Module II: Physical Geography

2.Composition and structure of the atmosphere

- **Atmosphere**
  - **The envelope of gasses surrounding the earth** is called the atmosphere. It forms a protective boundary between **outer space and the biosphere.**
  - The atmosphere is a **dynamic collection of gasses** that constantly move and change. These gasses form several layers around Earth that are loosely defined by composition and temperature.
  - The gasses of the present atmosphere are not the direct residue of the early stage of earth's formation. They are a product of progress through **volcanic eruptions, hot springs, chemical breakdowns of solid matter and redistribution from the biosphere**.
  - **It protects the earth from the harmful radiation from the sun. It acts as a greenhouse by allowing short-wave radiation (from the Sun) and trapping long-wave terrestrial radiation (from Earth's surface).**
  - The atmosphere also keeps the temperature over the earth's surface within certain limits. **In the absence of the atmosphere extremes of temperature would exist between day and night over the earth's surface.**
  - **The atmosphere also takes care of extra-terrestrial objects like meteors that get burnt up while passing through the atmosphere (mesosphere to be precise) due to friction.**
  - **Atmospheric pressure:** The air exerts pressure on earth's surface by virtue of its weight. This pressure is called atmospheric pressure. Atmospheric pressure is the most important climatic element. The atmospheric pressure at sea level is **1034 gm per square centimeter.**
- Role of Earth's Atmosphere

- The atmosphere contains various gasses like **oxygen, carbon dioxide, nitrogen etc.**
- Plants require carbon dioxide to survive while animals and many other organisms need oxygen for their survival. The atmosphere supplies these life-giving gasses.
- The atmosphere also keeps the **temperature over the earth's surface within certain limits.** In the absence of the atmosphere extremes of temperature would exist between day and night over the earth's surface.
- Harmful ultraviolet radiation would find its way through, if the atmosphere (ozone in the stratosphere to be specific) were absent.
- The atmosphere also takes care of extra-terrestrial objects like meteors which get burnt up while passing through the atmosphere (mesosphere to be precise) due to friction.
- Weather is another important phenomenon which dictates the direction of a number of natural and man-made processes like plant growth, agriculture, soil-formation, human settlements, etc. Various climatic factors join together to create weather.

- Composition of the atmosphere
  - The gasses in the atmosphere are composed of neutral, uncharged particles.
  - Except for the noble gasses, atoms in the gas phase share electrons with other atoms in chemical bonds so that their electron count can approach the more stable filled-shell configuration.
  - The Earth's atmosphere consists of a mixture of noble gas atoms and many kinds of molecules.
  - The atmosphere is composed of
    - **Gasses**
      - **Nitrogen and oxygen make up nearly 99%** of the clean, dry air. The **remaining gasses** are mostly inert and constitute about **1% of the atmosphere**.

- ➔ Oxygen
  - ★ Oxygen, although constituting only **21% of total volume of the atmosphere,** is the most important component among gasses.
  - ★ **All living organisms inhale oxygen.**
  - ★ Besides, oxygen can combine with other elements to form important compounds, such as oxides. Also, **combustion is not possible without oxygen.**
- ➔ Nitrogen
  - ★ Nitrogen accounts for **78% of total atmospheric volume**. It is a relatively inert gas, and is an important constituent of all organic compounds.
  - ★ The main function of nitrogen is to control combustion by diluting oxygen.
  - ★ It also indirectly **helps in oxidation of different kinds.**
- ➔ Carbon Dioxide
  - ★ constitutes only about **0.038% of the dry air and is a product of combustion.**
  - ★ Green plants, through photosynthesis, absorb carbon dioxide from the atmosphere and use it to manufacture food and keep other biophysical processes going.
  - ★ Carbon dioxide is considered to be a very important factor in the heat energy budget.
  - ★ With the increased burning of fossil fuels – **oil, coal, and natural gas – the carbon dioxide percentage in the atmosphere has been increasing at an alarming rate**.
  - ★ **More carbon dioxide in the atmosphere means more heat absorption.**
  - ★ This could significantly raise the temperature at lower levels of the atmosphere thus inducing drastic climatic changes.

★ **Carbon dioxide and water vapor are found only up to 90 km from the surface of the earth.**

➔ Argon

★ The third important gas

★ Argon which constitutes only about **0.93%.**

➔ Ozone (03)

★ a type of oxygen molecule consisting of **three,** instead of two, atoms

★ It forms less than **0.00006%** by volume of the atmosphere and is unevenly distributed.

★ It is between **20 km and 25 km** altitude that the greatest concentrations of ozone are found. It is formed at higher altitudes and transported downwards.

★ **Ozone plays a crucial role in blocking the harmful ultraviolet radiation from the sun.**

★ Other gasses found in almost negligible quantities in the atmosphere are **neon, helium, hydrogen, xenon, krypton, methane, etc.**

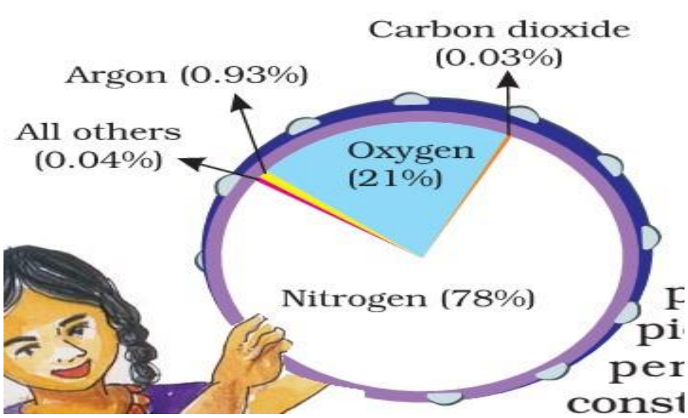


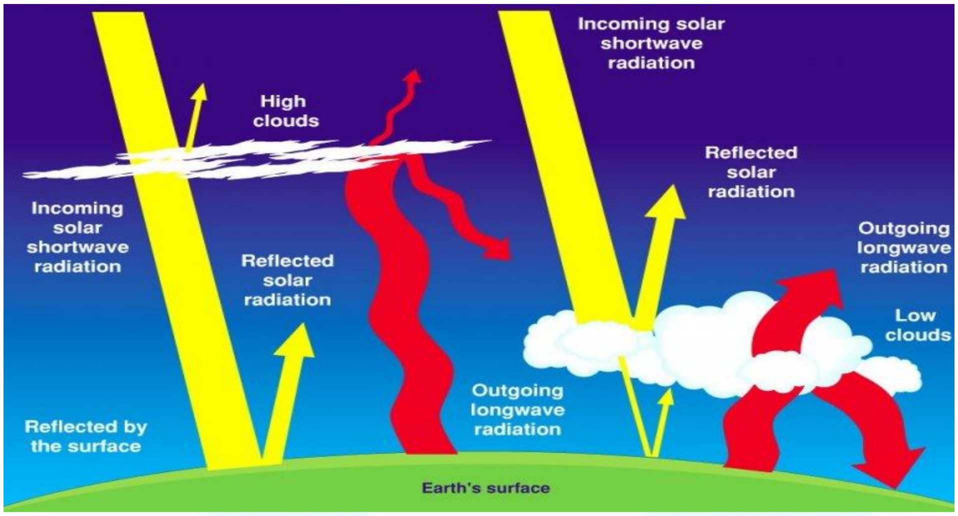
Table 8.1 : Permanent Gases of the Atmosphere

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

➢ Vapor

- ➔ The vapor content in the atmosphere ranges from **0 to 5 %** by volume.
- ➔ The atmospheric vapor is received through the evaporation of moisture and water from the water bodies **(like seas and oceans, lakes, tanks and ponds, rivers, etc.),** vegetation, and soil cover.
- ➔ Vapor depends on temperature and therefore it decreases from the equator poleward in response to decreasing temperature towards the poles.
- ➔ The content of the vapor in the surface air in the moist tropical areas, at 50-degree and **70-degree latitudes, is 2.6%, 0.9%, and 0.2% (by volume) respectively.**
- ➔ **The content of vapor decreases upward.**
- ➔ More than **90%** of the total atmospheric vapor is found up to the height of **5 km.**
- ➔ **The moisture content in the atmosphere creates several forms of condensation and precipitation e.g. clouds, fogs, dew, rainfall, frost, hailstorm, ice, snowfall, etc.**
- ➔ Vapor is almost t**ransparent for incoming shortwave solar radiation** so that the electromagnetic radiation waves reach

the earth's surface without many obstacles but **vapor is less transparent for outgoing longwave terrestrial radiation** and therefore it helps in **heating the earth's surface and lower portion of the atmosphere because it absorbs terrestrial radiation.**



➢ Particulates

➔ The Solid Particles present in the atmosphere consist of sand particles **(from weathered rocks and also derived from volcanic ash), pollen grains, small organisms, soot, ocean salts;** the upper layers of the atmosphere may even have fragments of meteors which got burnt up in the atmosphere.

