Unit 6

Atmosphere

Chapter Outline

6.1 Introduction
6.2 Composition of the Atmosphere
6.3 Temperature and Heat Budget
6.4 Atmospheric Pressure and Winds
6.5 Humidity, Condensation and Clouds
6.6 Precipitation
6.7 Atmospheric Disturbances (Cyclone and Anti Cyclone)

Learning Objectives:

Students must be able to

- *Understand the composition and nature of atmospheric layers.*
- *Understand the vertical and horizontal distribution of temperature in the atmosphere.*
- *Explain the mechanism of formation of various wind systems of the world.*
- *Identify various forms and types of precipitation.*

6.1 Introduction

You must have heard people, in the countryside, saying

"When sheep collect and huddle,
Tomorrow will puddle!"
"If ants march in a straight line,
expect rain"

Phrases like 'a cold morning', 'sunny day', 'cloudy day' and rainy day refer to the weather. Weather refers to the state of atmosphere at a particular place at any given time denoting the short term variations of atmosphere in terms of temperature, pressure, wind, moisture, cloudiness, precipitation and other elements. Weather is highly variable from time to time, day to day and place to place. Weather is not constant. It is always changing within hours or a day.

On the other hand, climate is the average weather conditions of an area for a long period of time. The World Meteorological Organisation (WMO) has suggested data for a period of 30 consecutive years to be referred for calculating the climatic averages of various weather elements. Climate is constant. It is a permanent condition of a place.

The ancient Greeks called the tilt of latitude as '***klima***', literally meaning 'slope' or 'inclination'. Then the earth was divided into seven latitudinal regions, called '***klimata***'. The word came into modern European languages as clime or 'climate', denoting the average weather condition.

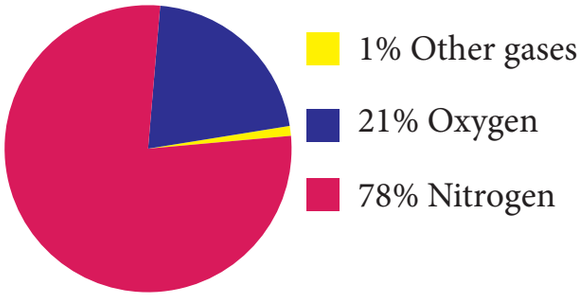


Figure 6.1 Components of Atmosphere

6.2 Composition of the Atmosphere

The atmosphere is essential for the survival of all the organisms on the earth. The atmosphere is a blanket of gases and suspended particles that entirely envelope the earth. It extends outward over thousands of kilometres from the earth's surface. Water vapour, aerosols and tiny solid particles occur in varying quantities as suspended material. These are responsible for weather phenomena as they have ability to absorb and release heat energy.

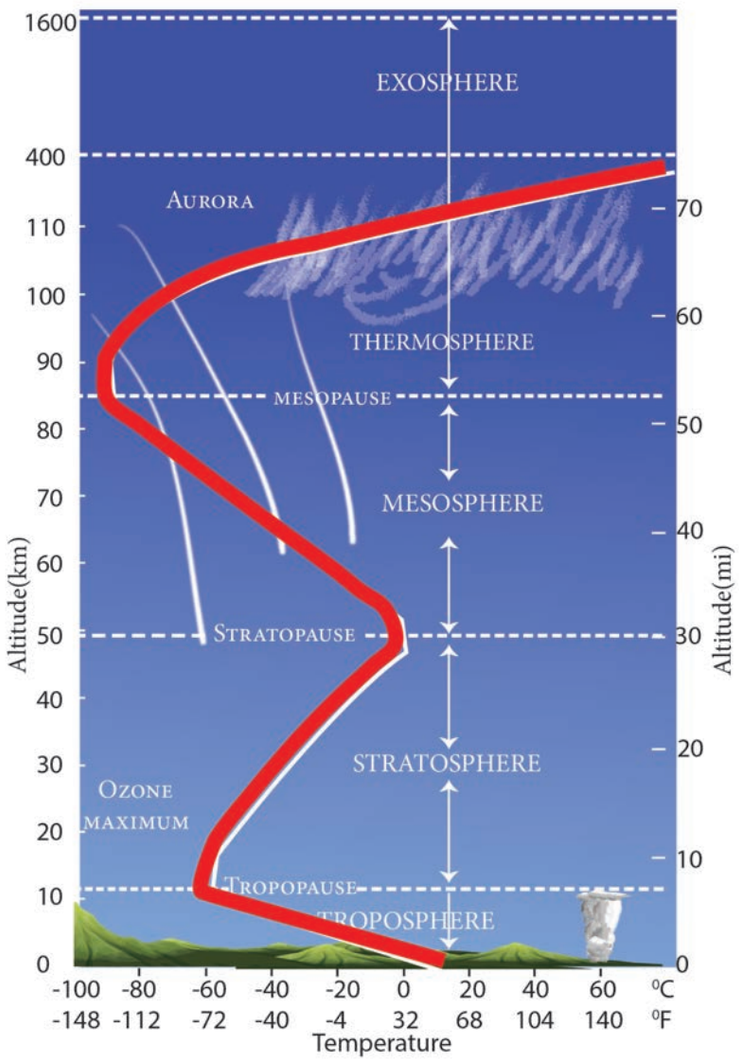


Figure 6.2 Structure of the Atmosphere

The atmosphere is composed of mixture of many gases, water vapour and other solid particles. The major components are nitrogen (78%), oxygen (21%) and other gases (1%). Argon, Carbon dioxide, Neon and the other gases found in the atmosphere (Figure 6.1).

