Chapter 9

Solar Radiation, Heat Balance and Temperature

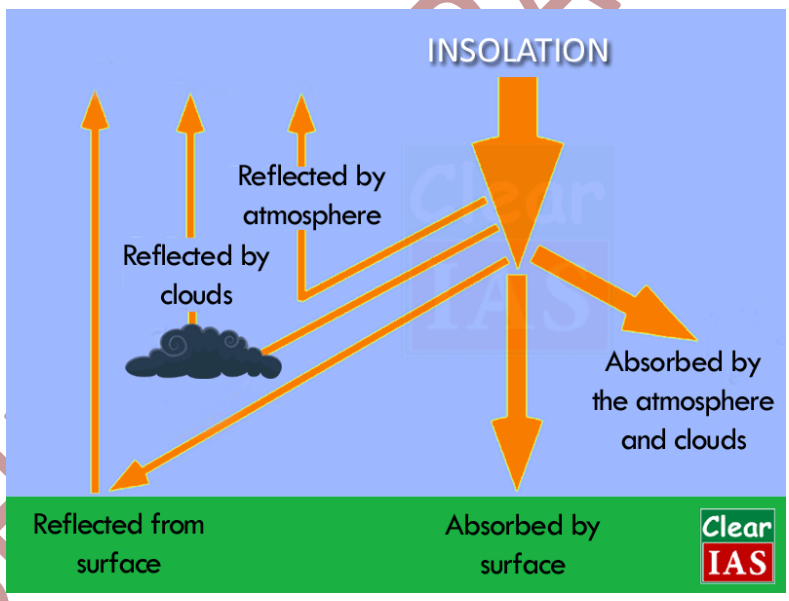
INSOLATION

- The earth receives heat energy from three basic sources viz.

(i) solar radiation,

(ii) gravity, and

(iii) endogenetic forces coming from within the earth but the solar radiation is the most significant source of terrestrial heat energy.



- The earth's surface receives most of its energy in short wavelengths.
- The energy received by the earth is known as incoming solar radiation which in short is termed as insolation. As the earth is a geoid resembling a sphere, the sun's rays fall obliquely at the top of the atmosphere and the earth intercepts a very small portion of the sun's energy.
- The earth receives almost all of its energy from the sun. The earth, in turn, radiates back to space the energy received from the sun. As a result, the earth neither warms up nor does it get cooled over a period of time.

- Thus, the amount of heat received by different parts of the earth is not the same. This variation causes pressure differences in the atmosphere. This leads to the transfer of heat from one region to the other by winds.

DISTRIBUTION OF INSOLATION

- On average, the amount of insolation received at the earth's surface decreases from the equator towards the poles but there is a temporal variation of insolation received at different latitudes at different times of the year. This trend reveals the fact that a sizeable portion of incoming solar radiation is lost while passing through the atmosphere due to cloudiness, atmospheric turbidity (scattering), reflection, and absorption (through ozone)
- A further reveal that maximum insolation reaches the outer limit of the atmosphere at the north pole at the time of summer solstice while maximum insolation is received at the ground the surface between latitudes 300-400 on 21 June because of the minimum amount of cloudiness due to the presence of subtropical high-pressure belt and anti-cyclonic conditions.

FACTORS AFFECTING THE DISTRIBUTION OF INSOLATION

It is apparent from the foregoing discussion that the amount of insolation received at the earth's surface varies significantly (decreases) from the equator towards the poles due to certain astronomical and geographical factors viz,

(i) angle of the sun's rays,
(ii) length of day,
(iii)distance between the sun and the earth,
(iv) sunspots and
(v) effects of the atmosphere.

Which factor is responsible for the varied distribution of energy?

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What is the average amount of energy received by the earth?

In an average the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere.

Give the reasons why it is summer when earth is far away from the sun and winter when it is nearest to the Sun.

- The solar output received at the top of the atmosphere varies slightly in a year due to the variations in the distance between the earth and the sun.
- During its revolution around the sun, the earth is farthest from the sun (152 million km) on 4th July.
- This position of the earth is called aphelion
- . On 3rd January, the earth is the nearest to the sun (147 million km). This position is called perihelion.
- Therefore, the annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July.
- However, the effect of this variation in the solar output is masked by other factors like the distribution of land and sea and the atmospheric circulation.
- Hence, this variation in the solar output does not have great effect on daily weather changes on the surface of the earth.
- Variability of Insolation at the Surface of the Earth

The incoming radiation is not fully reached to the earth surface. Why?