➔ These particulates help in the **absorbing, reflecting, and scattering of the solar radiation** which adds the varied charming color of red and orange at sunrise and sunset.

➔ **The sky appears blue in color due to the selective scattering of solar radiation by dust particles.**

➔ Salt particles become **hygroscopic nuclei** and thus help in the formation of **water drops, clouds, and various forms of condensation and precipitation.**

Hygroscopic nucleus – a microscopic particle (e.g. of sulfur dioxide, salt, dust, or smoke) in the free air, on which **water vapor may condense to form droplets**.

- Structure of the Atmosphere
  - ❖ The atmosphere can be divided into different layers according to **composition, density, pressure, and temperature variations.**
  - ❖ **Based on Composition**
    - ➢ **Homosphere**
      - ➔ The homosphere is the **lower segment of the two-part division of atmosphere and further consists of three regions namely troposphere, stratosphere and mesosphere.**
      - ➔ The **Troposphere is the earth's weather layer.** It contains nearly all weather conditions. As you go up in altitude the temperature goes down. It is the bottom-most layer of the
      - ➔ The **Stratosphere is the middle region of the Homosphere.**
      - ➔ The **Mesosphere is the top layer of the Homosphere.**
      - ➔ All the three regions have the same composition of air. However, the concentration of air keeps decreasing significantly as the altitude increases.
      - ➔ **It extends from the earth's surface up to an altitude of 80km.**
    - ➢ **Heterosphere**
      - ➔ The heterosphere is the layer of an atmosphere where the gasses are separated out by molecular diffusion with increasing altitude such that lighter species become more abundant relative to heavier species.
      - ➔ In the Heterosphere, there are two regions: **The Thermosphere and the Exosphere**. **These two regions are considered outer space.**

- The thermosphere is the **bottom region of the Heterosphere**.
- The exosphere is the **top region of the Heterosphere.**
- It begins over **80km and extends up to 10,000 km.**

❖ **Based on Change in temperature**

➢ **Troposphere**

- It is the atmospheric layer between the earth's surface and an altitude of **8 km at the poles and 18 km at the equator.**
- The **thickness is greater at the equator**, because the heated air rises to greater heights.
- The **troposphere ends with the Tropopause.**
- The temperature in this layer, as one goes upwards, falls at the rate of **5°C per kilometer**, and reaches **-45°C** at the poles and **-80°C** over the equator at Tropopause (greater fall in temperature above equator is because of the greater thickness of troposphere – 18 km).
- The fall in temperature is called **'lapse rate'. (more about this in future posts)**
- The troposphere is marked by **temperature inversion, turbulence and eddies.**
- It is also meteorologically the most significant zone in the entire atmosphere (Almost all the weather phenomena like rainfall, fog and hailstorm etc. are confined to this layer).
- It is also called the convective region, since all convection stops at Tropopause.
- The troposphere is the theater for weather because all **cyclones, anticyclones, storms and precipitation occur here, as all water vapors and solid particles lie within this.**
- The troposphere is influenced by **seasons and jet streams.**
- **Tropopause**

- ★ The tropopause is the **atmospheric boundary that demarcates the troposphere from the stratospherere.**
- ★ This layer is marked by constant temperatures.

➢ **Stratosphere**

- ➔ It lies beyond troposphere, up to an altitude of **50 km from the earth's surface.**
- ➔ The temperature in this layer remains constant for some distance but then rises to reach a level of **0°C at 50 km altitude.**
- ➔ This rise is due to the **presence of ozone** (harmful ultraviolet radiation is absorbed by ozone).
- ➔ This layer is almost free from clouds and associated **weather phenomenon, making conditions most ideal for flying airplanes.** So airplanes fly in the lower stratosphere, sometimes in the upper troposphere where weather is calm.
- ➔ Sometimes, **cirrus clouds are present at lower levels in this layer.**

➢ **Mesosphere**

- ➔ The mesosphere extends from **50 – 80 km.**
- ➔ The temperature again decreases in this layer and reaches its minimum mark averaging **-90 C**. Although this temperature can vary.
- ➔ The homogenous layer extends up to the mesosphere.
- ➔ At the upper boundary of the mesosphere, there exists a layer of ions extending in the other layer.
- ➔ **This layer of ions or charged particles is helpful in reflecting the radio waves and helps in telecommunication**

➢ **Thermosphere (Ionosphere)**

- ➔ The thermosphere temperature rises very rapidly with increasing height.

- Ionosphere is a part of this layer. It extends between **80-400 km.**
- This layer helps in radio transmission. In fact, radio waves transmitted from the earth are reflected back to the earth by this layer.
- Person would not feel warm because of the thermosphere's extremely low pressure.
- **The International Space Station and satellites orbit in this layer.** (Though temperature is high, the atmosphere is extremely rarefied – gas molecules are spaced hundreds of kilometers apart. Hence a person or an object in this layer doesn't feel the heat)
- **Aurora's** are observed in lower parts of this layer.

Exosphere

- This is the uppermost layer of the atmosphere extending beyond the ionosphere above a height of about 400 km.
- The air is extremely rarefied and the temperature gradually increases through the layer.
- **Light gasses like helium and hydrogen float into space from here**.
- **Temperature gradually increases** through the layer. (As it is exposed to direct sunlight)
- **This layer coincides with space.**

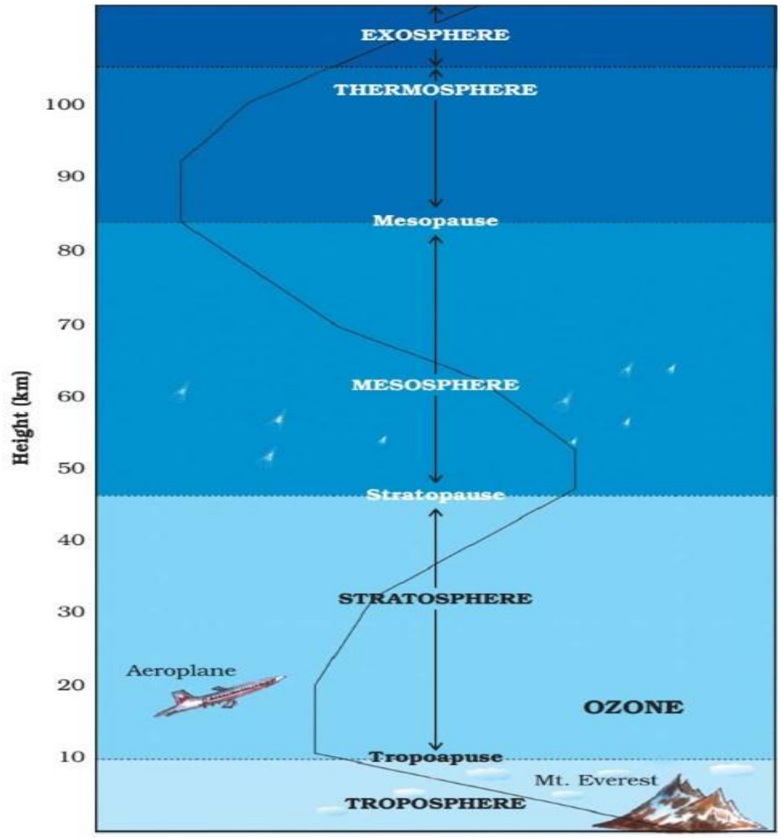


Fig. 4.2: Layers of Atmosphere

- Insolation or Incoming Solar Radiation
  - 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 radiated** from the sun because of the small size of the earth and its distance from the sun.
  - **water vapor, dust particles, ozone and other gasses** present in the atmosphere absorb a small amount of solar radiation.
  - 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.**