6.2.1 Layers of the Atmosphere

The atmosphere is divided into five distinct layers (Figure.6.2) based on the temperature variations. They are,

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Thermosphere
5. Exosphere

1. Troposphere

The troposphere is the lower most layer of the atmosphere. It extends approximately to a height of 8 km from the poles and 18 km from the equator. The height of the troposphere changes seasonally also. It increases during summer and decreases during winter.

All weather phenomena occur in this layer as it has dust particles and water vapour. This layer has clouds which produce precipitation on the earth. The Sun's rays directly fall on the earth and then they are reflected back into the atmosphere. The temperature decreases in the troposphere with increase in altitude at the rate of 1 °C for 165 metre or 6.5 °C for every 1000 metres of ascent. This is known as **lapse rate of temperature**. This is the densest layer as it contains 70 to 80 percent of gases. The outer boundary of the troposphere is called tropopause, which is about 1.5 km thick.

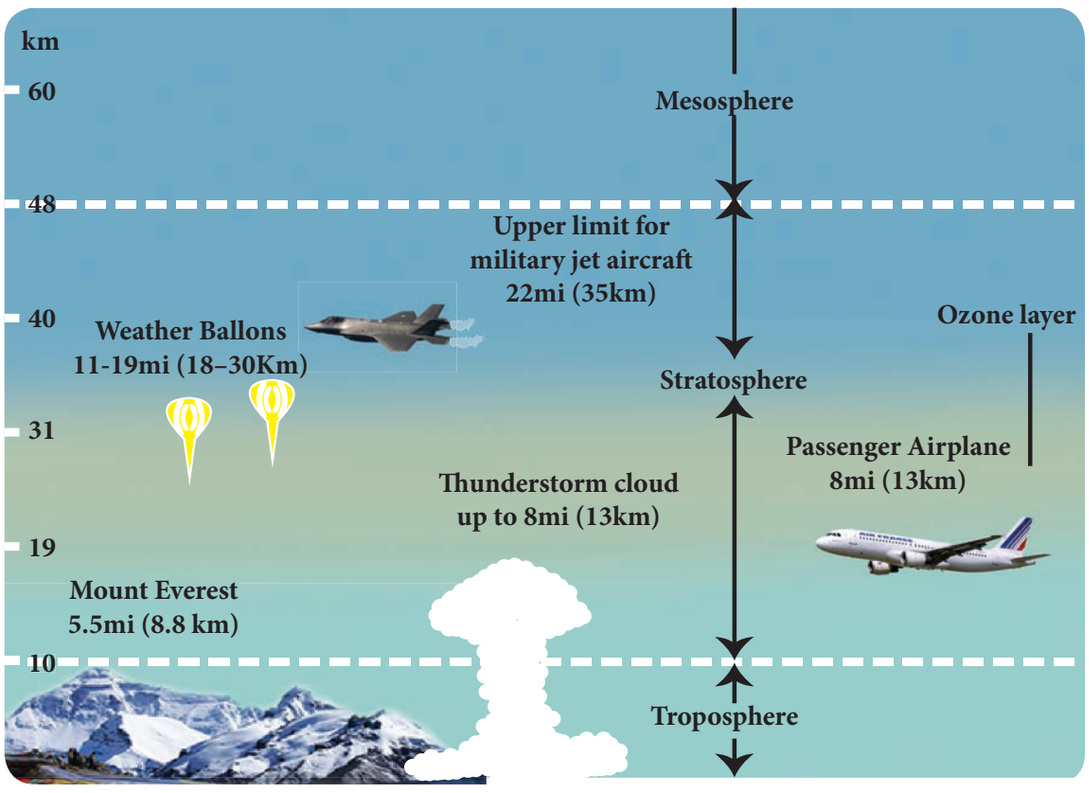


Figure 6.3 Stratosphere

2. Stratosphere

It is the second layer of the atmosphere found above the troposphere. It approximately extends up to a height of 50 km from the earth's surface. Temperature is constant up to a height of 20 km and increases gradually up to the stratopause where temperature is nearly -4°C. The lower part of this layer is highly concentrated with ozone gas which is called as '**ozonosphere**'. It prevents the ultra-violet rays from the Sun to enter into the lower part of the atmosphere as the rays are highly harmful it causes skin cancer and other ill effects to living organisms. But the ozone layer safeguards the life on the earth.

