APPROACH – ANSWER: G. S. MAINS MOCK TEST - 2342 (2024)

Answer all the questions in NOT MORE THAN 200 WORDS each. Content of the answers is more important than its length. All questions carry equal marks. ***12.5X20=250***

1. What are local winds? With the help of examples, discuss how they affect the climate of a region.

Approach:

- Give a brief introduction about local winds.
- Provide few examples to show the effect of local winds on climate of a region.
- Conclude suitably.

Answer:

Local winds are horizontal movement of air which blow on a small spatial scale typically spanning tens to a few hundred kms. horizontally. They also tend to be short-lived, typically, lasting several hours to a day. There are many such winds around the world, some of them cold, some warm, some wet, some dry. They are confined to lower levels of the troposphere. They affect and are in turn affected by local relief and weather.

Some examples of local winds and their impact on the climate of a region are discussed below:

- **Land and Sea Breezes:** They occur in coastal regions in the form of a diurnal (daily) cycle, in which the differential heating of land and water produces low and high pressures. Due to them coastal regions remain cooler in day and warmer in night when compared to adjacent inlands.
- **Mountain and Valley breeze:** On a warm sunny day the mountain slopes are heated more than the valley floor. As a result, gentle wind begins to blow from valley towards slopes and it assumes the name of valley breeze. Afterwards in the night, cold heavy air of mountain slopes starts moving down towards the valley floor. This is known as the mountain breeze.
- **Fohn/Chinook:** Dry, warm, down-slope wind that occurs in leeward side of mountain. It can raise temperatures by as much as 14 °in few minutes. For examplem Fohn blows from the Alps to the central Europe. The literal meaning of chinook is 'snow eater' as they help in melting the snow earlier in Eastern slopes of the Rockies in U.S.A. and Canada. They keep the grasslands clear of snow. Hence they are very helpful to ranchers.
- **Mistral:** They are strong, cold, north-westerly wind that blows from southern France. It creates sunny climate in usually clouded areas. Sunshine and dryness brought by it have an important effect on local vegetation.
- **Harmattan:** Dry and dusty north-easterly trade wind which blows from Sahara Desert into Gulf of Guinea. It brings desert-like weather conditions: lowers humidity, dissipates cloud cover, prevents rainfall formation and sometimes result in dust storms and sandstorms and can cause severe damage to crops/vegetation.
- **Khamsin/Sirocco/Simoon:** Dry, hot, sandy local wind, blowing from the south, in North Africa and Arabian Peninsula. It reduces humidity and raises temperature in the region.
- **Loo:** These are strong, hot and dry summer wind over western Indo-Gangetic Plain. These winds raise the temperature of the region, and exposure to these winds can even prove fatal. They also cause high dryness making the region unsuitable for kharif and rabi crops.

Thus, local winds have tremendous impact upon the local climate which also influences the agricultural practices and livelihood in the region in which they blow.

2. What is meant by tropical monsoon climate? Identifying its distribution, discuss the process of its onset in the Indian subcontinent.

Approach:

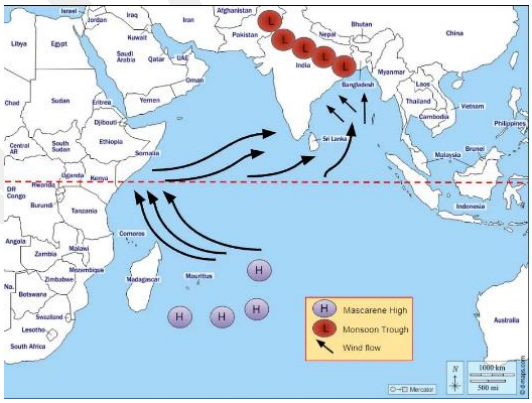
- Briefly define tropical monsoon climate.
- Write about its distribution around the world.
- Write about process of its onset in the Indian subcontinent.
- Conclude accordingly.

Answer:

The **Tropical monsoon climate** is characterized by the phenomena of seasonal reversal of wind along with corresponding change in the precipitation. Some of its characteristics include:

- Monthly mean temperatures **above 18 °C** with temperature ranging from 30-45° C in summer and 15-30° C in winters.
- Annual mean rainfall ranges from 200-250 cm. In some regions it is around 350 cm.
  - Heavy rainfall occurs mostly in the summer while the Winter is dry.

Distribution of tropical monsoon climate across the world is given below:

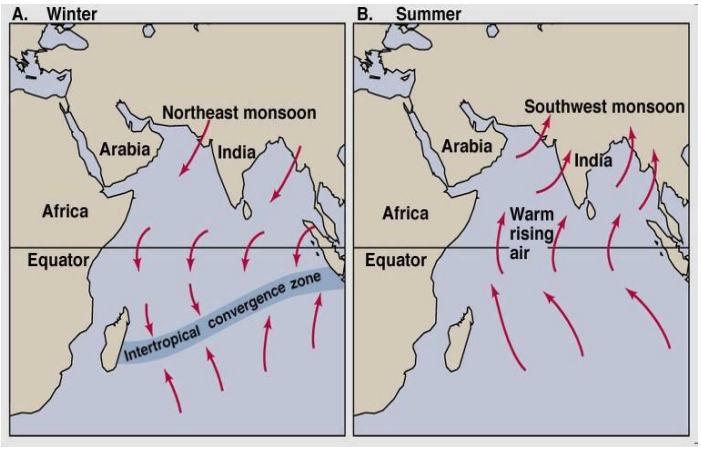


Tropical monsoon climate is found over the Indian sub-continent and South East Asia including Burma, Thailand, Laos, Cambodia, parts of Vietnam and south China , North Eastern part of South America and Northern Australia.

In Indian context, the summer monsoon (June to September) causes rainfall across the country, whereas the other phase, i.e. the retreating monsoon, causes rainfall in south-eastern coast of India during winter.

Process of onset of Indian Monsoon:

It includes the factors, which determine the origin of Indian monsoon as well as the timeline of its onset over the Indian subcontinent. The factors behind the origin of Indian Monsoon include:



- The **differential heating and cooling** of land and water creates low pressure on the landmass of India while the seas around experience comparatively high pressure.
- The **shift of the position of Inter Tropical Convergence Zone (ITCZ)** in summer, over the Ganga plain (this is the equatorial trough normally positioned about 5°N of the equator).
- Presence of the **high-pressure area** in the east of Madagascar.
- Intense **heating of the Tibetan plateau** during summer causing strong vertical currents.
- Movement of the **westerly jet stream** to the north of the Himalayas and the presence of the **tropical easterly jet stream** over the Indian peninsula during summer.

The seasonal reversal of wind is due to the shifting of **Inter-Tropical Convergence Zone** (ITCZ), the low-pressure region near the equator. As a result,

- In July, when the ITCZ is located in the north, it creates the Monsoon Trough. This encourages the development of **thermal low** over the North and Northwest India. Due to this shift of the ITCZ,

trade winds of the southern hemisphere cross the equator between 40oE and 60oE longitudes and start blowing from **southwest to northeast** due to the Coriolis force. It becomes **Southwest monsoon**.

- In winter, the ITCZ moves southward, and so the reversal of winds, from the northeast to south and southwest takes place thus leading to **Northeast monsoon**.
- The moisture is picked up from water bodies, mostly the Arabian Sea and the Bay of Bengal. The shape of the landmass and mountains (Western Ghats in the south and Himalayas in the North) guide the winds' direction.

Monsoon is that axis around which revolves the entire agricultural cycle of India. It is because over 60 per cent people of India depend on agriculture for their livelihood and agriculture itself is based on the monsoon.

3. What are volcanic landforms? Discuss with examples, the various types of intrusive forms.

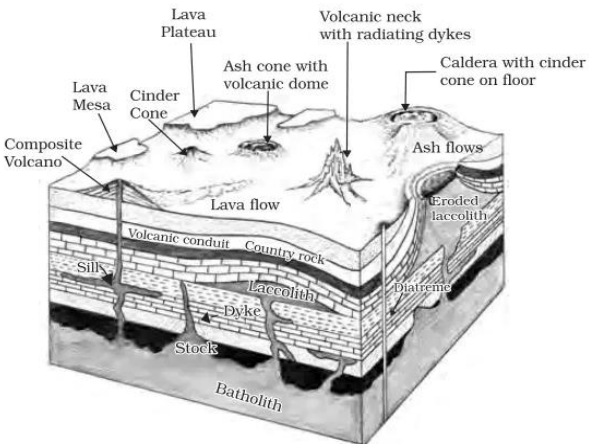
Approach:

- Define volcanic landforms.
- Discuss with illustrations various types of intrusive forms.
- Conclude accordingly.