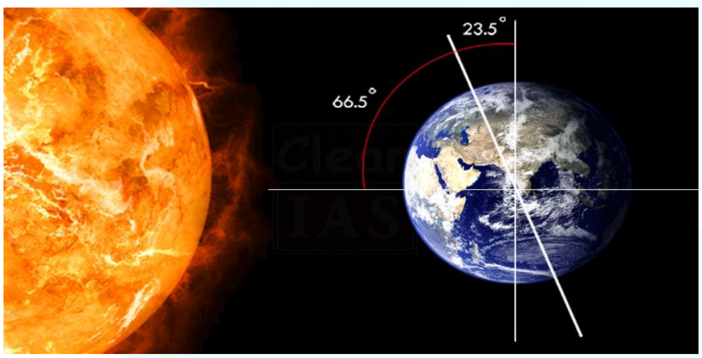
❖ Due to this variation in the distance between the earth and the sun, the **annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July.**

- Factors influencing Insolation

❖ **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



❖ **The angle of incidence of the sun's rays**

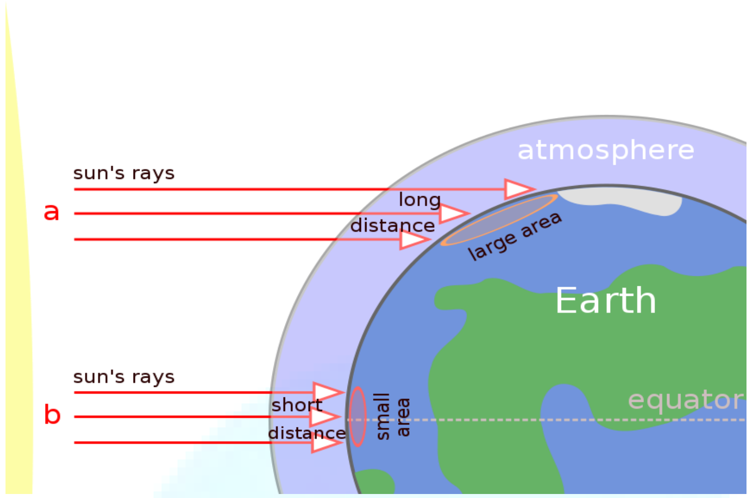
➢ Since the earth is a **geoid resembling a sphere,** the sun's rays strike the surface at different angles at different places. This depends on the latitude of the place.

➢ **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 angles 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



❖ 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.

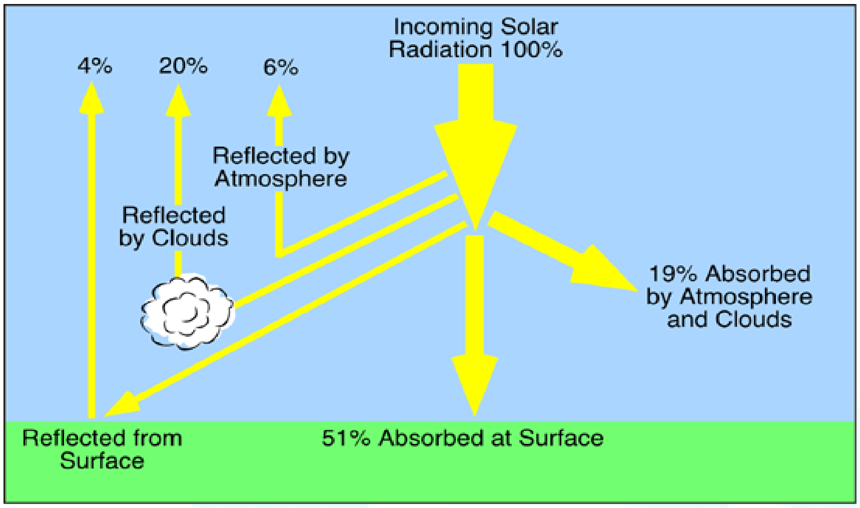
❖ Transparency of the atmosphere

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

➢ Thick clouds hinder the solar radiation from reaching the earth's surface. Similarly, water vapor absorbs solar radiation resulting in less amount of insolation reaching the surface.

➢ When the solar radiation passes through the atmosphere, water vapor, ozone and other gasses 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 color to the sky.
- ➢ The red color of the rising and setting sun and the blue color of the sky are the results of scattering of the light within the atmosphere.



- Heating and Cooling of the Atmosphere

❖ Terrestrial Radiation

- ➢ 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.**

❖ Conduction

- 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.

❖ **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**.

❖ **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.**

- Heat budget
  - ❖ 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.**
  - ❖ This is why the earth neither warms up nor cools down despite the huge transfer of heat that takes place.
  - ❖ **Albedo**
    - ➢ When **100%** of solar radiation reaches the earth's atmosphere, about **35%** is reflected back to space even before reaching the surface of the earth.
    - ➢ The reflected amount is called the **albedo** of the earth. This amount of energy does not heat either the earth or the atmosphere.
    - ➢ **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

- Weather and climate

Weather	Climate
Weather is **day-to-day information** of the changes in the atmospheric condition in any area.	Climate is statistical weather information that provides information about the **average weather condition of a particular place over a long period**
The changes in the weather condition can be observed very frequently.	**The changes in climate take a longer time to change.**
Weather forecasting is observed by the Meteorological Department	**Climatology is the scientific study of climate**, which is described as the average of weather conditions over time.
Weather is affected by **temperature, pressure, humidity, cloudiness**	Atmospheric conditions at any location like **humidity, temperature, the sunshine, wind,** etc are affected by climate

- Weather Maps

❖ **A weather map is the representation of weather phenomena of the earth or a part of it on a flat surface.**

- It depicts conditions associated with different weather elements such as **temperature, rainfall, sunshine and cloudiness, direction and velocity of winds, etc. on a particular day.**
- The central office keeps a record of the observations, which forms the basis for making a weather map.
- The upper air observations which are procured from hill stations, aeroplanes, pilot balloons, etc. are plotted separately.
- **Since the inception of the Indian Meteorological Department, the weather maps and charts are prepared regularly.**

- Horizontal Distribution of Temperature
  - Distribution of temperature across the latitudes over the surface of the earth is called its horizontal distribution.
  - On maps, the horizontal distribution of temperature is commonly shown by isotherms.
  - **Isotherms are line connecting points that have an equal temperature.**
  - When we analyse an isotherm map, it can be seen that the horizontal distribution of temperature is uneven.
  - **The factors responsible for the uneven horizontal distribution of temperature are**
    - **LATITUDE**
      - Higher the angle of incidence, higher is the temperature. Similarly, lower the angle of incidence, lower is the temperature.
      - This is why the **temperature is higher near the tropical regions and decreases towards the poles.**
    - **ALTITUDE**
      - As we all know, the temperature in the troposphere goes on decreasing with increase in height.