3. Mesosphere

The mesosphere is the third layer of the atmosphere found approximately up to a height of 80 km above the surface of the earth. It is the coldest layer of the atmosphere. The temperature decreases with increase of altitude due to the absence of ozone. Its upper boundary is called **mesopause** where temperature reaches −90°C. Luminous noctilucent clouds form here due to the presence of cosmic dust. Meteors falling from the space get burned in this layer. It is because when meteors hit the air, the air gets compressed and heated up causing meteors to burn out.

HOTS

Why is Mesosphere the coldest layer?

4. Thermosphere

The ionosphere is the fourth layer of the atmosphere extending approximately up to a height of 400 km. The temperature increases rapidly up to 1,000°C. It is due to the absorption of very short wave and high energy solar radiation by the atoms of hydrogen and oxygen gases. When light energy is transformed into heat energy, some gas molecules lose or gain electrons and become the charged particles called ions. The charged particles forming the lower part of the thermosphere as a zone, is called Ionosphere (Figure 6.4). These ionised particles create auroras at higher latitudes. Ionosphere can reflect radio waves back to the earth. This facilitates long distance wireless satellite communication. The credit of discovering ionosphere goes to Hennelly and Heaviside.

5. Exosphere

The upper most layer of the atmosphere which extends into the outer space from above 400 km up to 1600km. It has rarefied contents. It contains mainly oxygen and hydrogen atoms. These atoms can travel hundreds of kilometres without colliding with one another. Thus, the exosphere has no longer behaves like a gas. The temperature increases with increase of altitude and it ranges as high as 165 °C. The gravitational pull is minimal in this layer. This layer gradually merges with the space.

Ozone and Ozone Depletion

Ozone (O_3) is form of oxygen that combines three atoms into each molecule. It absorbs and filters the harmful ultraviolet B radiation coming from the sun. This way the ozone layer protects all life on earth. However, ozone is harmful when it develops near the ground. It causes health problems like asthma and other respiratory illness.