1. The atmosphere is largely transparent to short wave solar radiation. The incoming solar radiation passes through the atmosphere before striking the earth's surface.

2. Within the troposphere water vapor, ozone and other gases absorb much of the near infrared radiation.

3. Very small-suspended particles in the troposphere scatter visible spectrum both to the space and towards the earth surface.

4. This process adds colour to the sky.

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

What is the average distribution of insolation on the surface

- Spatial Distribution of Insolation on the Earth's Surface The insolation received at the surface varies from about 320 Watt/m in the tropics to about 70 Watt/ min the poles
- Maximum insolation is received over the subtropical deserts, where the cloudiness is the least.
- Equator receives comparatively less insolation than the tropics.
- Generally, at the same latitude the insolation is more over the continent than over the oceans. In winter, the middle and higher latitudes receive less radiation than in summe? Give the reasons for such variation

HEATING AND COOLING OF ATMOSPHERE

Name the ways of heating the atmosphere. 1. Radiation 2. Conduction 3. Advection 4. Convection

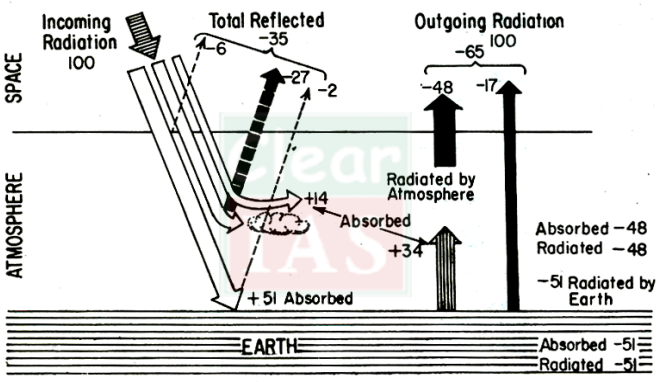
1. Horizontal movement of the air is relatively more important than the vertical movement.

2. In middle latitudes, most of diurnal (day and night) variation in daily weather are caused by advection alone

3. In tropical regions particularly in northern India during summer season local winds called 'loo' is the outcome of advection process.

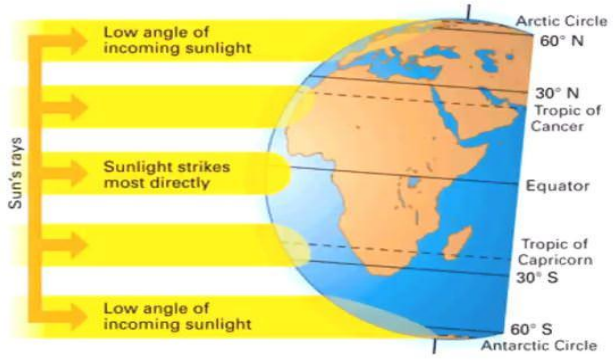
Heat Budget of the Earth

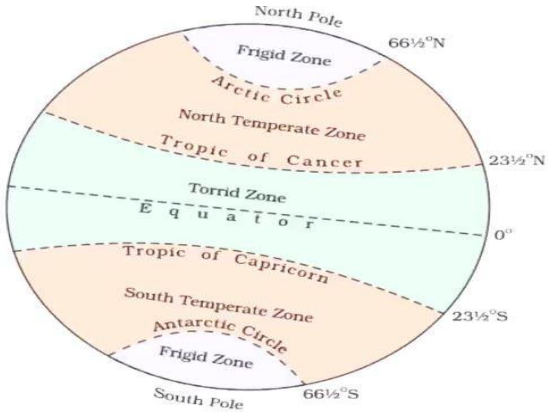
- The earth as a whole does not accumulate or lose heat. It maintains its temperature.



- This can happen only if the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation.

- This balance between the insolation and the terrestrial radiation is termed as the heat budget or heat balance of the earth.





Terrestrial Radiation

1. The insolation received by the earth is in shortwaves forms and heats up its surface.

2. The earth after being heated itself becomes a radiating body and it radiates energy to the atmosphere in long wave form.