- Temperature decreases at an average rate of nearly 6 degree Celsius per **1000 m altitude,** which is known as **Normal Lapse Rate.**

➢ LAND AND SEA CONTRAST

- Compared to land, the **sea gets heated slowly and loses heat slowly. Land heats up and cools down quickly.**
- As a result, the temperature is relatively higher on land during day time and it is higher in water during the night.
- Also, the places situated near the sea come under the moderating influence of the **sea and land breezes** which **moderates the temperature.**
- There are also seasonal variations in the temperature of land and sea. During summer, the air above land has a higher temperature than the oceans. But the air above oceans gets higher temperature than landmass in winter.
- Notwithstanding the great contrast between land and water surfaces, there are differences in the rate of heating of different land surfaces. A snow-covered land as in polar areas warms very slowly because of a large amount of reflection of solar energy. A vegetation covered land does not get excessively heated because a great amount of insolation is used in evaporating water from the plants.

➢ OCEAN CURRENTS

- Ocean Currents are of two types – **warm and cold.**
- **Warm currents make the coasts along which they flow warmer, while cold currents reduce the temperature of the coasts along which they flow.**
- The **North-Western European Coasts** do not freeze in winter due to the effect of **North Atlantic Drift (a warm current),** while the Quebec on the coast of Canada is frozen due to the **Cold Labrador** Current flowing along it, though the Quebec is

situated in lower latitudes than the **North-West European Coast**

- **AIR MASSES**
  - Like the land and **sea breezes, the passage of air masses also affects the temperature.**
  - The places, which come under the influence of warm air masses experience higher temperature and the places that come under the influence of cold air masses experience low temperature.
- **VEGETATION COVER**
  - Soil devoid of vegetation cover receives heat more rapidly than the soil under vegetation cover.
  - Because vegetation cover absorbs much of **sun's heat and then prevents quick radiation from the earth whereas the former radiates it more rapidly.**
  - **Hence the temperature variations in densely forested areas are lower than those in desert areas.**
- The horizontal distribution of temperature over the globe can be studied easily from the isotherm maps of **January and July** months since the **seasonal extremes of high and low temperature are most obvious in both northern and southern hemispheres during these months**.
- **Horizontal Distribution of Temperature in January**
  - In January, the **sun shines vertically overhead near the tropic of Capricorn.** Hence, **it is summer in southern hemisphere and winter in the northern hemisphere.**
  - A high temperature is found over the landmasses mainly in three regions of the southern hemisphere. These regions are **North-West Argentina, East and Central Africa, and Central Australia**.
  - Isotherm of **30°C** closes them.

- ➔ In the **northern hemisphere, landmasses are cooler than the oceans.** As the air is warmer over the oceans than over landmasses in the northern hemisphere, the **isotherms bend towards the north (poles) when they cross the oceans and to the south (equator) over the continents**.
- ➔ This can be clearly visible over the **North Atlantic Oceans**. The presence of warms ocean currents (**Gulf Stream and North Atlantic Drift**) make the **Northern Atlantic Ocean** warmer and the isotherms bend towards the poles. Over the land, the temperature decreases sharply and the isotherms bend towards the equator in **Europe.**
- ➔ In the southern hemisphere, the effect of the oceans is well pronounced (due to few landmasses).
- ➔ Here, the **isotherms are more or less parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere**.

➢ **Horizontal Distribution of Temperature in July**

- ➔ In July, the **sun shines vertically overhead near the Tropic of cancer**. Hence, **high temperatures are found in the entire northern hemisphere.**
- ➔ The regions having high temperature include **South Western USA, the Sahara, the Arabia, Iraq, Iran, Afghanistan, desert region of India and China.**
- ➔ However, the **lowest temperature of 0°C** is also noticed in the **Northern Hemisphere during summer in the central part of Greenland.**
- ➔ During summer in the northern hemisphere, isotherms bend towards the equator while crossing oceans and towards the poles while crossing landmasses.
- ➔ **Isotherms are wide spaced over oceans while they are closely spaced over landmasses.**

- ➔ In **July, the deviation of isotherms is not that much pronounced as in January.**

- Vertical Distribution of Temperature
  - ❖ We have already studied that the temperature in the **troposphere decreases with an increase in the altitude.**
  - ❖ This vertical gradient of temperature is commonly referred to as the standard atmosphere or **Normal Lapse Rate.**
  - ❖ **However, this normal lapse rate varies with height, season, latitude and other factors.**
  - ❖ Indeed the actual lapse rate of temperature does not always show a decrease with altitude.
  - ❖ **Inversion of Temperature**
    - ➢ The phenomenon in which **temperature increases with increasing altitude temporarily and locally under certain conditions is known as inversion of temperature**.
    - ➢ **Inversion is usually of short duration but quite common nonetheless.**
    - ➢ **Long winter night, clear sky, dry air and absence of winds leads** to quick radiation of heat from the earth's surface, as well as from the lower layers of the atmosphere.
    - ➢ This results in the cooling of the air near the earth's surface. The upper layers which lose their heat not so quickly are comparatively warm.
    - ➢ Hence the **normal condition, in which temperature decreases with increasing height, is reversed. The cooler air is nearer the earth and the warmer air is aloft.**
    - ➢ In other words, **temperature increases with increasing height temporarily or locally.**
    - ➢ The phenomenon of **inversion of temperature is mostly observed in intermontane valleys due to air drainage.**

- ➢ **During winters the mountain slopes cool very rapidly due to the quick radiation of heat.**
- ➢ The air resting above them also becomes cold and its density increases. Hence, it moves down the slopes and settles down in the valleys.
- ➢ This air pushes the comparatively warmer air of valleys upwards and leads to the phenomenon of inversion of temperature.
- ➢ Sometimes the temperature falls below freezing point in the valleys leading even to the occurrence of frost. In contrast, the higher slopes remain comparatively warmer.
- ➢ **This movement of heavy and dense cold air towards the valley slopes almost like water is termed as air drainage**.

- Atmospheric pressure
  - ❖ The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the **air or atmospheric pressure**
  - ❖ The atmospheric pressure is expressed in **units of millibar**. **At sea level the average atmospheric pressure is 1,013.2 millibar.**
  - ❖ 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.**
  - ❖ **Distribution of Pressure on Earth's Surface**
    - ➢ **Horizontal distribution of air pressure** on the earth's surface is closely related with that of temperature because the factors which control the distribution of temperature on the earth's surface equally govern the distribution of pressure as well.
    - ➢ **Unequal distribution of insolation over the surface,** differential heating of land and water and different **albedo** of the

earth surface are main factors which affect the distribution of pressure on the earth's surface.

- Pressure Belts
  - Based on the distribution pattern of surface pressure on a rotating earth with uniform surface (In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level), there are seven alternate low and high pressure belt on the earth's surface
  - These pressure belts are **not permanent in nature**
  - They oscillate with the apparent movement of the sun
  - **Equatorial low pressure belt**
    - It exists between **10°N to 10°S latitude.** It is a thermally induced belt caused by high insolation and the convective rise of air (updraft)
    - This region observes vertical cloud like **cumulonimbus** with **thunder & lightning and afternoon shower between 2 to 4 pm** followed by atmospheric stability with absolute calm
    - This region is also referred to as **doldrums due to absence of air movement and generation of intense low pressure.**
    - It is believed that the ships sailing through doldrums gets stuck for weeks if they do not have enough sail power to move forward
    - **This belt represents the zone of convergence of N-E and S-E Trade winds**
  - **Subtropical high pressure belt**
    - It exists between **25° to 35°** latitudes in both the hemisphere. It is dynamically induced **high pressure zone.**
    - This is caused by the **subsidence of cold and dry air** (downdraft) due to the mechanical force produced by air accumulated aloft.