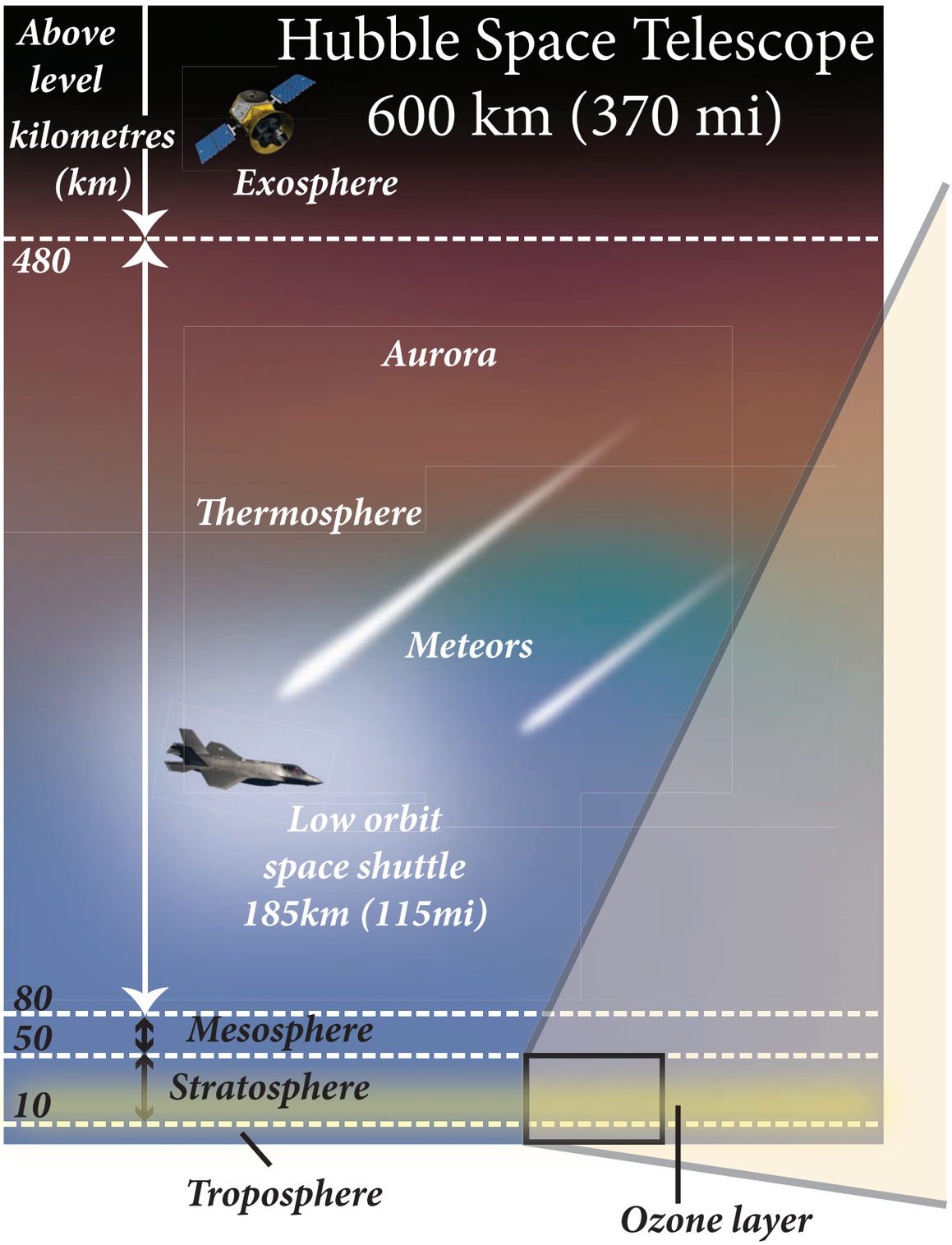


Figure 6.4 Thermosphere

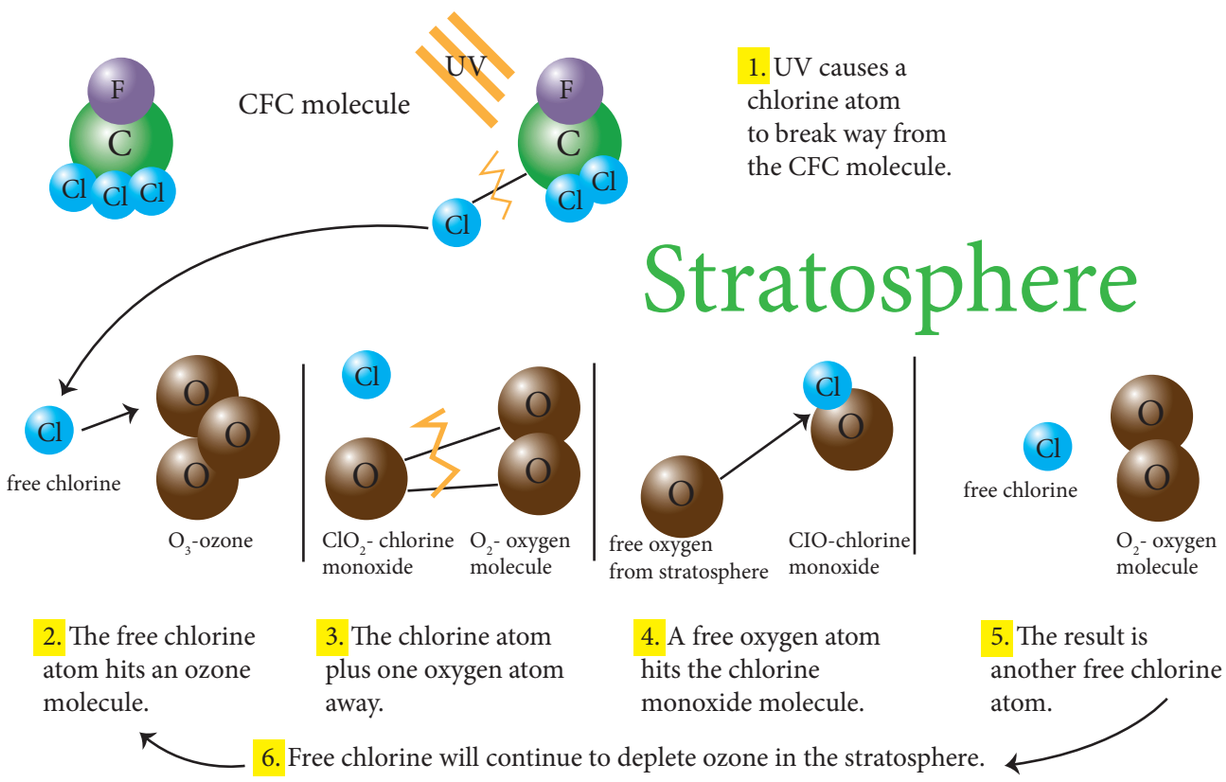
Ozone Depletion: A steady decline in the concentration of **ozone** in the earth's stratosphere is called ozone depletion.

Ozone depletion occurs when chloro fluoro carbon (CFC) and halon gases, formerly found in aerosol spray cans and refrigerants are released into the

atmosphere and they cause chemical reactions that break down **ozone** molecules and reduce the concentration of them. Nitrogen oxide released by emitted by supersonic aircrafts can also destroy the ozone molecules to break down. Ozone-depleting substances are present throughout the stratospheric ozone layer because they are transported great distances by atmospheric air motions. The severe depletion of the Antarctic ozone layer known as the "ozone hole" occurs because of the special atmospheric and chemical conditions that exist there and nowhere else on the globe. The very low winter temperatures in the Antarctic stratosphere cause polar stratospheric clouds (PSCs) to form. Special reactions that occur on PSCs, combined with the relative isolation of polar stratospheric air, allow chlorine and bromine reactions to produce the ozone hole in Antarctic springtime.