3. This energy heats up the atmosphere from below.

4. This process is known as terrestrial radiation.

5. The long wave radiation is absorbed by the atmospheric gases particularly by carbon dioxide and the other green house gases. Thus, the atmosphere is indirectly heated by the earth's radiation

TERRESTRIAL RADIATION

1. The earth radiates back 51 units in the form of terrestrial radiation.

2. 17 units are radiated to space directly

3. the remaining 34 units are absorbed by the atmosphere

4. 6 units absorbed directly by the atmosphere,

5. 9 units through convection and turbulence

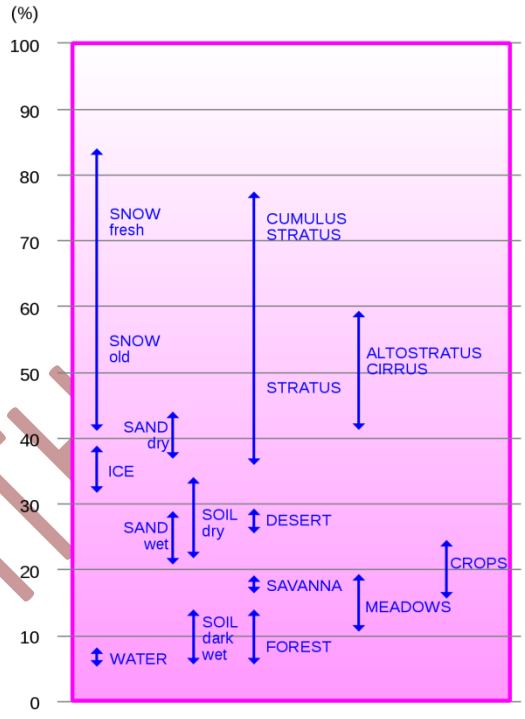
6. 19 units through latent heat of condensation

7. 48 units absorbed by the atmosphere (14 units from insolation +34 units from terrestrial radiation) are also radiated back into space.

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. This is termed the heat budget or heat balance of the earth.

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

What is Albedo?



• Albedo is the portion of solar energy reflected from the surface of the Earth back into space. It is a reflection coefficient and has a value of less than one.

• When the solar radiation passes through the atmosphere, a certain amount of it is scattered, reflected and absorbed. The reflected sum of radiation is called the albedo of the earth.

• Albedo is an important concept in climatology, astronomy, and environmental management.

• It plays a major role in the energy balance of the earth's surface, as it defines the rate of the absorbed portion of the incident solar radiation

Values of Albedo

• Different surfaces have different values.

• Albedo is higher in Snow or Ice.

Types of Albedo

There are two types of Albedo:

Terrestrial Albedo

• The measurement of Earth's albedo is known as Terrestrial Albedo.
• The Terrestrial Albedo of Earth around 0.31 which is about two-thirds of the solar radiation reaching the Earth.

• This figure (0.31) is dependent on many factors like an ocean, forest, clouds, deserts etc.

Astronomical Albedo

• Astronomical albedo is the measure of the reflectivity of planets (excluding Earth), asteroids and other celestial bodies the albedo is an indicator of the surface and atmospheric characteristics of a celestial body.

• It is important in the study of astronomy.

How does the Albedo of Earth affect Climate? Albedo and Global Warming

The difference in the average albedo of Earth has an important influence on the temperature of the Earth.

• If the average albedo is lower than the previous year's albedo, it specifies that the amount of radiation absorbed is higher

• This results in the rise in the temperature of the Earth.

• Earth's albedo is constantly measured using satellites to monitor global warming.

WHAT IS THE DIFFERENCE BETWEEN HEAT AND TEMPERATURE

Temperature

The interaction of insolation with the atmosphere and the earth's surface creates heat which is measured in terms of temperature.

While heat represents the molecular movement of particles comprising a substance, the temperature is the measurement in degrees of how hot (or cold) a thing (or a place) is.

Factors Controlling Temperature Distribution

The temperature of air at any place is influenced by

(i) the latitude of the place;

(ii) the altitude of the place;

(iii) distance from the sea, the air mass circulation;

(IV) the presence of warm and cold ocean currents;

(v) local aspects.