Answer:

Volcanic landforms are geographical features that are formed by volcanic activity and are divided into extrusive and intrusive landforms based on whether magma cools within the crust or above the crust.

- **Extrusive landforms** are formed when magma reaches the Earth's surface and solidifies. Examples of extrusive landforms include lava flows, ash deposits, and volcanic cones.
- **Intrusive landforms** are formed when when magma cools and solidifies beneath the Earth's surface The lava that cools within the crustal portions assumes different forms.



Different types of intrusive landforms

- **Batholiths:** A large body of magmatic material that cools in the deeper depth of the crust develops in the form of large domes. They appear on the surface only after the denudational processes remove the overlying materials. They cover large areas, and at times, assume a depth that may be several km. These are granitic bodies. Batholiths are the cooled portion of magma chambers.
- **Laccolith:** These are large dome-shaped intrusive bodies with a level base and connected by a pipe-like conduit from below. It resembles the surface volcanic domes of composite volcano, only these are located at deeper depths. It can be regarded as the localized source of lava that finds its way to the surface. The Karnataka plateau is spotted with domal hills of granite rocks. Most of these, now exfoliated, are examples of laccoliths or batholiths.
- **Lopolith:** As and when the lava moves upwards, a portion of the same may tend to move in a horizontal direction wherever it finds a weak plane. It may get rested in different forms. In case it develops into a saucer shape, concave to the sky body, it is called lopolith.
- **Phacolith:** A wavy mass of intrusive rocks, at times, is found at the base of synclines or at the top of anticline in folded igneous country. Such wavy materials have a definite conduit to source beneath in the form of magma chambers (subsequently developed as batholiths). These are called the phacoliths.
- **Sills**: The near horizontal bodies of the intrusive igneous rocks are called sill or sheet, depending on the thickness of the material. The thinner ones are called sheets while the thick horizontal deposits are called sills

- **Dykes:** When the lava makes its way through cracks and the fissures develop in the land, it solidifies almost perpendicular to the ground. It gets cooled in the same position to develop a wall-like structure. Such structures are called dykes.

Most commonly found intrusive volcanic forms are in the western Maharashtra area. These are considered the feeders for the eruptions that led to the development of the Deccan traps.

4. What are non-metallic minerals? Highlight their usage and distribution in India.

Approach:

- Define non-metallic minerals.
- Elaborate distribution of these resources in India and their usage.
- Conclude accordingly.

Answer:

Non-metallic minerals are those, which do not contain any metal. These can be further categorized into **Fuel Minerals** like coal, petroleum, natural gas and **Nonfuel minerals** like mica, limestone, salt, potash, granite, sandstone, marble etc.

Usage and distribution of minerals

- **Coal:** It is one of the important minerals, which is mainly used in the generation of thermal power and smelting of iron ore.
  - **Distribution**-The most important Gondwana coal fields of India are in **Damodar Valley,** with Jharia being the largest coal field followed by Raniganj. The other river valleys associated with coal are **Godavari, Mahanadi and Sone**. **Tertiary coals** occur in Assam, Arunachal Pradesh, Meghalaya and Nagaland. Besides, **the brown coal or lignite** occur in the coastal areas of Tamil Nadu, Puducherry, Gujarat and Jammu and Kashmir.
- **Petroleum:** It is an essential source of energy for all internal combustion engines in automobiles, railways and aircraft. Its numerous by-products are processed in petrochemical industries, such as fertilizer, synthetic rubber, synthetic fiber, medicines, vaseline, lubricants, wax, soap and cosmetics.
  - **Distribution-**Crude petroleum occurs in **sedimentary rocks of the tertiary period.** In **Assam**, Digboi, Nahar Katiya and Moran are important oil producing areas. The major oilfields of **Gujarat** are Ankaleshwar, Kalol, Mehsana, Nawagam, Kosamba and Lunej. Oil and natural gas have been found in exploratory wells in **Krishna-Godavari and Kaveri basin** on the east coast.
- **Natural Gas:** It is used as fuel in the power sector to generate electricity, for heating purposes in industries, as raw material in chemical, petrochemical and fertilizer industries. It is also emerging as a preferred **transport fuel (CNG) and cooking fuel (PNG) for homes**.
  - **Distribution**: India's major gas reserves are found in the Mumbai High and allied fields along the west coast which are supplemented by finds in the Cambay basin. Along the East Coast, new reserves of natural gas have been discovered in the Krishna-Godavari basin.
- **Mica**: Due to its excellent di-electric strength, low power loss factor, insulating properties and resistance to high voltage, mica is one of the most indispensable minerals used in **electric and electronic industries**.
  - **Distribution**-Mica deposits are found on the northern edge of the **Chota Nagpur plateau. Koderma – Hazaribagh belt** of Jharkhand is the leading producer. In **Rajasthan**, the major mica producing area is around Ajmer. Nellore in Andhra Pradesh is also an important mica producer in the country.
- **Limestone:** Limestone is the basic raw material for the cement industry and essential for smelting iron ore in the blast furnace.
  - **Distribution:** Rajasthan is the leading producer of limestone, accounting for 21% of total production. Madhya Pradesh produces roughly 13% of India's limestone. Andhra Pradesh, Chhattisgarh, Tamil Nadu are other limestone producing states in India.

A clear roadmap and policy framework is needed for mining of minerals to create a balance between development and regional welfare.

5. Enumerating the suitable conditions for the formation of coral reefs, bring out the factors leading to their decline.

Approach:

- Introduce briefly by defining coral reefs.
- Enumerate the suitable conditions for the formation of coral reefs.
- Mention the factors leading to their decline.
- Conclude accordingly.

Answer:

Coral reefs are large underwater structures composed of the skeletons of colonial marine invertebrates called coral. The coral species that build reefs are known as hermatypic, or "hard," corals because they extract calcium carbonate from seawater to create a hard, durable exoskeleton that protects their soft, sac-like bodies. They are known for their colourful appearance and are called **'rainforests of the sea"** because of the rich biodiversity supported by them.

The reef building corals survive best under following conditions:

- **Water Temperature:** It must not fall below 20^0C. Because of this more than 90% of coral reefs are confined to tropical and sub-tropical regions.
    - Warm currents promote their growth but where the cold current is present and up-welling they do not flourish. This explains why coral reefs are generally absent on western coasts of continents.
- **Salinity of water:** Most reef-building corals also require very saline water ranging from 32 to 42 parts per thousand.
- **Depth of water:** It should not exceed 180 feet, because beyond this point availability of sunlight is too faint for photosynthesis. This is essential for survival of the microscopic algae/zooxanthellae on which the corals depend.
- **Water clarity:** Oceans survive best in the moving ocean water away from silty coasts or muddy mouths of streams. They are best developed on the seaward side of the reef where constantly moving waves, tides and currents maintain an abundant supply of clear oxygenated water, which also bring phytoplankton as food supply.

Key factors leading to the decline of coral reefs are:

- **Physical damage**: Coastal development, dredging, quarrying, destructive fishing practices and gear, boat anchors and groundings, recreational misuse (touching or removing corals) and coral harvesting for trade leads to destruction of coral reefs.
- **Coral bleaching:** When water is too warm, corals expel the colourful zooxanthellae living in their tissues causing the coral to turn completely white. Such corals are under stress and subject to mortality.
- **Ocean acidification:** Increased levels of atmospheric CO2 contribute to ocean acidification, which in turn threatens the survival of corals by reducing the concentration of carbonate ions that they need to construct their skeletons.
- **Eutrophication:** An increased nutrient supports larger algal growths, but decreases the oxygen level of water, and brings corals under stress. Also, higher concentration of contaminants increases susceptibility of corals to diseases.

Although reefs cover only 0.2 per cent of the ocean floor, they are home to at least a quarter of all marine species. It is estimated that hundreds of millions of people around the world depend on them for food, jobs and protection from storms and erosion. The **"Status of Coral Reefs of the World: 2020"** report documents the loss of approximately 14 per cent of the world's coral since 2009.