Satellite images of the earth over last decades observed that the atmospheric ozone layer is getting thinner. On October 2, 2015, the ozone hole was recorded to its maximum size of **28.2 million sq.km** over Antarctica (Figure 6.5). The size of the ozone hole is larger than the size of continent of North America. The ozone holes over Antarctica allow the ultraviolet radiation to enter and cause of global warming, skin cancer, eye cataract and even blindness.

Depletion of the **ozone layer** has consequences on human, animal, plants and micro organisms. This typically results from higher UV levels reaching us on earth. Research confirms that high levels of UV rays cause non-melanoma skin cancer.



To protect the ozone layer for our future generation, avoid using products which are emitting pollutants such as aerosol sprays, blowing agents for foams and packing materials, as solvents and as refrigerants.

The Dobson Unit (DU) is the unit of measurement for total ozone.

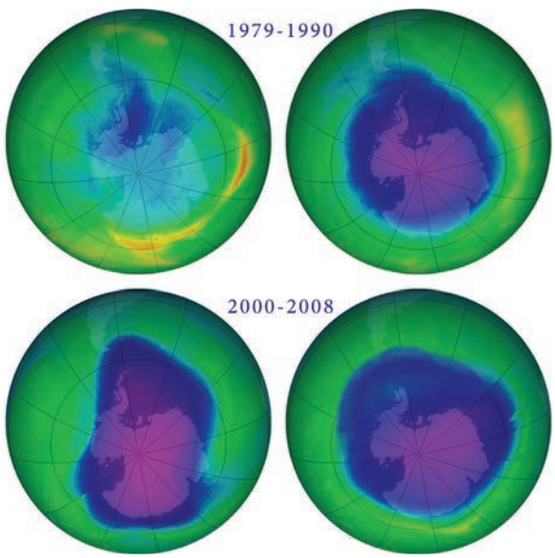


Figure 6.5 Spread of Ozone hole

6.3 Temperature and Heat Budget

Air temperature of a particular place denotes the degree of hotness or coldness of air at a given place. It is measured in Celsius. Let us understand how the earth is heated. The surface of the earth is heated by the sun's rays in the form of short wave radiation. The heat received by the earth is called 'Solar Radiation' or 'Insolation'. Heating of atmosphere is an indirect process. The processes are:

a. Terrestrial radiation

The solar radiation reflected by the earth's surface is called 'Terrestrial radiation'. Terrestrial radiation supplies more heat energy to the atmosphere due to its long wave length.

b. Conduction

The heat energy from the earth's surface is transferred to the lower atmosphere which is directly in contact with the surface by the process of conduction.

c. Convection and advection

The movement of air molecules in vertical and horizontal direction is called as 'convection and advection' respectively. This movement carries heat energy to the various parts of the earth and at different altitudes.

Heat budget

The heat energy reflected, absorbed and radiated back into the space equals the energy received by the earth. Incoming radiation and the outgoing radiation pass through the atmosphere. The earth maintains its optimum temperature.

When 100% solar radiation reaches the earth's atmosphere, 35% is reflected back to space by clouds, water bodies and ice covered areas. This heat does not heat either the earth or atmosphere.

Of the remaining 65% of heat, 14% are absorbed by the atmosphere and 51% are absorbed by the earth's surface (34% of direct solar radiation and 17% from scattered radiation). 51% received by the earth are radiated back to the space directly as terrestrial radiation (Figure 6.6).

In total, 17% are radiated to space directly and 48% are absorbed by the atmosphere (14% from insolation and 34% from terrestrial radiation) are radiated