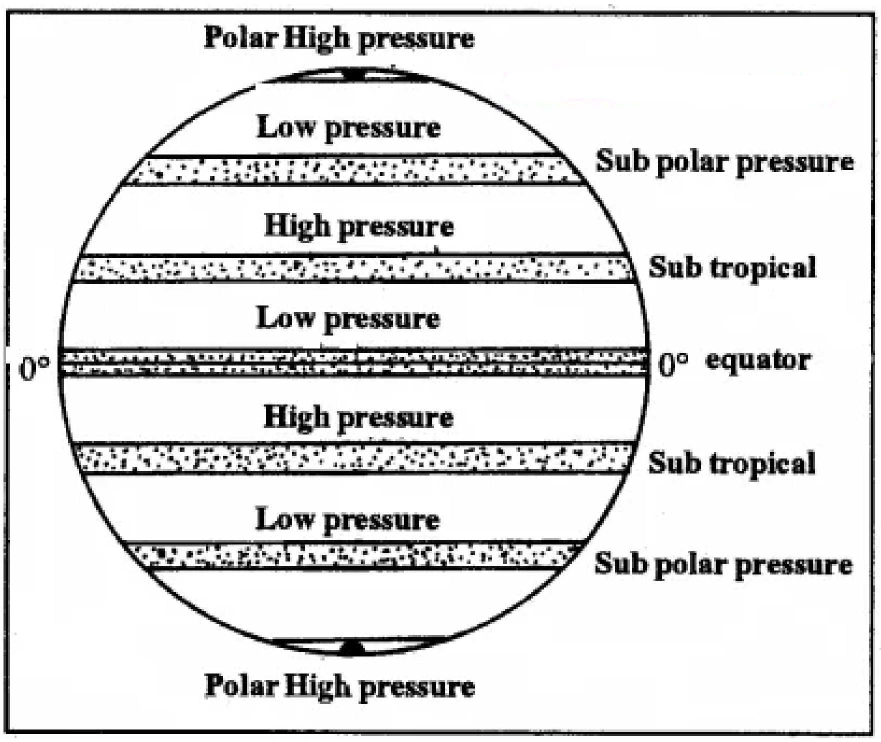
- ➔ The air accumulation is caused by air coming from the equatorial region which descends after becoming heavy.
- ➔ **Coriolis** force and **geostrophic effect** are contributing factors for accumulation of air
- ➔ Hot tropical deserts are developed in the western side of continents in this zone as subsiding air is warm and dry that discourage rainfall.
- ➔ This zone of high pressure is called **'Horse Latitude'** because of prevalence of frequent calms

➢ **Subpolar low pressure belt**

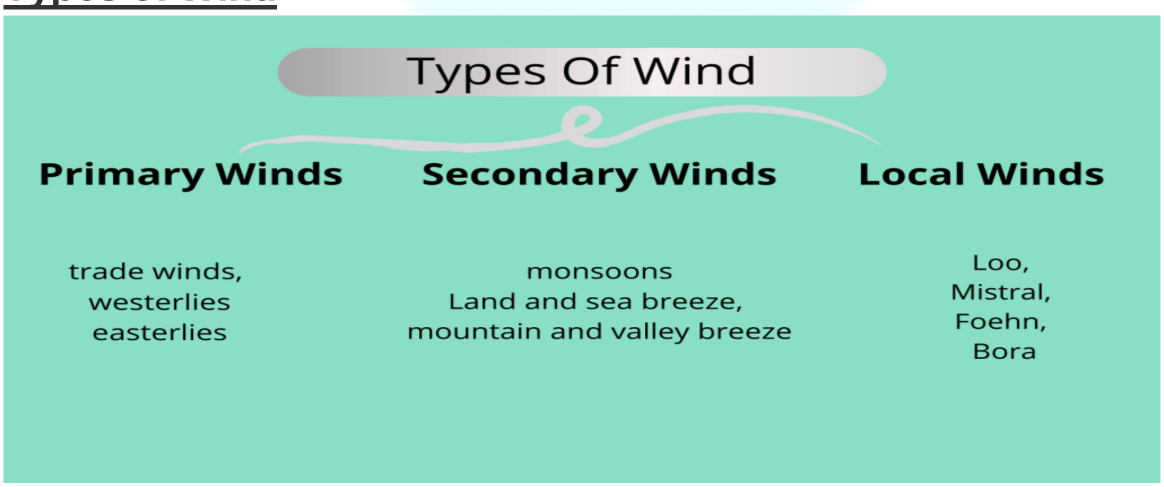
- ➔ It exists along **60° to 65° latitude in both the hemisphere**.
- ➔ It is dynamically induced pressure belt but thermal factors cannot be ignored.
- ➔ It is a zone of convergence of warm and cold air masses and also known as **temperate convergence zone.**
- ➔ Development of fronts as well as temperate cyclone and frequent change in weather conditions are the common phenomena observed here

➢ **Polar high pressure belt**

- ➔ It exists near the poles between **75° to 90° latitude in both the hemispheres.**
- ➔ It is thermally induced pressure belt but the role of dynamic factors cannot be denied.
- ➔ The region observes the subsidence of cold and dry air which causes the high pressure.
- ➔ The subsiding air is converted into **anti cyclone** due to the **coriolis' effect and leads to the outflow of air in the form of gale**
- ➔ **These gales are known as blizzard in North America and buran in Siberia.**



- Winds
  - ❖ **The horizontal motion of air parallel to the pressure gradient force and perpendicular to the isobar is called wind**
  - ❖ It always blows from high pressure to low pressure and acts as a medium for the transfer of heat and moisture from one place to another
  - ❖ **Types of Wind**



1. **Permanent winds or Primary winds or Prevailing winds or Planetary Winds**

- ➢ These are the planetary winds which blow **extensively over continents and oceans.**
- ➢ **The two most well- understood and significant winds for climate and human activities are trade winds and westerly winds**.
- ➢ **Trade Winds**
  - ➔ The trade winds are those blowing from the **sub-tropical high-pressure areas towards the equatorial low-pressure belt.**
  - ➔ Therefore, these are confined to a region between **30°N and 30°S throughout the earth's surface.**
  - ➔ They flow as the **north-eastern trades in the northern hemisphere and the south-eastern trades in the southern hemisphere**.
  - ➔ These **Winds are called trade winds because of the fact that they helped the sea merchants in sailing their ships as their (of trade winds) direction remains more or less constant and regular.**
  - ➔ This deflection in their ideally expected north-south direction is explained on the basis of **Coriolis force and Farrel's law.**
  - ➔ According to **Ferrell's law trade winds are deflected to the right in the northern hemisphere and to the left in the southern hemisphere.**
  - ➔ Trade winds are descending and stable in areas of their origin (sub-tropical high-pressure belt), and as they reach the equator, they become humid and warmer after picking up moisture on their way.
  - ➔ The trade winds from two hemispheres meet at the equator, and due to convergence they rise and cause heavy rainfall.

- The eastern parts of the trade winds associated with the cool ocean currents are drier and more stable than the western parts of the ocean.

Westerlies

- The westerlies are the winds blowing from the **subtropical high-pressure belts (30°-35°) towards the sub-polar low-pressure belts (60°-65°) in both hemispheres.**
- They blow from south-west to **north-east** in the northern hemisphere and north-west to **south-east** in the southern hemisphere.
- The westerlies of the southern hemisphere are stronger and persistent due to the vast expanse of water, while those of the northern hemisphere is irregular because of the uneven relief of vast land-masses.
- Because of the **dominance of the land in the northern hemisphere, the westerlies become more complex and complicated and become less effective during the summer seasons and more vigorous during the winter season.**
- These westerlies bring much precipitation in the western parts of the continents (**e.g. north-west European coasts**) because they pick up much moisture while passing over the vast stretches of the oceans.
- The westerlies become more vigorous in the southern hemisphere because of a lack of land and dominance of oceans. **Their velocity increases southward and they become stormy. They are also associated with boisterous gales.**
- The westerlies are best developed between **40° and 65°S** latitudes. These latitudes are often called **Roaring Forties,**