6. Give an account of the distribution of rare earth elements in the world. Also, highlight their economic significance.

Approach:

- Define rare earth elements in introduction.
- Explain the distribution of rare earth elements around the world.
- Briefly mention about their distribution in India.
- Explain the economic significance of rare earth elements
- Conclude appropriately.

Answer:

The rare earth elements (REE) are a set of seventeen metallic elements. These include the fifteen lanthanides on the periodic table plus scandium and yttrium. **The distribution of rare earth elements (REEs) is widespread in the earth's crust, but they are typically not found in concentrated deposits, making them difficult and expensive to extract.** The rare earths' unique properties are used in a wide variety of applications.

Distribution of Rare Earth Elements (REE) in the world:

- **China has the largest reserves (38%) of rare earth elements**, with 44 million tons in reserves and an estimated 70 per cent share of the global production. Production centres of rare earth are located in **Baotou, Inner Mangolia, Jiangxi and Sichuan provinces of China**.
- **Vietnam (19%) and Brazil (18%)** have the second and third largest reserves of rare earth metals yet their production is low. In Vietnam deposits are found in **border with China** whereas major deposits of Brazil are located in **Araxa, Serra Verde, Pitinga, etc.**
- **Russia (10%) and India (6%)** have the fourth and fifth largest reserves respectively with fifth and sixth largest production. Major production of REE in Russia comes from **Murmansk region.**
- Sixth and seventh largest reserves of REE are found in **Australia (3.5%) and USA (1.3%)** respectively. **USA is the second largest producer, whereas Australia is fourth largest producer after Myanmar. Mount Weld region in Australia and Mojave Desert in California**, USA are major producing regions of respective countries.

Distribution in India

In India, monazite is the principal source of rare earths. The total reserve of monazite in India is 12.47 million tonnes. The major deposits containing REE are found in:

- Chavara barrier beach and Eastern Extension, Kollam district, **Kerala.**
- Manavalakurichi beach sand deposit, Kanyakumari, **Tamil Nadu**.
- Bhimunipatnam beach sand deposit, **Andhra Pradesh**.
- Gopalpur beach sand deposit, **Odisha.**

Other than that, West Jaintia Hills and East Khasi Hills districts of **Meghalaya** and Barmer district of **Rajasthan** have been identified with encouraging values for REE.

Economic significance of Rare Earth Elements

- **Manufacturing permanent magnets** is the single largest and most important end use for REEs. Alloys of neodymium (Nd) and samarium (Sm) can be used to create strong magnets that withstand high temperatures, making them **ideal for modern electronics such as cell phones, televisions, computers, electric vehicles, wind turbines, jet aircraft and many other products.**
- REEs are also used widely in **high technology and "green" products**. Because of their unique physical, chemical, magnetic, luminescent properties, these elements help to make many technological advantages such as **performing at reduced energy consumption, greater efficiency, miniaturization, speed, durability and thermal stability**.
    - In recent years, their demand is particularly on rise in **energy efficient gadgets** (green technology) which are faster, lighter, smaller and more efficient.
- Cerium finds application in **polishing of glass items such as lenses, display screens of LCD panels**.

- Mixed salts of cerium group of elements are used in **medicines, non-irritating antiseptic dressings, waterproofing agents etc.**
- Scandium is used mainly in **aluminium alloys for sporting goods**.
- Erbium used as **fibre optic** has emerged as major tool for communication technology.
- Europium is being used as a way to identify legitimate bills for the Euro bill supply and to **dissuade counterfeiting**.

REE finds important application on most of the emerging technologies and hence India needs to explore and increase the production of these minerals to reduce its dependence on a handful of countries, including China.

7. What are the factors influencing the temperature of the oceans? Highlight the horizontal and vertical distribution of temperature in the oceans.

Approach:

- Briefly introduce with varied temperature in the oceans of world.
- Discuss the factors affecting temperature difference of oceans.
- Showcase the horizontal and vertical distribution of temp in the oceans.
- Conclude accordingly.

Answer:

The ocean surface water is warmest in low latitude regions, while it is much colder at poles. At equivalent latitudes, water on the eastern side of the ocean basins is colder than the water on the western side. Even though surface water can be quite warm, most of the water in the oceans is deeper, colder water, so that the average temperature of the entire ocean is about 4^0 C.

Factors affecting the temperature distribution of Oceans:

- **Latitude:** The temperature of surface water decreases from the equator towards the poles because the amount of insolation decreases poleward.
- **Unequal distribution of land and water**: The oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than the oceans in the southern hemisphere.
- **Prevailing wind**:
  - The winds blowing from the land towards the oceans drive warm surface water away from the coast resulting in the upwelling of cold water from below.
  - Contrary to this, the onshore winds pile up warm water near the coast and this raises the temperature.
- **Ocean currents**: Warm Ocean currents (such as Gulf stream) raise the temperature of the surface water in affected areas while the cold currents (such as Labrador current) decrease it.
- **Other Factors:** location and shape of area, presence of ridges or local weather conditions such as storms, cyclones, hurricanes, fog, cloudiness, etc. also affect the distribution of temperature of the oceans

The distribution of ocean temperature is not uniform. It varies from latitude to latitude and from surface to bottom.

Horizontal Distribution of Temperature (surface water):

- The average temperature of surface water of the oceans is about 27°C and it **gradually decreases from the equator towards the poles.**
  - The rate of decrease of temperature with increasing latitude is generally 0.5°C per latitude.
  - The **highest temperature is not recorded at the equator** but slightly towards north of it, because of lesser cloudiness in subtropical areas than equator.
- The **oceans in the northern hemisphere record relatively higher temperature (around 19° C) than in the southern** hemisphere (**16° C)**. This variation is due to unequal distribution of land and water.

Vertical Distribution of Temperature (from surface water to bottom):

In Polar Regions only one layer of cold water is identified. It extends from the surface to the bottom. The temperature-depth profile for ocean water in other regions can be understood with **the 3-layer approach.**

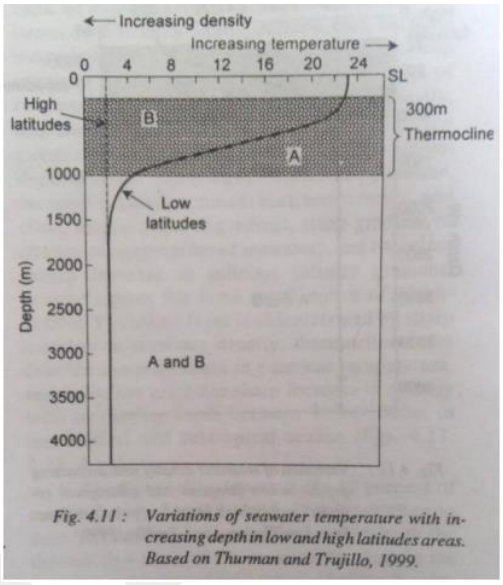


Fig. 4.11 : Variations of seawater temperature with increasing depth in low and high latitudes areas. Based on Thurman and Trujillo, 1999.

- **1st Layer**: It represents the top layer of warm water mass with a thickness of approx. 500m and average temperature ranging between 20°C to 25°C. This layer is present within the tropics throughout the year but it develops in middle latitudes only during summer season.
- **2nd Layer**: The upper and lower ocean water masses are separated by a transitional zone called thermocline extending between 300 m to 1000 m depth. It is characterized by rapid fall in temperature with increasing depth.
- **3rd Layer**: The lower layer extends beyond 1000 m depth up to the ocean bottoms. This layer is very cold and represents denser ocean water mass.

The deeper ocean contains about 90% of all ocean water. They do not mingle much with the surface layers. However, they do mix gradually over hundreds of years through the movements of a global ocean current (a pattern called **thermohaline circulation**).

8. What is temperature inversion? Mentioning its various types, discuss its implications.

Approach:

- Define temperature inversion.
- Mention the different types of temperature inversion.
- Discuss its implications on the earth.

Answer:

Temperature inversion is a reversal of the normal behaviour of temperature in the troposphere, in which a layer of cool air at the surface is overlain by a layer of warmer air. Under normal conditions, temperature usually decreases with height, but in case of temperature inversion, the situation gets reversed and temperature starts increasing with height rather than decreasing.