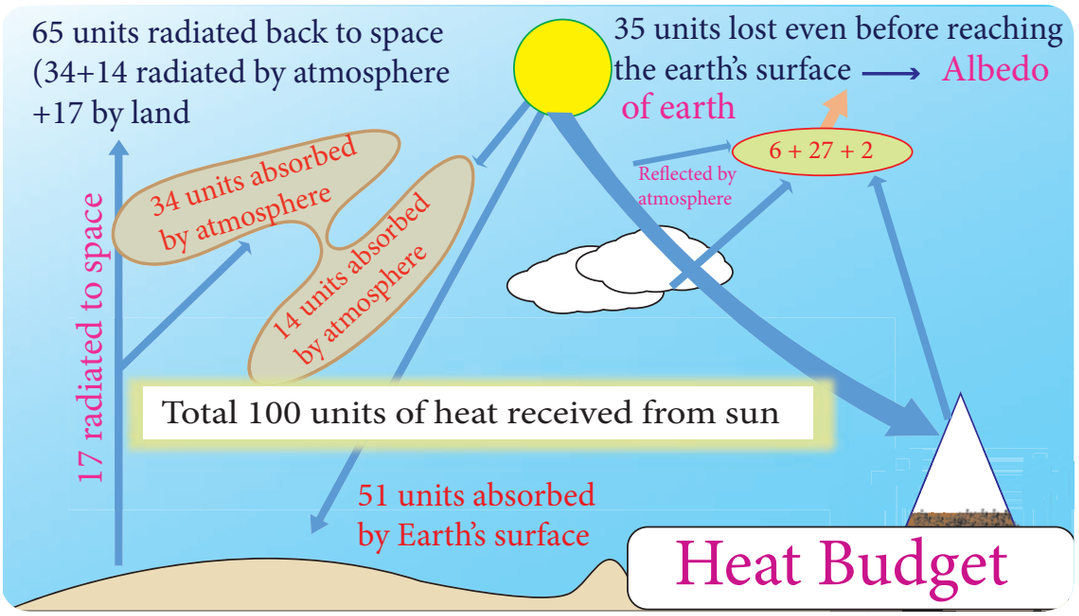


Figure 6.6 Heat Budget

back to space gradually. Therefore, 65% heat received from the sun is balanced by the 65% radiated by the earth. This balance between the incoming and the outgoing heat energy is called the **global heat energy balance**.

Distribution of Temperature

Distribution of temperature varies both horizontally and vertically. Let us study it under

a. Horizontal Distribution of Temperature
b. Vertical Distribution of Temperature

A) Horizontal Distribution of Temperature

Distribution of temperature across the latitudes over the surface of the earth is called horizontal distribution of temperature. On maps, the horizontal distribution of temperature is commonly shown by isotherms. **Isotherms** are line connecting points that have an equal temperature at mean sea level.

The average time taken by the solar radiation to reach the earth's surface is 8 minutes 20 seconds.

6.3.1 Factors Affecting the Horizontal Distribution of Temperature

The horizontal distribution of temperature on the earth's surface varies from place to place. Following are the factors affecting the horizontal distribution of temperature of the earth:

a. **Latitude:** The angle formed by the solar radiation to the ground is called 'angle of incidence'. The solar radiation passes vertically along the equator. The angle of incidence decreases from equator towards the poles. The area heated by the solar radiation increases towards the poles and therefore, temperature decreases from the equator to the poles.

b. **Distribution of land and water:** Land is heated and cooled at a faster rate due the conduction process whereas water is heated and cooled at slower rate due to convection process. Water takes 2.5 times of heat energy to heat a unit area compared to land. Thus, the land will have higher temperature than the water in summer and vice versa during the winter. So more land mass in northern hemisphere (15.2°C) leads to higher average temperature than the southern hemisphere (13.3°C).

c. **Ocean currents:** Warm ocean currents carry warm water from the tropical region towards the poles and increase the temperature while cold ocean currents carry cold water from Polar Regions and reduce the temperature along the coasts.

d. **Prevailing winds:** Warm winds like trade wind and westerly, that carry higher heat energy, increase the temperature while cold polar easterlies carry lower heat energy from polar region reduces the temperature.

e. **Cloudiness:** The cloudy sky obstructs the solar radiation from the sun to earth and reduces the temperature. But the clear sky during the day allows more solar radiation to reach the earth's surface and increases the temperature. Meanwhile clear sky at night allows more terrestrial radiation to escape. For example, the tropical hot deserts experience higher temperature at day and lower temperature at night.

f. **Nature of the surface:** The reflection from surface varies based on the nature of land cover. The more reflection from the snow surface leads to low temperature accumulation. But the dense forest, which reflects less heat energy and absorbs more heat energy, leads to higher temperature.

g. **Mountain barriers**: If a wind or air mass blows towards the mountain, it influences the distribution of temperature on either side of the mountain.

For example, polar easterlies and blizzards are obstructed by Himalayas in Asia and Alps in Europe respectively. This leads to lower temperature in the northern slopes and higher temperature in the southern slopes of the respective mountains.

6.3.2 Factors Affecting the Vertical Distribution of Temperature

We all know that the temperature decreases with increasing altitude from the surface of the earth. The vertical decrease in temperature of troposphere is called as 'Normal Lapse Rate' or 'vertical temperature (Figure 6.7) gradient' at which the temperature reduces at the rate of 6.5 °C per 1000 meter of ascent. This is influenced by the following factors:

a. Amount of terrestrial radiation reaching the altitude and

b. Density of air to absorb the heat energy at higher altitude.

As both the above said factors decrease with altitude, the temperature also decreases (Figure 6.5).