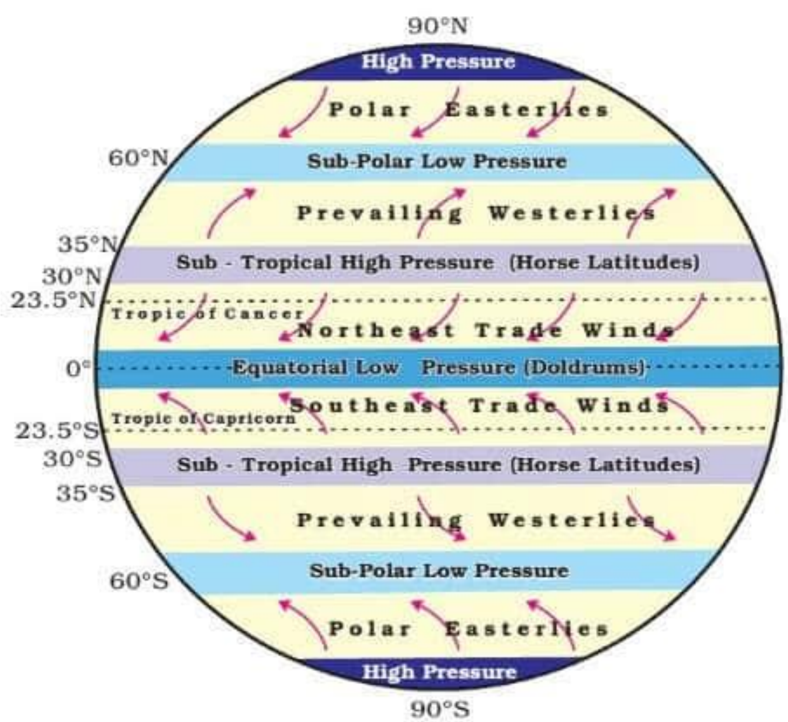
Furious Fifties, and Shrieking Sixties – dreaded terms for sailors.

➔ The poleward boundary of the westerlies is highly fluctuating. There are many seasonal and short-term fluctuations. These winds produce wet spells and variability in weather.

➢ **Polar easterlies**

➔ The Polar easterlies are dry, cold prevailing winds blowing from north-east to south-west direction in **Northern Hemisphere and south-east to the north-west in Southern Hemisphere.**

➔ **They blow from the polar high-pressure areas of the sub-polar lows**



Major Pressure Belts and Wind System

2. **Secondary or Periodic Winds**

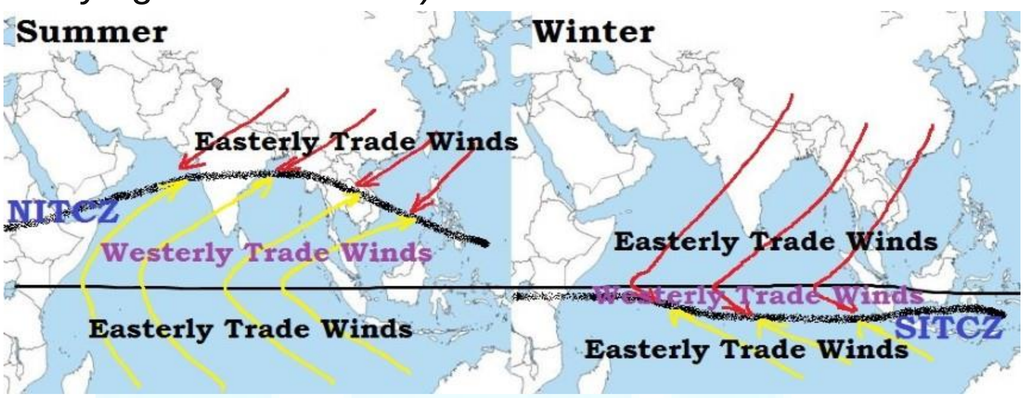
➢ These winds change their direction with **change in season.**

➢ **Monsoons** are the best example of large-scale modification of the planetary wind system.

- Other examples of periodic winds include land and **sea breeze, mountain and valley breeze, cyclones and anticyclones, and air masses.**
- **Monsoons**
  - **Monsoons were traditionally explained as land and sea breezes on a large scale.** Thus, they were considered a convectional circulation on a giant scale.
  - **The monsoons are characterized by seasonal reversal of wind direction.**
  - **During summer**, **the trade winds of the southern hemisphere are pulled northwards by an apparent northward movement of the sun and by an intense low-pressure core in the north-west of the Indian sub-continent.**
  - While crossing the equator, these winds get deflected to their right under the effect of **Coriolis force.**
  - These winds now approach the Asian landmass as **south-west monsoons**. Since they travel a long distance over a vast expanse of water, by the time they reach the south-western coast of India, they are over-saturated with moisture and cause heavy rainfall in India and neighboring countries.
  - During winter, these conditions are reversed and a high-pressure core is created to the north of the Indian subcontinent. Divergent winds are produced by this anticyclonic movement which travels southwards towards the equator. This movement is enhanced by the apparent southward movement of the sun. These are north-east or winter monsoons which are responsible for some precipitation along the east coast of India.

➔ The monsoon winds flow over **India, Pakistan, Bangladesh, Myanmar (Burma), Sri Lanka, the Arabian Sea, Bay of Bengal, south-eastern Asia, northern Australia, China and Outside India, in the eastern Asiatic countries, such as China and Japan**

➔ **The winter monsoon is stronger than the summer monsoon.** (we will study about monsoons in detail while studying Indian Climate).



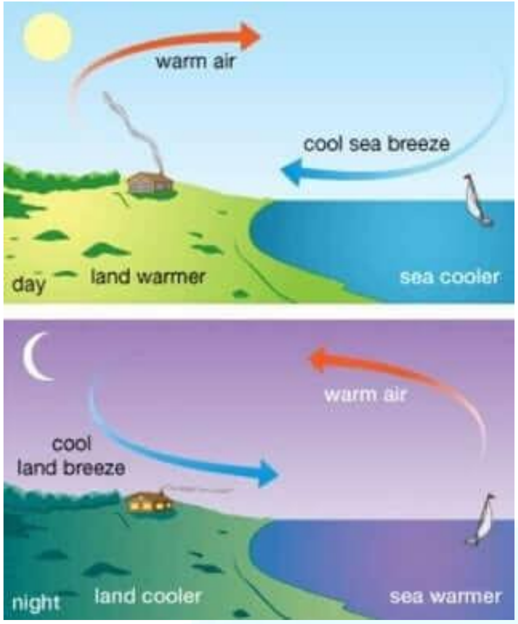
➢ **Land Breeze and Sea Breeze**

➔ The land and sea absorb and transfer heat differently. During the day the land heats up faster and becomes warmer than the sea.

➔ Therefore, over the land, the air rises giving rise to a low-pressure area, whereas the sea is relatively cool and the pressure oversea is relatively high. **Thus, the pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze**.

➔ At the night the reversal of condition takes place.

➔ **The land loses heat faster and is cooler than the sea. The pressure gradient is from the land to the sea and hence land breeze results.**

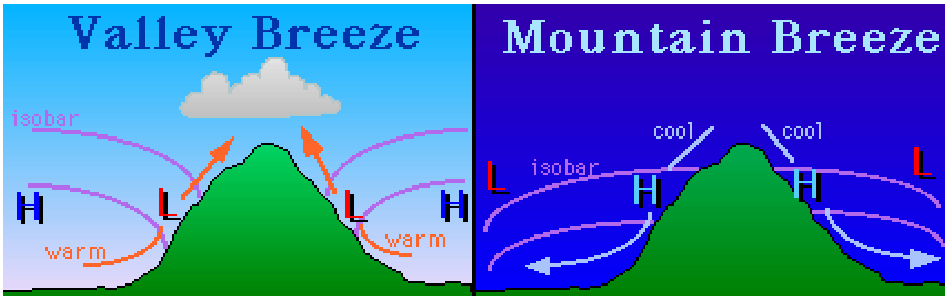


➢ **Valley Breeze and Mountain Breeze**

➔ In mountainous regions, during the day the slopes get heated up and air moves upslope and to fill the resulting gap the air from the valley blows up the valley. This wind is known as the **valley breeze**.