The ideal conditions for temperature inversion are long nights with clear skies along with calm and stable air, so that there is no vertical mixing at lower levels. Temperature inversion occurs in several conditions ranging from ground surface to great heights.

Thus, there are several kinds of temperature inversions, such as:

- **Frontal or cyclonic inversion**: When the warm and cold fronts meet, the warm front rises up and being heavier, the cold front sinks down. It results in the formation of frontal inversion. This kind of inversion has a considerable slope, whereas other inversions are nearly horizontal.
- **Valley inversion**: Sometimes in high mountains or deep valleys, the temperature of the lower layers of air increases instead of decreasing with elevation along a sloping surface.
  Here, the surface radiates heat back to space rapidly and cools down at a faster rate than the upper layers. As a result, the lower cold layers get condensed and become heavy.
  The sloping surface underneath makes them move towards the bottom where the cold layer settles down as a zone of low temperature while the upper layers are relatively warmer.
- **Surface inversion:** A ground inversion develops when air is cooled by contact with a colder surface until it becomes cooler than the overlying atmosphere. This occurs most often on clear nights, when the ground cools off rapidly by radiation. If the temperature of surface air drops below its dew point, fog may result. It is very common in the higher latitudes and in lower and middle latitudes, it occurs during cold nights and gets destroyed during day time.

- **Subsidence inversion**: A subsidence inversion develops when a widespread layer of air descends. The layer is compressed and heated by the resulting increase in atmospheric pressure, and as a result, the lapse rate of temperature is reduced. If the air mass sinks low enough, the air at higher altitudes becomes warmer than at lower altitudes, producing a temperature inversion.

Implications of temperature inversion on the earth:

- Inversions play an important role in **determining cloud forms, precipitation, and visibility**.
- **Intense thunderstorms and tornadoes** are also associated with inversion of temperature because of the intense energy that is released after an inversion blocks an area's normal convention patterns.
- Due to inversion of temperature, **air pollutants** such as dust particles and smoke **do not disperse** on the surface.
- **Visibility may be greatly reduced** below the inversion due to the accumulation of dust and smoke particles. Because air near the base of an inversion tends to be cool, fog is frequently present there.
- Temperature inversion also leads to **atmospheric stability** that stops the downward and upward movement of air.
- Due to temperature inversion, temperature of the air at the valley bottom reaches below the freezing point, whereas the air at higher altitude remains comparatively warm. As a result, the **trees along the lower slopes are bitten by frost**, whereas **those at higher levels are free from it**.

9. Highlighting the conditions necessary for precipitation to occur, mention its different forms and types.

Approach:

- Introduce by briefly explaining the meaning of precipitation.
- Mention the conditions required for precipitation to occur.
- Explain in brief the forms and types of precipitation.

Answer:

Precipitation is any product of the condensation of atmospheric water vapour that falls under gravitational pull from clouds. The conditions that are necessary to the formation of precipitation include:

- There should be **sufficient amount of evaporation** from the water bodies so that air mass must be **saturated** with water vapour.
- There must be **sufficient nuclei** present to aid condensation.
- **Weather conditions must be good for condensation** of water vapour to take place.
- The products of condensation **must reach the earth** in any form of precipitation.

Precipitation can take many forms, which are a result of different conditions, which are as follows:

- **Rain:** It occurs as liquid droplets fall to the surface. The droplets grow and reach a size that is too heavy to keep up via drag.
- **Snow:** It occurs as small frozen flakes fall to the surface. The cloud and atmosphere must be below freezing for the snowflake to form and reach the surface.
- **Sleet:** It occurs as small ice pellets. Snowflakes reach a part of the atmosphere that is above freezing and melt but refreeze as they encounter another section of the atmosphere that is below freezing. These newly frozen pellets fall to the surface, oftentimes along with snow or freezing rain.
- **Freezing rain:** It occurs as liquid droplets that were melted by a section of the atmosphere that is above freezing but the section of atmosphere below freezing below is too thin to refreeze the rain droplets. They fall as liquid and freeze as they come in contact with the below-freezing surface.
- **Hail:** It is formed as the ice in the tops of thunderstorms becomes too heavy for the updraft to support. The hail then falls in hailstones. Hail generally occurs in warmer times of the year.

- **Drizzle:** It is a form of rainfall with droplets smaller than 0.5 mm and is generally associated with cooler times of the year, such as late fall and early spring in moderate climates.
- **Sun Shower:** It is a precipitation event that is registered when rain falls while the sun shines. It gives rise to raindrops into an area without clouds. It is often accompanied by a rainbow.
- **Snow Grains:** They are very small white and opaque grains of ice and are fairly flat having a diameter generally less than 1mm.
- **Diamond Dust:** It is extremely small ice crystals usually formed at low levels and at temperatures below -30 °C. It shows the sparkling effect due to reflection of light on the ice crystals in the air.

The different types of precipitation include:

- **Cyclonic Precipitation**: The cyclonic precipitation is caused due to the movement of moist air mass to this region by the difference in pressure. It is of two types: frontal (caused due to the expansion of air near the frontal surface) and non-frontal precipitation (cold moist air mass boundary that moves and results in precipitation).
- **Convective Precipitation:** The air above the land area gets heated up due to some cause. Most of this warmer air rises up, cools, and precipitates. Convective precipitation is showery by nature. This type of precipitation occurs in varying intensities.
- **Orographic Precipitation:** When the moving air masses strike the barriers such as mountains, they rise up causing condensation and precipitation. The precipitation that occurs is greater on the windward side.

10. Give a brief note on the propagation of earthquake waves. How do they help in the study of the earth's interior?

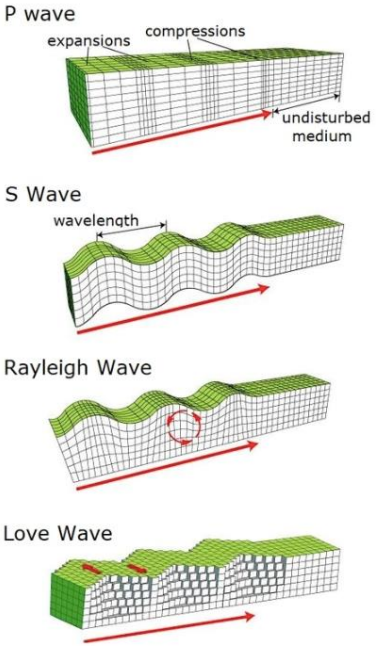
Approach:

- Introduce by explaining the meaning of earthquake waves.
- Briefly explain the process of propagation of earthquake waves.
- Explain their significance in acquiring information about the interiors of the earth.

Answer:

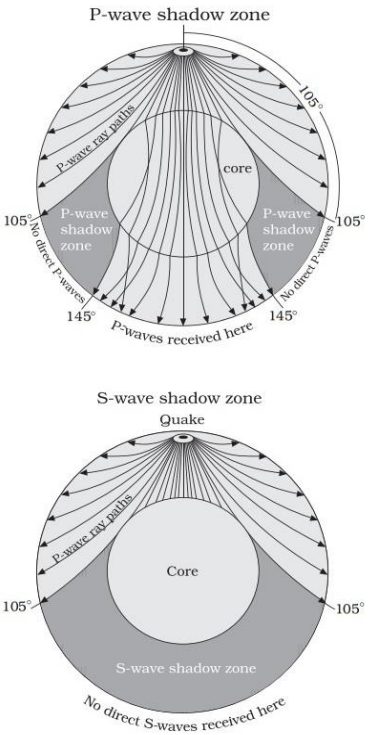
A seismic wave is a mechanical disturbance or energy packet that can propagate from point to point in the Earth. The earthquake waves are basically of two types: body waves and surface waves.

These earthquake waves propagate differently as follows:



- **Body waves:** They are generated due to the release of energy at the focus and move in all directions travelling through the body of the earth. They are of different types:
  - **P waves** which exert pressure on the material in the direction of the propagation. They create density differences in the material.
  - Another type of earth quake wave is **S wave** whose direction of vibration of S wave is perpendicular to the wave direction in the vertical plane. They create troughs and crests in the material through which they pass.
- **Surface waves:** The body waves interact with the surface rocks and generate new set of waves called surface waves. These waves move along the surface. The velocity of waves changes as they travel through materials with different densities. The denser the material, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities. They can be:
  - **Love waves,** which have the same motion as S-waves but without the vertical displacement. They move the ground from side to side in a horizontal plane but at right angles to the direction of propagation.
  - Rayleigh waves, also known as ground roll, spread through the ground as ripples, similar to rolling waves on the ocean.