1. The latitude: The temperature of a place depends on the insolation received. It has been explained earlier that the insolation varies according to the latitude hence the temperature also varies accordingly

2. The altitude: The atmosphere is indirectly heated by terrestrial radiation from below. Therefore, the places near the sea-level record higher temperature than the places situated at higher elevations. In other words, the temperature generally decreases with increasing

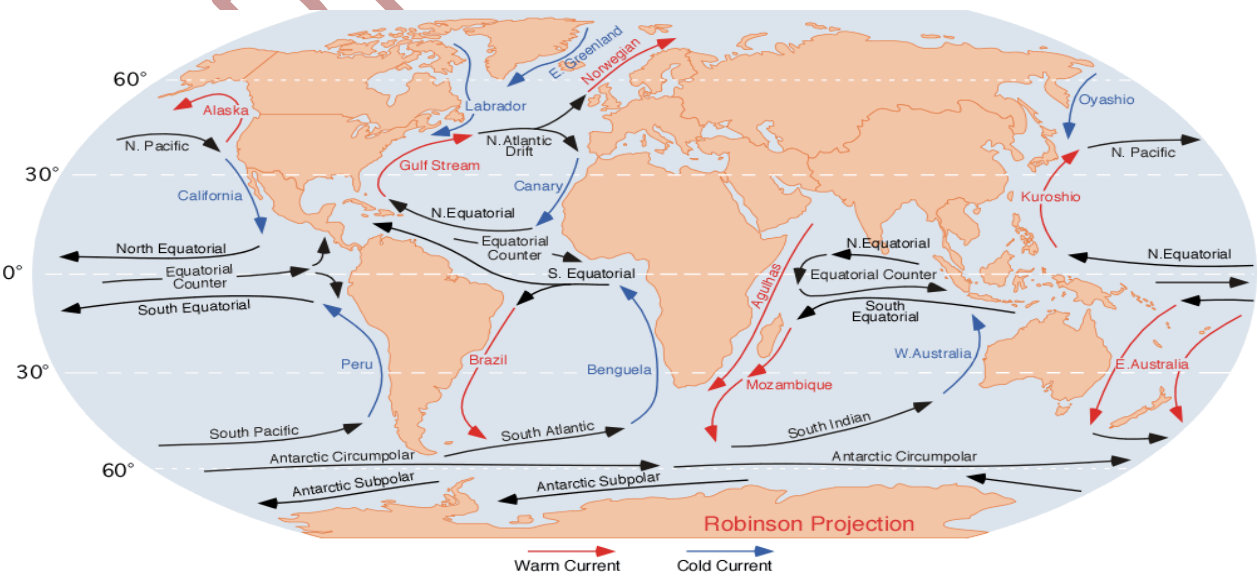
height. The rate of decrease of temperature with height is termed as the normal lapse rate. It is 6.5°C per 1,000 m.

Distance from the sea: Another factor that influences the temperature is the location of a place with respect to the sea. Compared to land, the sea gets heated slowly and loses heat slowly. Land heats up and cools down quickly. Therefore, the variation in temperature over the sea is less compared to land. The places situated near the sea come under the moderating influence of the sea and land breezes which moderate the temperature.

Air-mass: 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.

Ocean Currents

The movements of water in oceans can be categorized into currents, waves, and tides. Among these, ocean currents are the large masses of surface water that circulate in regular patterns around the oceans.



Ocean Current

- Depending upon their temperature, ocean currents can be classified into warm currents and cold currents.
- Warm currents flow from equatorial regions towards the polar regions and hence have a higher surface temperature. [from lower latitudes to higher latitudes]
- These currents flow in the clockwise direction in the northern hemisphere and in the anti-clockwise direction in the southern hemisphere.
- Cold currents flow from polar regions towards the equator and have a lower surface temperature [from higher latitudes to lower latitudes].
- They flow in the anti-clockwise direction in the northern hemisphere and in the clockwise direction in the southern hemisphere

Factors responsible for Ocean Currents

The following are the factors responsible for ocean currents

- The Planetary winds,
- Temperatures,
- Salinity,
- The earth s rotation,
- Obstruction from land

The Planetary winds

- The general distribution of winds in the lower atmosphere is called as Planetary winds.
- The Earth's atmosphere is divided into permanent pressure belts - The Equatorial low-pressure belt, The Sub-tropical high-pressure belt, Sub polar low-pressure belt and Polar high-pressure belts.

The planetary winds are permanent winds that blow from one pressure belt to the other.

- Accordingly, they have been divided into - Tradewinds, Westerlies and Polar Easterlies. The Planetary winds are probably the dominant influence on the flow of ocean currents.
- The oceanic circulation pattern roughly corresponds to the earth s atmospheric circulation pattern.