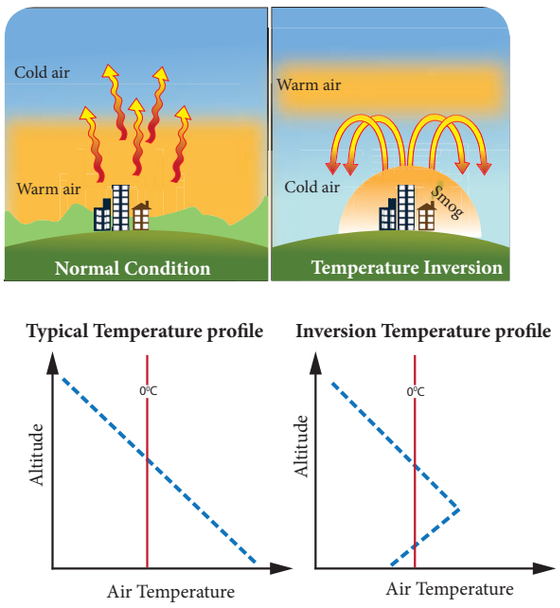


Figure 6.7 Vertical distribution of Temperature

Student Activity

If the temperature of Chennai (7 m) is 34°C, calculate the temperature of Kodaikanal (2133m) using normal lapse rate.

6.3.3 Inversion of Temperature

The condition at which the temperature increases with altitude is called as 'inversion of temperature'. In this condition, warm air lies over cold air.

The conditions for inversion of temperature are:

a. **Long winter nights:** The bottom layer of the atmosphere in contact with the ground is cooled and the upper layer remains relatively warm.

b. **Cloudless sky:** The higher amount of terrestrial radiation reaches the higher altitude which leads to lower temperature at low level due to clear sky.

c. **Dry air near the surface:** the dry air absorbs less terrestrial radiation and allows them to escape into space.

d. **Snow covered ground:** During night, due to terrestrial radiation and higher albedo, most of the heat is lost to the atmosphere and the surface is cooled.

e. **Formation of fronts:** the movement of warm air over the cold air during the formation of the various fronts leads to inversion condition.

f. **Mountain wind:** The subsidence of cold mountain wind at the early morning leads to the displacement of warm air from the valley to higher altitude. This type of inversion is called as 'valley inversion'.

Albedo is the amount of solar radiation reflected from the surface. The variation is based on the nature of the earth's surface. Snow has higher albedo compared to forest.

6.3.4 Measurements of Temperature

Unit of Temperature	Scientist	Year
Fahrenheit	Gabriel Fahrenheit	1714
Celsius	Andrew Celsius	1742
Kelvin	Lord Kelvin	1848

Conversion of Units

Celsius to Fahrenheit

Ex. 20°C

$F = (C \times 1.8) + 32$

$F = (20 \times 1.8) + 32$

$F = 36 + 32$

$F = 68$

∴ 20°C = 68°F

Celsius to Kevin

Ex.20°C

$K = C + 273.15$

$K = 20 + 273.15$

$K = 293.15$

∴ 20°C = 293.15K

6.3.5 Heat Zones of the World

The earth has been divided into three heat zones according to the amount of insolation received. These are the Torrid Zone, the Temperate zone and the Frigid Zone.

Torrid Zone (23 ½ °N to 23 ½ °S)

The zone lying between the Tropic of cancer and Tropic of Capricorn is called 'Torrid zone' (Figure 6.8). The sun's rays are vertical throughout the year and it receives maximum insolation. Thus, this is the hottest zone.

Temperate Zone (23 ½ °N to 66 ½ °N and 23 ½ °S to 66 ½ °S)

The temperate zone lies between the Tropic of Cancer and the Arctic Circle in the northern hemisphere and the Tropic of Capricorn and the Antarctic circle in the southern hemisphere. This region never experiences over head sun light but experiences longer days and shorter nights during summer and vice versa during winter. This region