➔ During the night the slopes get cooled and the dense air descends into the valley as the **mountain wind**. The cool air, of the high plateaus and ice fields draining into the valley, is **called katabatic wind.**

➔ Another type of **warm wind (katabatic wind)** occurs on the leeward side of the mountain ranges. The moisture in these winds, while crossing the mountain ranges condenses and precipitate. When it descends down the leeward side of the slope the dry air gets warmed up by the adiabatic process. **This dry air may melt the snow in a short time.**



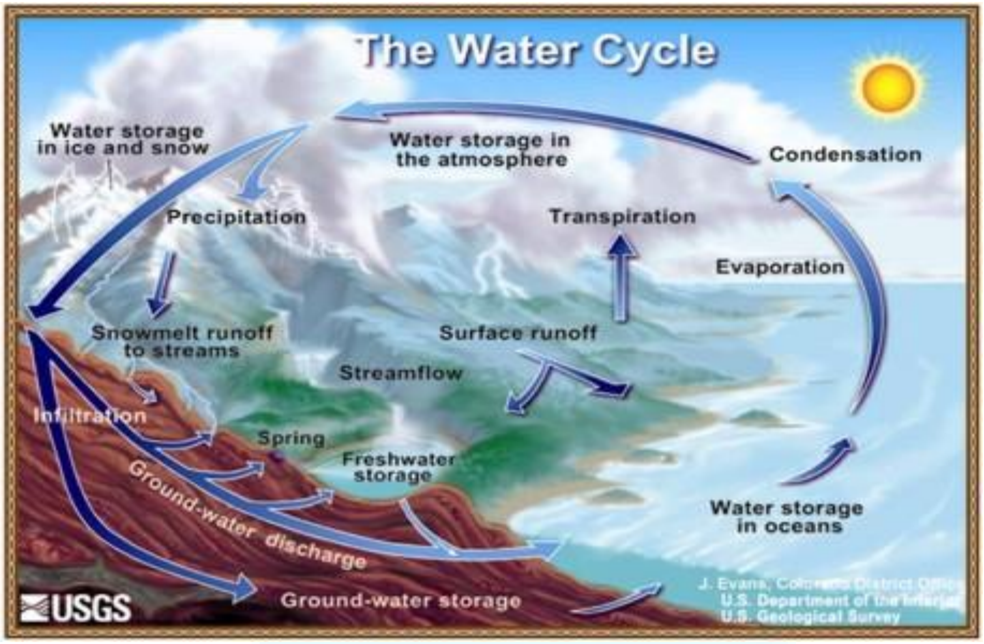
3. Local winds

- Local differences in temperature and pressure produce local winds.
- Such winds are local in extent and are confined to the lowest levels of the troposphere. Some examples of local winds are discussed below.
- **Loo**
  - **Harmful Wind**
  - In the plains of northern **India and Pakistan**, sometimes a very hot and dry wind blows from the west in the months of M**ay and June, usually in the afternoons**. It is known as Its temperature invariably ranges between **45°C and 50°C**. It may cause **sunstroke to people.**
- **Foehn or Fohn**
  - **Beneficial Wind**
  - **Foehn is a hot wind of local importance in the Alps**.
  - It is a strong, gusty, dry and warm wind which develops on the leeward side of a mountain range.
  - As the windward side takes away whatever moisture there is in the incoming wind in the form of orographic precipitation, the air that descends on the leeward side is dry and warm **(Katabatic Wind).**
  - The temperature of the wind varies between **15°C and 20°C.** The wind helps animal grazing by **melting snow and aids the ripening of grapes.**

- ➢ **Chinook**
  - ➔ **Beneficial Wind**
  - ➔ Foehn like winds in **USA and Canada** move down the west slopes of the **Rockies**
  - ➔ It is beneficial to **ranchers east of the Rockies as it keeps the grasslands clear of snow during much of the winter.**
- ➢ **Mistral**
  - ➔ **Harmful Wind**
  - ➔ Mistral is one of the local names given to such winds that blow from the **Alps over France towards the Mediterranean Sea.**
  - ➔ It is channeled through the **Rhone River valley**. It is very cold and dry with a high speed.
  - ➔ It brings **blizzards into southern France.**
- ➢ **Sirocco**
  - ➔ **Harmful Wind**
  - ➔ Sirocco is a **Mediterranean wind** that comes from the Sahara and reaches hurricane speeds in **North Africa and Southern Europe.**
  - ➔ It arises from a warm, dry, tropical air mass that is pulled northward by low-pressure cells moving eastward across the Mediterranean Sea, with the wind originating in the Arabian or Sahara deserts. The hotter, drier continental air mixes with the cooler, wetter air of the maritime cyclone, and the counterclockwise circulation of the low propels the mixed air across the southern coasts of Europe.
  - ➔ **The Sirocco causes dusty dry conditions along the northern coast of Africa, storms in the Mediterranean Sea, and cool wet weather in Europe.**

- Atmospheric moisture

- Water vapor in air varies from zero to four per cent by volume of the atmosphere (**averaging around 2% in the atmosphere**). Amount of water vapor (Humidity) is measured by an instrument called a **Hygrometer.**
- **Significance of Atmospheric Moisture**
  - Water vapor absorbs radiation—both **incoming and terrestrial. It thus plays a crucial role in the earth's heat budget**.
  - The amount of water vapor present decides the quantity of latent energy stored up in the atmosphere for development of storms and cyclones.
  - The atmospheric moisture affects the human body's rate of cooling by influencing the sensible temperature.
- **Water Cycle – Hydrological cycle**
  - There is a continuous exchange of water between the atmosphere, the oceans and the continents through the processes of **evaporation, transpiration, condensation and precipitation.**
  - The moisture in the atmosphere is derived from water bodies through evaporation and from plants through transpiration **(evapotranspiration).**
  - **Evaporated water undergoes condensation and forms clouds.**
  - When saturation is reached, clouds give away water in the form of precipitation.
  - Since the total amount of moisture in the entire system remains constant, a balance is required between evapotranspiration and precipitation. **The hydrological cycle maintains this balance.**



- Evaporation
  - Process by which water or a **liquid is transformed from liquid to gaseous or vapors state**
  - Evaporation increases with **temp., dryness & movement of air**
  - **Evaporation decreases with cloud cover**
  - The highest annual evaporation occurs in the sub-tropics of the western **North Atlantic and North Pacific** because of the influence of the **Gulf Stream** and the **Kuroshio Current**, and in the trade wind zone of the southern oceans.
  - The land maximum occurs in equatorial region because of high insolation and luxuriant
- Humidity
  - Defined as amount of **water vapor present in air**
  - Capacity of air to absorb water vapor **increases with increase in temperature**
  - Absolute Humidity
    - **The actual amount of the water vapor present in the atmosphere is known as the absolute humidity.**

- ➢ It is the weight of water vapor per unit volume of air and is expressed in terms of grams per cubic meter.
- ➢ The absolute humidity differs from place to place on the surface of the earth.
- ➢ **The ability of the air to hold water vapor depends entirely on its temperature (Warm air can hold more moisture than cold air).**

❖ Relative Humidity

- ➢ **The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the relative humidity.**
- ➢ Relative Humidity = **[Actual amount of water vapor in air (absolute humidity)/humidity at saturation point (the maximum water vapor air can hold at a given temperature)] X 100**
- ➢ Relative humidity is greater over the oceans and least over the continents (absolute humidity is greater over oceans because of greater availability of water for evaporation).
- ➢ The relative humidity determines the amount and rate of evaporation and hence it is an important climatic factor.
- ➢ If the air has **half the amount of moisture** that it can carry, then it is unsaturated and its **relative humidity is only 50%.**