Temperature

- The differential heating of the Sun at the equator and the poles causes a difference in the temperature of ocean water.
- At the equator, since the temperature is higher the ocean water gets heated up and expands.
- This makes the warm water lighter and hence rises while at the poles, cold water is denser and sinks.
- Warm water from the equator slowly moves along the surface towards the poles, while the cold water from the poles slowly creeps along the bottom of the sea towards the equator.
- Hence, the difference in heating and surface temperatures play a key role in movements of ocean water.

Salinity

- The density of water also depends on its salinity and the salinity of water varies from place to place. Waters of low salinity flow on the surface of waters of high salinity while waters of high salinity flow at the bottom

The earth's rotation and Coriolis force

The earth's rotation deflects moving objects to the right and ocean currents are no exception. Under the action of Coriolis force, the movement of ocean currents in the northern hemisphere is in the

clockwise and in the southern hemisphere it is in the anti-clockwise direction. Hence it can be said that ocean currents obey Ferrel's law.

Obstruction due to land

A land mass obstructs the direction of flow of ocean current and divides the ocean current which in turns flow in a different direction. Example: The south equatorial current in the Atlantic Ocean is obstructed by South American continent and the South equatorial current divides to create the Brazilian current which flows in the south Atlantic Ocean.

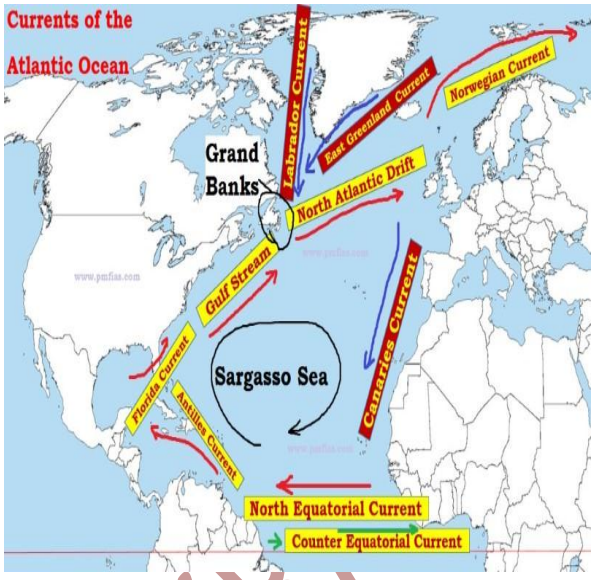
Currents in the Pacific Ocean

- North Equatorial Current (Warm)
- South Equatorial Current (Warm)
- Counter Equatorial Current (Warm)
- Kuroshio System (Warm)
- Oyashio Current (Cold)
- California Current (Cold)
- Peruvian or Humboldt Current (Cold)
- East Australia Current (Warm)
- North Pacific Drift (Warm)

Currents in the Atlantic Ocean

- **Currents in the Indian Ocean**
- The North East Monsoon Drift

- The South West Monsoon Drift
- North Equatorial Current (Warm)
- South Equatorial Current (Warm)
- Somali Current (Cold)
- Mozambique Current (Warm)
- Madagascar Current (Warm)
- Agulhas Current (Warm)
- West Australian Current (Cold)



Currents in the Indian Ocean

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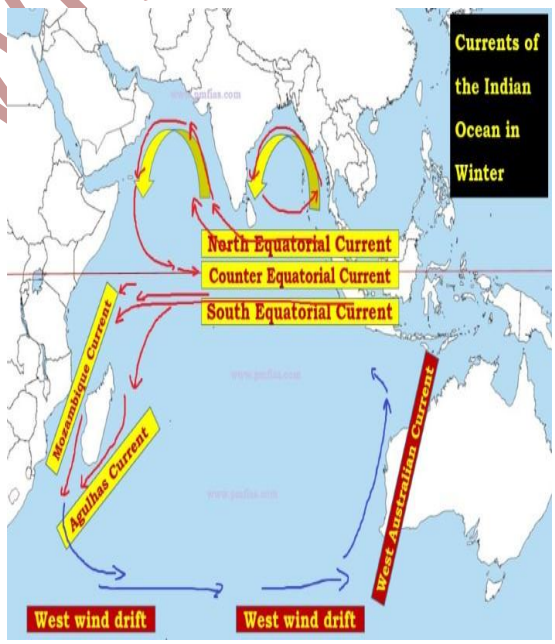


Impact of Ocean Currents

Local Climate

• Warm and Cold currents affect the local climate of a region.