The propagation velocity of a seismic wave depends on density and elasticity of the medium as well as the type of wave. The recorded data or seismograms can be used to study the earth's interior and build models of the Earth's interior structure.



- P and S waves travel very differently through the Earth. The velocity tends to increase with depth through Earth's crust and mantle, but drops sharply going from the mantle to Earth's outer core.
- Initially P and S waves travel in all directions from the epicentre of an earthquake outwards. They are refracted as they travel from the epicentre and follow arcs. However, S waves cannot travel through the liquid outer core of the Earth.
- The P-waves were recorded at most seismographs because they have the ability to pass through both solid and liquid layers, but refraction caused them to 'bend' away from areas between 100 and 150 degrees away from the epicentre.
- These **seismic shadow zones** were caused by the inability of S-waves to pass through liquids which proved that the interior of the Earth must contain a layer of liquid material. Further, by finding the angles at which the P and S waves both disappear, the radius of the liquid core of the earth could be calculated.

11. What are footloose industries? Discuss the factors responsible for the location of these industries.

Approach:

- Explain what you understand by footloose industries in the introduction.
- Discuss the factors responsible for the location of these industries.
- Give a brief conclusion.

Answer:

Footloose industries are those industries, which are **not tied to a particular location** and can be set up anywhere. Examples include information technology, software development, and consulting services. **They have the following features:**

- They are not dependent on any specific raw material, weight losing or otherwise.
- They are largely dependent on component parts which can be obtained anywhere.
- They produce in small quantities and also employ a small labour force.
- These are generally not polluting industries and have a negligible carbon footprint.

Factors responsible for the location of the footloose industries are:

- **Access to skilled labor**: Footloose industries require a highly skilled workforce, so they tend to locate in areas with a large pool of educated workers. For instance, the IT industry in India is concentrated in Bangalore, Hyderabad, etc.
- **Communication infrastructure:** Availability of infrastructure such as communication systems, power, water, and technology are important factors in attracting footloose industries.
- **Cost of living and doing business:** Footloose industries prefer to locate in areas with lower cost of living and lower business costs, as it enables them to keep their operating costs low.
- **Quality of life**: A good quality of life, including a good environment and access to amenities, can attract highly skilled workers to a location.
- **Government incentives**: Government incentives such as tax breaks, grants, and subsidies can also be a factor in the location of footloose industries.
- **Transportation infrastructure:** Accessibility by transportation network enables the workers to commute hassle free. Good transportation links are thus essential for footloose industries, as they need to connect with clients and suppliers globally.

- **Market demand:** Footloose industries also consider market demand when choosing their locations. For example, technology companies tend to locate in regions with high concentrations of tech-savvy consumers.
- **Capital availability and ancillary services:** Generally, these industries tend to develop where financial services are easily accessible, as they need capital to start a business and procure basic inputs.

Other **minor factors** are desirable climate to improve employee morale and productivity as well as political stability to ensure a secure investment. Footloose industries can provide employment in areas that lack locational advantages such as port facilities, access to weight losing raw materials such as coal, iron ore, limestone, etc. Thus, impetus should be given for the development of footloose industries in such areas to increase employment opportunities.

12. What is weathering? Discuss the different types of weathering processes.

Approach:

- Define weathering and state its relevance.
- Explain the various types of weathering processes.
- Conclude accordingly.

Answer:

Weathering is defined as **mechanical disintegration and chemical decomposition of rocks** through the actions of various elements of weather and climate.

It is responsible for breaking down the rocks into smaller fragments and preparing the way for formation of not only regolith and soils, but also erosion and mass movements, which ultimately results in the creation of various landforms.

Weathering leads to enrichment and concentrations of certain valuable ores such as iron, manganese, aluminium, copper, etc.

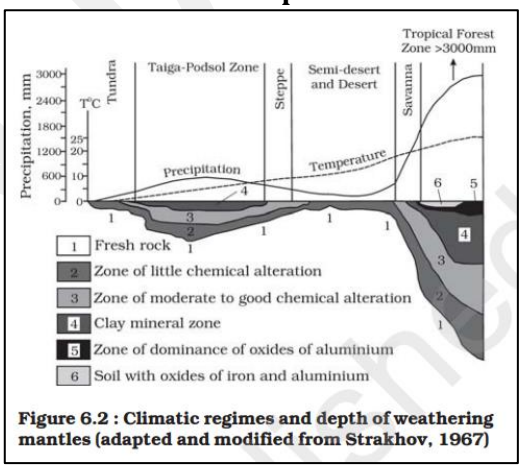


Figure 6.2 : Climatic regimes and depth of weathering mantles (adapted and modified from Strakhov, 1967)

Following are the three major types of weathering processes:

- **Chemical weathering processes:**
  - **Solution:** Rock forming minerals like nitrates, sulphates, potassium etc. are readily soluble in water. They leach out without leaving any residue in rainy climates and accumulate in dry regions. Decaying organic matters creates carbonic acid, which helps in dissolving rocks such as limestone.
  - **Carbonation:** Carbon dioxide from the atmosphere and soil air is also absorbed by water to form carbonic acid. The acid dissolves rocks containing calcium carbonates and magnesium carbonates, resulting in cave formation.
  - **Hydration:** Minerals take up water and expand; this expansion causes an increase in the volume of the material itself or rock. Continued repetition of this process causes fatigue in the rocks and leads to their disintegration or rock-fracturing.
  - **Oxidation and reduction**: Rocks containing iron, manganese and sulphur get oxidised when there is ready access to the atmosphere and oxygenated waters. When oxidised minerals are placed in an environment where oxygen is absent, reduction takes place. Such conditions exist usually below the water table, in areas of stagnant water and waterlogged ground.
- **Physical weathering processes:**
  - **Unloading and expansion:** Removal of overlying rock load because of continued erosion causes vertical pressure release with the result that the upper layers of the rock expand producing disintegration of rock masses, thereby exfoliation domes are formed.

- **Temperature changes and expansion**: Minerals expand with the rise in temperature and contract when it falls. In dry climates and high elevations where diurnal temperature changes are drastic, they make the rock weak due to continued fatigue. Tors are formed due to such exfoliation.
- **Freezing, thawing and frost wedging:** Frost weathering occurs due to growth of ice within pores and cracks of rocks during repeated cycles of freezing and melting. This process is most effective at high elevations in mid-latitudes where freezing and melting is often repeated.
- **Salt weathering:** Rocks containing salts like calcium, sodium, magnesium, potassium and barium have a tendency to expand due to thermal action (above 30 degrees Celsius), hydration and crystallisation. It leads to granular disintegration and development of polygonal cracks over the heaved surface.

- **Biological weathering:**
  - **Burrowing and wedging:** Burrowing and wedging by organisms like earthworms, termites, rodents etc., help in exposing the new surfaces to chemical attack and assists in the penetration of moisture and air.
  - **Human action:** Human beings by disturbing vegetation, ploughing and cultivating soils, also help in mixing and creating new contacts between air, water and minerals in the earth materials.
  - **Decaying plant and animal matter:** They help in the production of humic, carbonic and other acids, which enhances decay and solubility of some elements.
  - **Plant roots:** These exert a tremendous pressure on the earth materials by mechanically breaking them apart.

Weathering processes rarely ever operate completely by themselves, but quite often a dominance of one process can be seen.

13. Explaining the meaning of land subsidence, discuss the factors that may have led to the subsidence observed at Joshimath in Uttarakhand.

Approach:

- Explain the meaning of land subsidence.
- Give an overview of the subsidence observed at Joshimath and discuss the different factors that may have led to land subsidence in the region.
- Conclude appropriately.

Answer:

Land subsidence is defined as a gradual settling or sudden sinking of the earth's surface due to removal or displacement of sub-surface earth materials. It is a geological process that can be caused by natural events such as earthquakes, soil compaction, erosion, sinkhole formation, and adding water to fine soils deposited by wind. It is also caused by anthropological activities such as removal of groundwater, oil, or natural resources, along with mining activities.