- Condensation
  - ❖ Defined as transformation of **water vapor into water, caused by loss of heat when moist air is cooled.**
  - ❖ Cooling may reach a level when air's capacity to hold water vapor ceases, then excess of water vapor condenses into liquid form
  - ❖ If water vapor directly condenses into solid form, it is known as **sublimation**
  - ❖ In free air, condensation results from cooling around very small particles termed as condensation nuclei

- Particle of dust, smoke & salt from oceans are particularly good nuclei as they absorb water (Hygroscopic nuclei)
- Form of Condensation
    - **Dew**
        - Forms when moisture is deposited in form of **water droplets on cooler surfaces of solid objects such as stone, glass, blades, plant leaves etc. rather than on nuclei in air above**
        - Forms when temperature of **air falls below dew point but above freezing point**
    - **Frost**
        - Forms on solid surfaces when condensation takes place below **freezing point i.e. 0*C**
        - **Means dew point is at or below freezing point**
    - **Fog & Mist**
        - When temp. of an air mass containing large quantity of water vapor falls all of a sudden, condensation takes place on fine dust & smoke particles
        - So, **fog is basically a cloud with its base at or very near to ground**
        - Only difference b/w fog & mist is that **mist contains more moisture than fog** & **each nuclei in mist contains thicker layer of moisture**
        - **Fog is formed generally when warm & cold currents meet**
        - **Mist is formed frequently over the mountains when rising warm air up the slopes meet cold surfaces**
    - **Smog**
        - In u**rban & industrial areas, smoke provides plenty of nuclei which helps in the formation of fog & mist**
        - Such a condition, when **fog is mixed with smoke is called smog**

- Clouds
  - ❖ It is mass of minute water droplets or tiny crystals of ice formed by condensation of water vapor in free air at considerable elevations
  - ❖ Formed mainly because of **adiabatic cooling of air below its dew point**
  - ❖ **Cirrus Clouds**
    - ➢ Formed at higher altitudes **(8 – 12 km)**
    - ➢ **Thin, white in color**, composed of ice crystals & gives **feathery appearance**
  - ❖ **Cumulus Clouds**
    - ➢ Looks like a **cotton wool,** have flat base
    - ➢ Exist in patches, formed at **4-7 km**
  - ❖ **Nimbus Clouds**
    - ➢ **Black & gray** color clouds, **formed near earth's surface**
    - ➢ Extremely dense & opaque to sun rays
  - ❖ **Stratus Clouds**
    - ➢ Occurs in form of **sheet of layers**, covering almost all the sky
    - ➢ Generally formed due to loss of heat or mixing of air masses at different temperatures.
- Precipitation
  - ❖ **Condensation of water vapor in air in form of water droplets or ice**
  - ❖ **Their falling on earth surface is known as precipitation**
  - ❖ **Snowfall**
    - ➢ When **condensation takes place below freezing point**
    - ➢ Means at 0*C, conversion of water vapor directly into solid state
    - ➢ **Precipitation occurs in forms of fine flakes of snow**
  - ❖ **Sleet**
    - ➢ **Sleet is frozen raindrops or refrozen melted snow water**

- ➢ When a layer of temp. above freezing point overlies a sub freezing layer near the ground, precipitation occurs in form of sleet

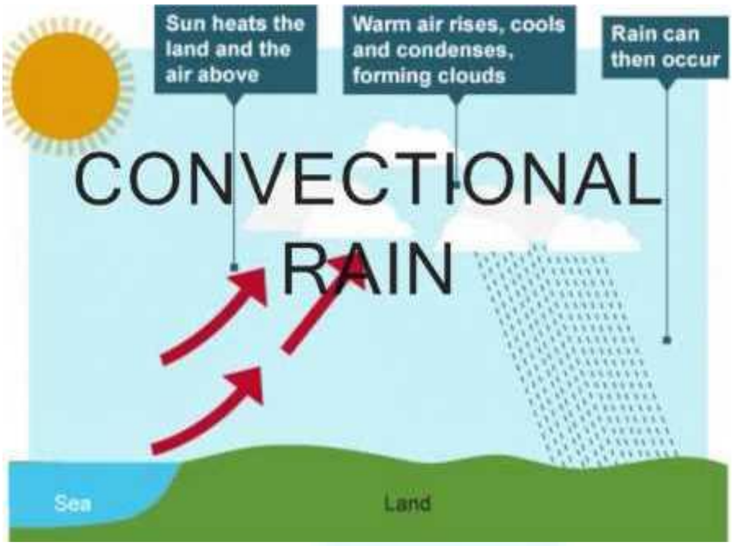
❖ **Hail**

- ➢ Sometimes, **drops of rains after being released by the clouds become solidified into small rounded stone pieces of ice, known as hailstones**
- ➢ Formed by rainwater passing through colder layers hence have several concentric layers of ice, one over the another

❖ **Rainfall**

- ➢ Most common form of precipitation
- ➢ Precipitation in form of water
- ➢ Also known as cloud particles
- ➢ Types of Rainfall

1. **Convectional Rainfall**
    - ➔ Air on being heated becomes light & rises up as conventional currents
    - ➔ As it rises, it loses heat & consequently condensation takes place with the formation of cumulus clouds.
    - ➔ Under these conditions, heavy rainfall takes place along with thunder & lightening, but does not last for long
    - ➔ **Common in Equatorial & Tropical regions in summers daily**



2. Orographic / Relief Rainfall

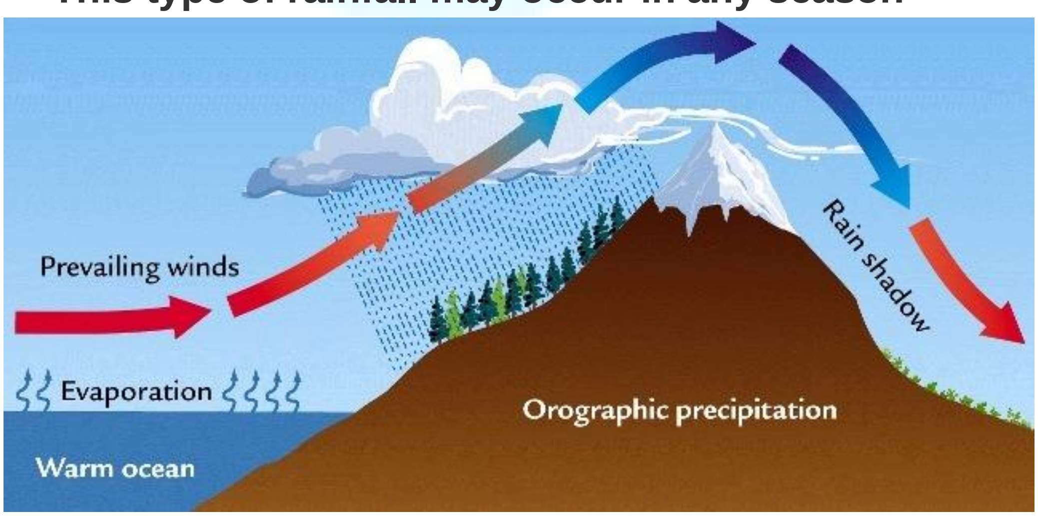
➔ When a **warm & moist air currents is obstructed by a mountain range, it is forced to ascent along its slopes**

➔ It gets cooled while ascending & when it's temp. falls below dew point, it causes rainfall on windward slope of mountain range

➔ However, when these winds cross mountain range & descend along its leeward side

➔ Here, they get warm & dry & causes only little rain (Rain shadow areas)

➔ **This type of rainfall may occur in any season**



3. Cyclonic / Frontal Rainfall

- ➔ **Rainfall associated with cyclone is known as cyclonic/ frontal rainfall**
- ➔ Occurs along the fronts of the cyclone viz. cold front & warm front
- ➔ At the warm front, the warm lighter wind rises gently over the heavier cold air, which being heavy stays close to the ground
- ➔ As the warm air rises, it cools, and the moisture present in it condenses to form clouds altostratus clouds
- ➔ **This rain falls steadily for a few hours to a few days**.