• For example, the Gulf Stream which is driven to the western coast of Europe as the North Atlantic Drift keeps the coasts of North Sea warm which is unusual for such high latitudes.

• Similarly, the warm waters of the Kuroshio current in the North Pacific ocean are carried as the North Pacific Drift keeping the ports off the Alaskan coast ice-free in winter

Rains and Desert Formation

• Warm ocean currents bring rains to the coastal regions and also the interiors while cold currents do not.

• Warm currents flow along the east coast of continents in tropical and sub-tropical latitudes resulting in warm and rainy climates while cold currents flow along the west coast of continents.

• Cold currents are one of the reasons why deserts are located the western margins of continents in the sub-tropical belts.

• For example, Californian current which is a cold current brings a dry and desert type of climate to the region.he Alaskan coast ice-free in winter.

Fishing grounds

• The mixing of warm and cold currents help to replenish the oxygen and favour the growth of planktons which is the regions are rich in microscopic marine plants and animals.

• These are crucial for the survival of marine ecosystems.

• Hence these regions form excellent fishing grounds as phytoplankton is the primary source of food for the fish.

• For example, the Great Banks near Newfoundland is formed by the mixing of cold Labrador current with the warm Gulf Stream

Navigation

• The atmospheric circulation of the winds and the oceanic circulation of the currents are almost coincidental and together they aid in the navigation of the ships.

• Ocean currents flow for great distances and together with the winds create a conveyor belt kind of system for navigation of the ship

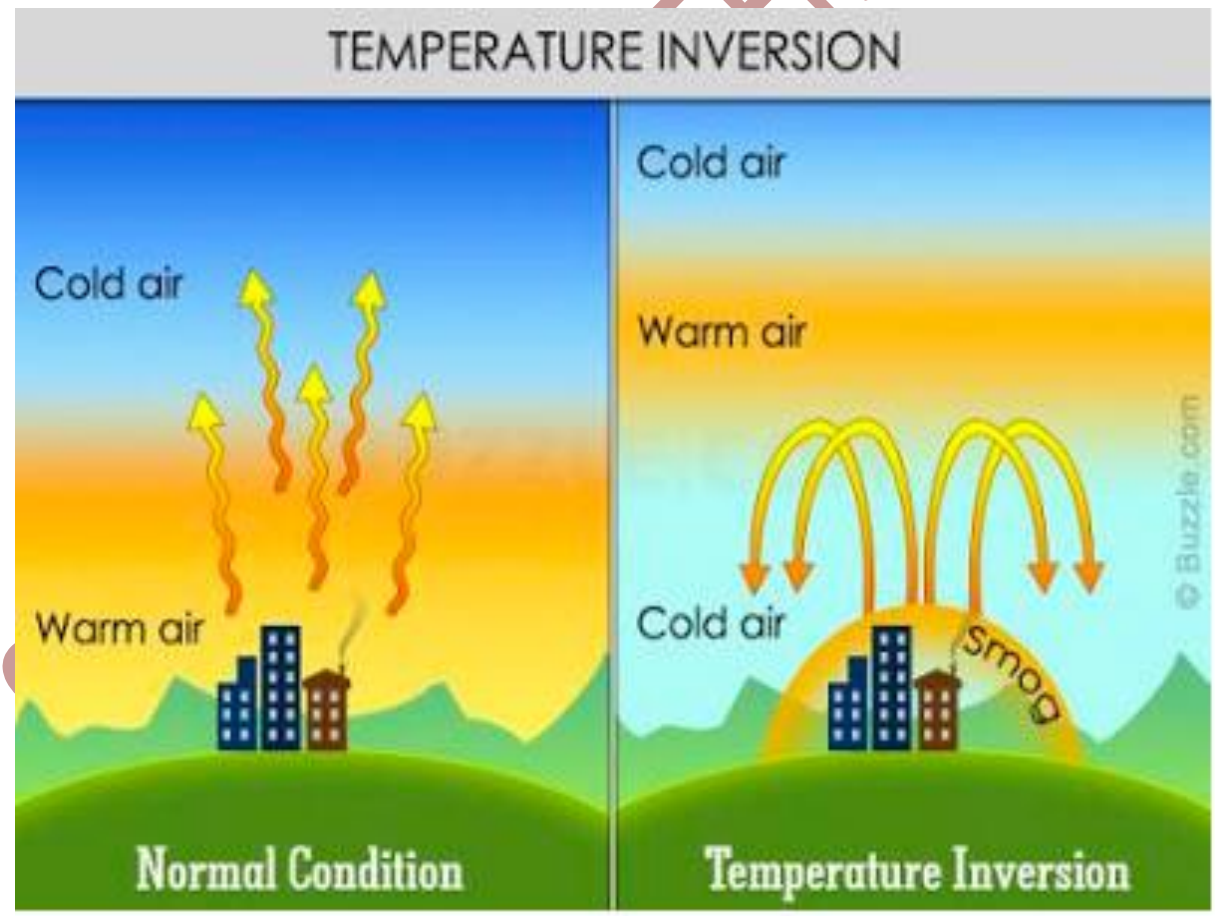
Temperature Inversion And Its Effects on weather