Recently, Joshimath in Uttarakhand has been declared a **landslide-subsidence zone** as large cracks started to appear in buildings and roads. Further, scientists from the Indian Institute of Remote Sensing observed that Joshimath and the surrounding areas have been sinking at a rate of 6.5 cm (2.5 inches) per year based on satellite data from July 2020 to March 2022.

The land subsidence in Joshimath is believed to be a result of a combination of both natural and man-made reasons. **They are:**

- **Built on an ancient landslide material:** Experts have pointed out that Joshimath city has been built on an ancient landslide material, meaning it rests on a deposit of sand and stone, and not rock, which does not have high load-bearing capacity. This makes the area extremely vulnerable to the ever-burgeoning infrastructure and population.
- **Geographic fault**: Another possible factor for land subsidence argued by experts is the **re-activation of a geographic fault.** It is a fracture or zone of fractures between two blocks of rocks where the Indian Plate has pushed under the Eurasian Plate along the Himalayas.

- **Prone to extreme weather events**: Climatologically, the town lies in a region that receives very high rainfall frequently, which leads to heightened erosion as witnessed during the floods of 2013 and 2021.
- **Lack of proper drainage system**: Unplanned and unauthorised construction has blocked the natural flow of the water, which leads to frequent landslides and may also have contributed to land subsidence.
- **Hydel power activities:** The tunnelling work being carried out for development of hydel power like **Tapovan Vishnugad Hydro Power Project** may have hit and drained an aquifer. This would have caused the land to subside.
- **Administrative apathy:** The issue of land subsidence and its resultant effects have been visible since long and the **M.C. Mishra Committee** had warned against unscientific and heavy construction. However, due to inaction, unabated construction was witnessed in the area.

The events of Joshimath in Uttarakhand have posed social, environmental, technical, and economic challenges before the national and state governments. They raise the critical question of balance between economic development and environmental protection.

Apart from the immediate relief and rehabilitation for the affected people, a long-term view of different development projects such as the Char Dham Highway and Hydel projects in Uttarakhand and other hilly states needs to be taken based on the sustainable development of the Himalayas.

14. Provide an account of the various challenges that India faces in realising the potential of solar energy.

Approach:

- Mention India's goal for renewable energy by 2030 and the role of solar energy in this context.
- Discuss the challenges encountered in realising the potential of solar energy.
- Suggest a way forward to address these issues.

Answer:

India is in the midst of an unprecedented renewable energy expansion and has set itself a target to achieve 500 GW of renewable energy by 2030. While India has an installed capacity 62 GW of solar in 2022, it plans to expand it to 300 GW by 2030 requiring addition of 30 GW capacity each year.

Over half of India's terrain is sunny and semi-arid, receiving 1,000 mm of rainfall or less every year making it too dry to support continuous canopy. This gives India an immense potential to generate solar power.

However, there are multiple challenges that prohibit India from utilising its potential, such as:

- **High import dependency:** In aspects of solar energy production, 80 per cent of India's solar photovoltaic module market is being controlled by imports from Chinese suppliers. This is despite initiatives like the Production Linked Incentives (PLIs) and imposition of Basic Customs Duty (BCD) to support local manufacturing of the same.
- **Financing of solar energy:** Different subsidies and tax cuts that have supported solar energy production are going to get difficult to maintain as the finances of the state governments and discoms are stressed. Further, it would take a long time to bring complete parity with the conventional sources such as thermal power.
- **High T&D (Transmission and Distribution):** The cost of T&D losses is approximately 40%, making generation through solar energy sources highly unfeasible.
- **No solar waste management policy:** Despite ambitious solar installation targets, India does not have a policy for managing its solar waste.
- **Issues with rooftop solar plants:** Challenges in implementation of the rooftop solar plants and their integration with the national grid in a cost-effective manner including net-metering are hampering the success of this initiative.
- **Land acquisition with clear titling:** Solar plants require large open spaces which have been difficult to acquire. Further, even planned projects are getting delayed and cost overruns are observed.

Despite the above-mentioned challenges, renewable energy and solar in particular is critical for India to progress towards its net-zero goal. By mobilising finances and technology, focusing on enhanced cooperation under the International Solar Alliance, removing bottlenecks in policy implementation and adopting the ecosystem approach, India can take firm step towards increasing solar energy production and realising its aim of green growth.

15. Explain the phenomenon of heat budget of the earth. Also, enumerate the factors controlling the distribution of temperature on the earth's surface.

Approach:

- Start by defining the Heat Budget of the Earth.
- Using diagram, explain how Heat Budget of Earth works.
- Elaborate on the various factors controlling the temperature distribution on the earth's surface.
- Conclude appropriately.

Answer:

The **earth as a whole does not accumulate or loose heat.** Earth maintains its temperature and 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. **The mechanism by which this is maintained is termed as Heat Budget of the Earth.**

Mechanism in Heat Budget:

- **Short Wave Solar Radiation**: Assuming 100 units arrive from the Sun, 35 are reflected back in the form of Albedo and remaining 65 units are absorbed (14 units within the atmosphere and 51 units by the earth's surface).
- **Long Wave Earth Radiation**: The earth radiates back 51 units in the form of terrestrial radiation. Of these, 17 units are radiated to space directly and the remaining 34 units are absorbed by the atmosphere. The 48 units absorbed by the atmosphere (14 units from insolation + 34 units from terrestrial radiation) are also radiated back into space.

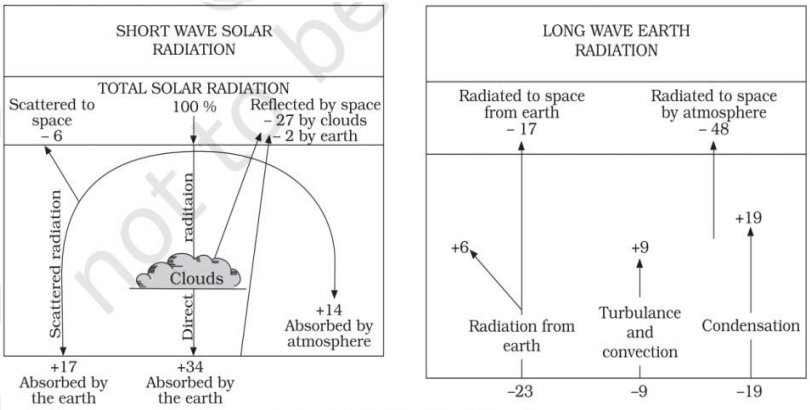


Figure 9.2 : Heat budget of the earth

- Thus, the total radiation returning from the earth and the atmosphere respectively is 17+48=65 units which balance the total of 65 units received from the sun.

Factors controlling temperature distribution on the Earth's surface:

- **Latitude**: The latitudes closer to the equator are hotter than compared to the polar ones. This is because the sun rays become more and more inclined towards poles vis-à-vis equator and hence the amount of insolation minimizes poleward.
- **Altitude**: As the Earth is heated from below in the form of terrestrial radiation, the places near the sea-level record higher temperature than the places situated at higher elevations.

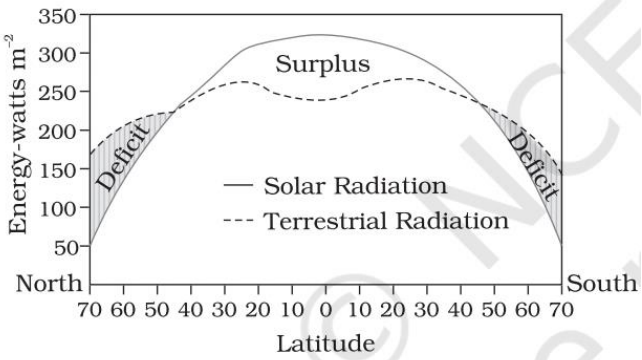


Figure 9.3 : Latitudinal variation in net radiation balance

- **Continentality:** Compared to land, the sea gets heated slowly and loses heat slowly. Therefore, the variation in temperature over the sea is less compared to land.
- **Air-mass and Ocean currents**: The places, which come under the influence of warm air masses or warm ocean currents experience higher temperature and the places that come under the influence of cold air-masses or cold ocean currents experience low temperature.
- **Other factors**: There are other factors like winds, nature of the soil, slope and aspect of the surface, etc. that are responsible for controlling temperature distribution. For instance, dark-coloured soil absorbs more insolation compared to the light-coloured soil.

