the climate system.

Natural cycles can cause the climate to alternate between warming and cooling. There are also natural factors that force the climate to change, known as 'forcings'. Even though these natural causes contribute to climate change, we know that they are not the primary cause, based on scientific evidence.

Some of these natural cycles include:

- **Milankovitch cycles** – As Earth travels around the sun, its path and the tilt of its axis can change slightly. These changes, called Milankovitch cycles, affect the amount of sunlight that falls on Earth. This can cause the temperature of Earth to change. However, these cycles take place over tens or hundreds of thousands of years and are unlikely to be causing the changes to the climate that we are seeing today.
- **El Niño Southern Oscillation (ENSO)** – ENSO is a pattern of changing water temperatures in the Pacific Ocean. In an 'El Niño' year, the global temperature warms up, and in a 'La Niña' year, it cools down. These patterns can affect the global temperature for a short amount of time (months or years) but cannot explain the persistent warming that we see today.

Natural forcings that can contribute to climate change include:

- **Solar irradiance** – Changing energy from the sun has affected the temperature of Earth in the past. However, we have not seen anything strong enough to change our climate.

Any increase in solar energy would make the entire atmosphere of Earth warm, but we can only see warming in the bottom layer.

- **Volcanic eruptions** – Volcanoes have a mixed effect on our climate. Eruptions produce aerosol particles that cool Earth, but they also release carbon dioxide, which warms it. Volcanoes produce 50 times less carbon dioxide than humans do, so we know they are not the leading cause of global warming. On top of this, cooling is the dominant effect of volcanic eruptions, not warming.

12.6 Global warming

- 2011-2020 was the warmest decade recorded, with global average temperature reaching 1.1°C above pre-industrial levels in 2019. Human-induced global warming is presently increasing at a rate of 0.2°C per decade.
- An increase of 2°C compared to the temperature in pre-industrial times is associated with serious negative impacts on to the natural environment and human health and wellbeing, including a much higher risk that dangerous and possibly catastrophic changes in the global environment will occur.
- For this reason, the international community has recognised the need to keep warming well below 2°C and pursue efforts to limit it to 1.5°C.