- Ideally, with an increase in height, temperature decreases.
- Under normal situations, in the troposphere, the temperature of the atmosphere decreases with an increase in the altitude at the rate of 1 degree for every 165 meters which are called normal lapse rate.
- However, there are certain conditions when the temperature increases with height instead of decreasing which is contrary to the ideal situation.
- This contradictory phenomenon is called temperature inversion.

Temperature Inversion

- The cool layer of air is overridden by a warm layer of air above in te There are certain ideal conditions for temperature inversion.
- Calm and stable air, Long nights and Clear skies are those conducive factors which give rise to a temperature inversion

- This phenomenon of temperature inversion occurs in mountainous areas during winters.
- During long winter nights, due to high pressure, cold air on the mountains seeps down and occupies valley floors.
- Hence the warm air is pushed upwards as a consequence.
- This gives rise to temperature inversion when the layers of warm and cold air are formed
- There are different types of Temperature inversion such as Air drainage type inversion, Surface temperature inversion, Advection type of temperature inversion, ground, turbulence, subsidence, frontal and Upper surface Temperature inversion



Types of Temperature Inversion

- **Frontal Temperature inversion**:
  When warm and cold fronts meet, the warm front rises above and the cold front being heavier sinks. Hence a series of layers are formed. It often occurs in the temperate zone and causes anticyclonic conditions which result in precipitation in different forms. Frontal or cyclonic inversion is caused in the temperate zones due to temperate cyclones which are formed due to the convergence of warm westerlies and cold polar winds in the northern hemisphere.
- **Vertical advection**:
  At valleys where the air in the valley gets heated and rises resulting in colder air from the slopes to sink to the bottom, a temperature inversion is formed. Valley inversion occurs in the mountainous valleys due to radiation and vertical movement of air. This is also called vertical advection inversion of temperature.
- **Radiation Inversion**:
  During the day, the sun heats the earth and air near it. At night, the ground and the air near it cool faster than that high up, creating an inversion of temperature. This is also called as non-advection inversion because it occurs in static atmos pheric condition as there is no movement of air whether horizontal or vertical
- **Subsidence Inversion**:
  It is associated with anticyclones. This kind of temperature inversion results when the upper layer of air descends during a developing anticyclone.

Effects of Temperature Inversion on weather and habitats

- Fog is formed due to the situation of warm air above and cold air below, and hence Visibility is reduced due to the formation of fog. This causes a lot of problem to the people, particularly in the transportation, as flights and trains are cancelled due to low visibility. Highways get blocked due to the slow movement of vehicles.
- It causes frost when the condensation of warm air due to its cooling by cold air below occurs at a temperature below freezing point. Temperature Inversion also determines precipitation, cloud forms etc.
- It causes atmospheric stability which stops upward and downward movements of air.
- Diurnal variations in temperature are affected due to temperature inversion.
- Diffusion of air pollutants is limited in case of temperature inversion, and hence stagnation in weather is witnessed for some period.
- The convective clouds cannot grow high enough, and hence there are no showers, hence less rainfall. This causes problems in agriculture and its productivity.
- Valleys may become very cold due to temperature inversion. People have to face cool weather and hence migrate up to the hills.
- It may disturb the radio signals in the region as more of it is refracted from layers above the cold air.
- It can also lead to violent thunderstorm if the temperature inversion is broken.
- Sometimes, it also decreases the amount of sunlight reaching the ground due to the formation of cumulous clouds.