The understanding of the heat budget helps us **reflect upon dynamic nature of the Earth's functioning.** However, the recent events like global warming and greenhouse effect have the potential to distort this delicate balance and adequate care must be taken towards restoring it.

16. What are glacial lakes? Discuss the various factors behind glacial lake outburst floods.

Approach:

- In the introduction, explain glacial lakes.
- Discuss the various factors behind glacial lake outburst floods.
- Conclude by stating their impact and an appropriate way forward.

Answer:

Glacial lakes are bodies of water that originates from glaciers. It typically forms at the foot of a glacier, but may form on, in, or under it. They are common around the borders of glaciers and ice sheets and are generally divided into two main groups: **ice contact lakes and distal lakes**. Ice contact lakes are characterized by the presence of glacier ice terminating in lake water and distal lakes are somewhat distant from but still influenced by the presence of glaciers and/or ice sheets.

Often glacial lakes cause **glacial lake outburst floods (GLOFs).** GLOF refers to the flooding that occurs when the water dammed by a glacier or a moraine is released suddenly. GLOFs have three main features i.e. they involve sudden release of water, they tend to be rapid events and they result in large downstream river discharges. In 2021, Chamoli district in Uttarakhand witnessed flash floods, which are suspected to have been caused by GLOFs. The Kedarnath tragedy in 2013, which left about 5000 dead was also related to a glacial lake breach.

Factors behind glacial lake outburst floods:

- **Heavy rainfall:** Very heavy rainfall on the upstream of glacier leads to piling up of water in glacial lakes, which may trigger breach of the lake boundary which is formed by moraines. Cloud burst, a common phenomenon in hills, is also one factor that can trigger GLOFs.
- **Snowmelt:** Due to global warming, glaciers are melting rapidly thus creating more glacial lakes and releasing more water into these lakes. The increased water level is one of the reasons for GLOFs.
- **Rapid slope movement into the lake:** Mass movements into the lake (i.e., rockfalls, landslide, avalanches, etc.) may create extra pressure to breach the sides of the lake.
- **Earthquakes:** They may triggers slope movements which may lead to breach of lakes and consequently GLOFs.
- **Blocking of subsurface outflow:** Due to natural as well as anthropogenic factors, blockage of sub-surface outflow may lead to compiling of water in glacial lakes which on reaching levels of threshold may trigger GLOFs.
- **Anthropogenic activities:** Activities such as dam construction and other infrastructure construction often lead to destabilization of slopes, which can also trigger breaching of lakes.

When a glacial lake bursts, its water flows into downstream areas at extreme speed. This causes massive damage to the infrastructure. The Himalayas are witnessing an increasing threat of glacial lake outburst flooding and massive destruction to the infrastructure, which can claim thousands of lives.

In the wake of recent increased disasters like that of Chamoli, the **NDMA has released guidelines** on how to deal with disasters caused by them. Apart from that, anthropogenic footprints in such hazard prone areas need to be regulated, as there is increased threat of GLOFs.

17. Enlisting the key factors responsible for rubber production in India, give an overview of the rubber industry in the country.

Approach:

- Introduce by giving a brief account of rubber crop.
- Elaborate on the key factors for rubber production in India.
- Give an overview of the rubber industry in India.
- Conclude appropriately.

Answer:

Natural rubber is a **commercial plantation crop** from the tree species Hevea brasiliens and is grown in tropical humid climatic conditions. Rubber is largely perceived as a strategic industrial raw material and has been accorded a special status globally for defence, national security and industrial development.

Factors responsible for rubber production in India include:

- **Climate and geography**: Rubber requires a **moist and humid climate with rainfall of more than 200 cm and temperature above 25°C.**
  - India has a **tropical climate** that is **ideal** for growing rubber trees.
  - Some Indian regions have **abundant rainfall and high humidity**, which support the growth of rubber trees.
- **Socio-economic factors**: Rubber is largely grown by smallholders and 91% of rubber planted area and 92% of production is in the smallholding sector (below 10 ha).
  - There are **around 1.3 million rubber growers and 0.6 million workers** in the rubber plantation sector in India.
  - Most of the growers in the non-traditional rubber growing regions **are from tribal and other resource poor communities.**
- **Soil fertility:** Rubber is grown in **literate or loamy soil, mostly in slope and undulated land or slightly high elaborated flat land** where there is no possibility of water stagnation, and having well drainage facilities.
- **Availability of skilled labour:** India has a large pool of skilled and unskilled labour that is involved in the production and processing of rubber.
- **Government support:** The Indian government provides various incentives and subsidies to the rubber industry to promote its growth and development.
  - **The Rubber Act, 1947,** provides for the development of the rubber industry under the control of the Union.
  - **The Rubber Board,** headquartered at Kottayam, Kerala, under the administration of the Ministry of Commerce and Industry has been effectively supporting the rubber industry.

Rubber industry in India:

- It is mainly grown **in Kerala, Tamil Nadu, Karnataka, Andaman and Nicobar Islands and Garo hills of Meghalaya**.
  - Kerala and Tamil Nadu account for about 81% of the total production.
- **As per the National Rubber Policy 2019:**
  - India is amongst the major producers of natural rubber globally.
  - India is currently the 6th largest producer of natural rubber in the world with one of the highest productivities (694,000 tonnes in 2017-18).
  - The **production capacity** in India is **around 900,000 tonnes**, of which around 75% is tapped.
  - India is the **2nd largest consumer** of natural rubber globally.

In the recent years, natural rubber production in India has been witnessing a sharp decline. In order to boost the rubber industry in India, challenges like lower productivity per hectare, constant fall in prices of natural rubber, rising labour cost, conflict of interest between the rubber growers and tyre companies, high input costs, etc. need to be overcome.

18. What are air masses? Highlighting their different types, discuss their significance.

Approach:

- Explain what you understand by air masses in the introduction.
- Highlight the different types of air masses.
- Discuss the significance of air masses.
- Conclude accordingly.

Answer:

An air mass is a large volume of air in the atmosphere that is mostly uniform in temperature and moisture. Air masses can extend thousands of kilometers in any direction, and can reach from ground level to the stratosphere—16 kilometers (10 miles) into the atmosphere. They are identified based on their temperature and humidity characteristics as well as their geographical region of origin.

The common types of air masses are:

- **Maritime Tropical (mT):** These air masses are warm and humid, and they originate from the oceans in the tropics.
- **Maritime Polar (mP):** These air masses are cold and humid and originate from the oceans in the polar latitudes.
- **Continental Polar (cP):** They are cold, dry air masses originating from land regions in the polar latitudes.
- **Continental Tropical (cT)**: These air masses are hot and dry originating from land in the tropics.
- **Continental Arctic (cA):** They are cold, dry air masses originating from the North Pole.
- **Continental Antarctic (cAA):** These air masses are extremely cold and dry originating from land at the South Pole.

Significance of air masses:

- **Formation of fronts**: When air masses move, they may collide with other air masses and when a collision occurs, the two air masses develop a boundary called a **front**.
- **Temperature:** When winds move the air masses, they carry their weather conditions (heat or cold, dry or moist) from the source region to a new region thus affecting the temperature in a region. For instance, maritime polar air mass affects the temperature in the coastal areas of the sub-tropical and Arctic regions.
- **Air mass modification**: Air masses have characteristic weather in their source regions. But, as air masses leave their source regions, they are modified according to the surface over which they travel, and the air-mass weather changes. For example, a continental polar air mass moving over the Gulf of Mexico takes on the characteristics of a maritime tropical air mass.
- **Precipitation**: If the surface over which an air mass is located is warmer than the air mass, the lower layers will be heated. If sufficient moisture is present, cumulus clouds and possible showers may be formed. The increased mixing generally results in good visibility.
- **Drought**: They are the result of hot, dry air mass which can destroy natural vegetation and trees. Regions with this type of air mass have the increased risk of devastating wildfires.
- **Variations in air-mass weather**: In frontal zones, where differing air masses meet, considerable weather is concentrated. Cloudiness, precipitation, and strong and shifting winds are characteristic of frontal passages, but occasionally, frontal passages are dry and adversely affect fire behaviour.

Thus, air masses have a considerable influence on the climatic conditions of the region over which they lodge and carry with them distinctive climatic features of their source region.

19. Explain the factors responsible for the formation of tsunamis. What measures has India taken to mitigate their effects?

Approach:

- Introduce with the definition of a tsunami.
- Discuss the factors responsible for the formation of tsunamis.

- Mention the measures taken by India to mitigate the effects of tsunamis.
- Conclude accordingly.

Answer:

A tsunami is a series of enormous waves created by an underwater disturbance usually associated with earthquakes occurring below or near the ocean.

The following are the factors responsible for the formation of tsunamis:

- **Earthquakes**: They can be generated by movements along fault zones associated with plate boundaries. All earthquakes do not cause tsunamis. There are four conditions in this context which have a high probability of causing a tsunami:
  - The earthquake must occur beneath the ocean or cause the material to slide into the ocean.
  - The earthquake must be strong, at least **magnitude of 6.5** on the Richter scale.
  - The earthquake must rupture the Earth's surface and it must **occur at shallow depth – less than 70 km** below the surface of the Earth.
  - The earthquake must cause vertical movement of the seafloor (up to several meters).
- **Landslides**: A landslide that occurs along the coast can force large amounts of water into the sea, thereby disturbing the water and generating a tsunami. Underwater landslides can also result in tsunamis when the material loosened by the landslide moves violently, pushing the water in front of it.
- **Volcanic eruptions**: Although relatively infrequent, violent volcanic eruptions also represent impulsive disturbances, which can displace a great volume of water and generate extremely destructive tsunami waves in the immediate source area.
- **Extra-terrestrial collision**: Tsunamis caused by extra-terrestrial collision (i.e., asteroids, meteors) are extremely rare occurrences. Although no meteor/asteroid induced tsunami has been recorded in recent history, scientists realize that if these celestial bodies strike the ocean, a large volume of water would undoubtedly be displaced to cause a tsunami.

Measures taken to mitigate the effects of tsunamis in India include:

- **Institutional measures**: The government of India has put in place an **Early Warning System** for mitigation of such oceanogenic disasters under the control of the **Indian National Centre for Ocean Information Services (INCOIS),** Hyderabad.
  - A **state-of-the-art infrastructure** enables reception of real-time data from sensors, analysis of data, generation and dissemination of tsunami advisories following a standard operating procedure.
  - **Seismic and sea-level data** are continuously monitored using a custom-built software application that generates alarms/alerts in the warning centre whenever a pre-set threshold is crossed.
  - **Tsunami warnings/watches** are then generated based on pre-set decision support rules and disseminated to the concerned authorities for action, as per the pre-decided standard operating procedure.
- **Administrative measures:** The **National Disaster Management Authority** has formulated the **Tsunami Risk Management Guidelines** to outline inter-agency roles and responsibilities, tsunami risk preparedness, mitigation, and response. The Guidelines recommend practical and effective ways for awareness generation, capacity building, education, training, and research and development for better tsunami risk management.
  - A strong mechanism has been recommended for effective emergency response by involving local police networks, civil defence volunteers wherever available, home guards, State Disaster Response Forces and National Disaster Response Force. Further, the Guidelines explore the provisions of the **Disaster Management Act, 2005** to mainstream the concern of tsunami risk management in the disaster management plans of various levels.

Apart from these, measures like **bio-fencing, repair of existing coastal protection infrastructure, construction of New Sea Walls, more focus on awareness generation**, etc. should be adopted.

20. What are western disturbances? How do they influence the weather in India?

Approach:

- Briefly give an introduction about western disturbances.
- Discuss how western disturbances influence the weather in India.
- Conclude accordingly.

Answer:

A western disturbance **is an extra-tropical storm originating in the Mediterranean region** that brings sudden winter rain to the north-western parts of the Indian subcontinent.

Phenomenon of western disturbance:

- **The disturbance** i.e., area of disturbed or reduced air pressure, travels from the western to eastern direction.
- Western disturbances are **driven by the Westerlies,** which are prevailing winds from the west towards the east in the middle latitudes between 30- and 60-degrees.
- **Low pressure usually forms over the Mediterranean Sea** and moves across Iran, Iraq, Afghanistan, and Pakistan. Thereafter, it takes fresh moisture feed from the Arabian Sea and causes precipitation over the Western Himalayan Region.
- Thereafter, while moving eastward, **it causes some precipitation over Nepal, Bhutan and Arunachal Pradesh**.
- In **the absence of fresh moisture feed from Arabian Sea**, it only causes light precipitation over higher reaches of the Western Himalayan Region.

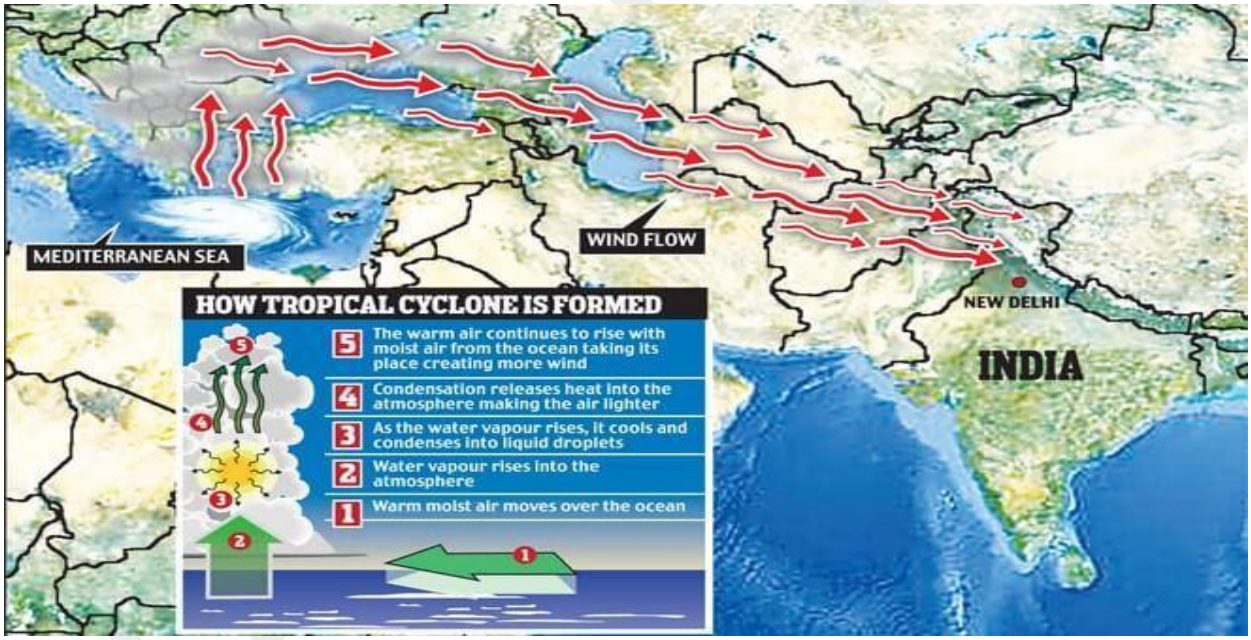


Figure: **Phenomenon of Western Disturbance**.

India is a rain dependent country, and while the South-West Monsoon covers much of the country, it misses regions of the North-West. During the winter months of November to March, these areas rely on snow and rain from the western disturbances.

Impact of western disturbances on the Indian weather:

- **Precipitation in northern India:** Western disturbances embedded in the Sub-tropical Westerly Jet produce extreme precipitation over northern India and are further enhanced over the Himalayas due to orographic land-atmosphere interactions.
  - As per the IMD, the western disturbances are estimated to account for around 5 to 10 percent of India's total yearly rainfall.
- **Role in snowfall**: During December, January, and February, western disturbance snowfall is the dominant precipitation input to establish and sustain regional snowpack, thereby replenishing regional water resources.

- **Role in the onset of monsoon during summer in India**: Winter-time precipitation provides critical mass input to existing glaciers and modulates the albedo characteristics of the Himalayas and Tibetan Plateau, thereby affecting large-scale circulation and the onset of the succeeding Indian summer monsoon.
- **Regional extent of impact**: Weather conditions are affected by western disturbances during the winter season up to Patna (Bihar), and there is occasional rainfall, which is favourable to the standing rabi crops (wheat, barley, mustard, gram, lentil, etc.).

The recent heavy rainfall in different parts of India due to western disturbances, associated cyclonic circulations and thunderstorms has the imprint of global warming written over it. In this light, it is important to closely monitor the western disturbance phenomenon to protect the rabi crops in India.