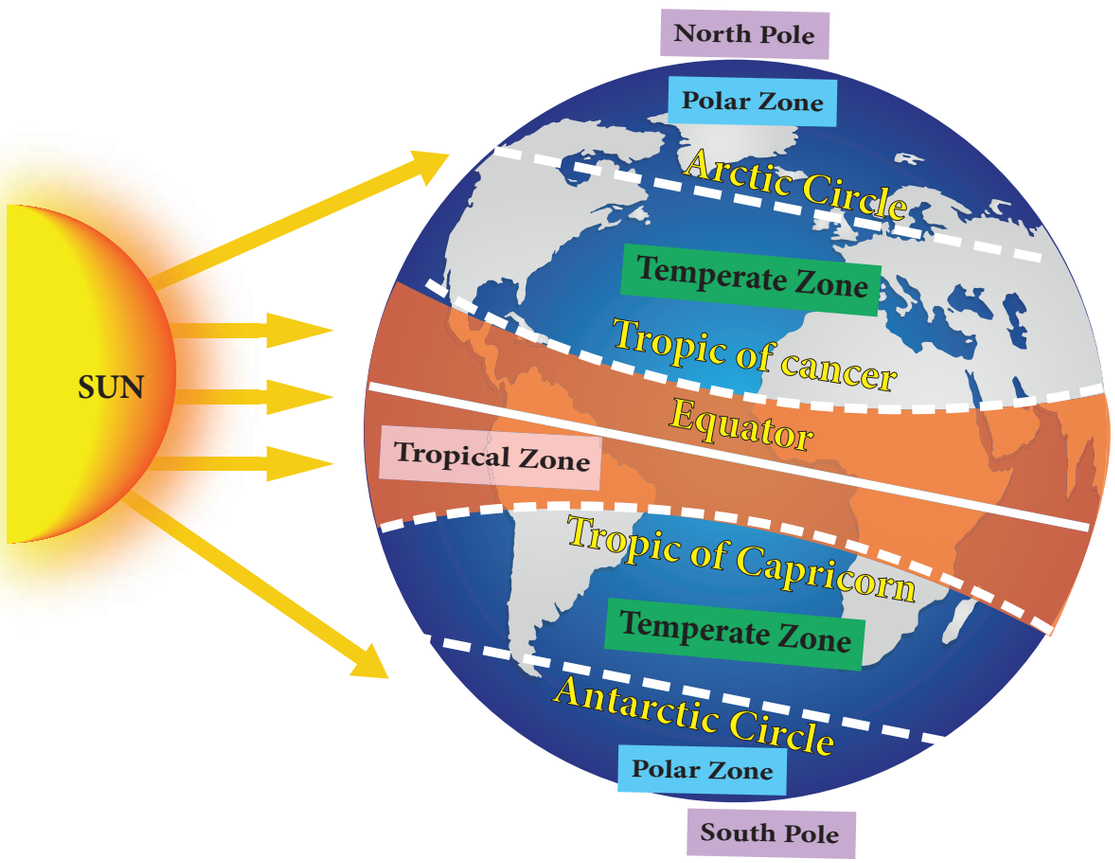


Figure 6.8 Heat Zones

experiences moderate temperature and is therefore called as '**Temperate zone**'.

Polar Zone (Frigid Zone – 66 ½ °N to 90°N and 66 ½ °S to 90°S)

The region between North pole and Arctic Circle in the northern hemisphere and South pole and Antarctic Circle in the southern hemisphere is called 'Polar Zone'. This region always receives more oblique rays of the sun and so the temperature is very low. It is the coldest zone. This region experiences 24 hours of day and night during peak summer and winter respectively.

Annual Temperature : The average annual temperature of a region for a year.

Mean Annual Temperature: The average of 30 years of annual temperature of the region.

Range of Temperature: Difference between highest and lowest temperature of a place.

Annual Range of Temperature: The difference between highest and lowest temperature of a place in a year.

Diurnal range of Temperature: The difference between highest temperature and lowest temperature of a place in a day.

Green House Effect:

As seen in the heat budget, the longer wavelengths are absorbed by greenhouse gases in the atmosphere, increases the temperature of the atmosphere. These greenhouse gases act like a green house and retains some of the heat energy would otherwise be lost to space. The retaining of heat energy by the atmosphere is called the 'greenhouse effect'.

Global Warming

Global warming is observed in a centuryscale. The temperature increase over the years has been due to the greenhouse gas concentration such as carbon dioxide (CO_2), water vapour, methane and ozone. Greenhouse gases are those gases that contribute to the greenhouse effect. The largest contributing source of greenhouse gas is the burning of fossil fuels leading to the emission of carbon dioxide from industries, automobiles and domestic.

6.3.6 Urban Heat Island (UHI)

An urban heat island is an urban area or metropolitan area that is significantly warmer than its surrounding rural area due to high concentration of high rise concrete buildings, metal roads, sparse vegetation cover and less exposure of soil. These factors cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures (Figure. 6.9).

Ways to reduce the impact of urban heat island:

1. Increase shade around your home: Planting trees and other vegetation, provides shade and cooling effect through evapotranspiration and it lowers the surface and air temperature.

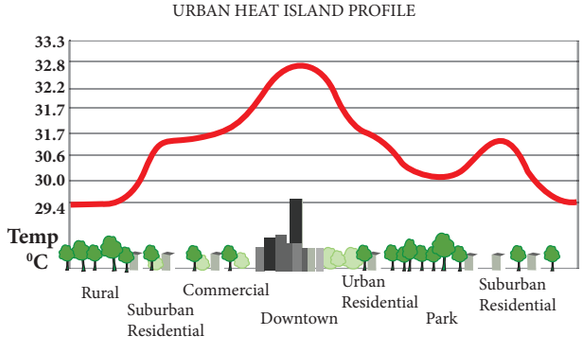


Figure 6.9 Urban Heat Island

2. Install green and cool roofs.
3. Use energy-efficient appliances and equipments.
4. Shift all industries away from the urban area.
5. Reduce emission from automobiles.

6.4 Atmospheric Pressure and Wind

Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air molecules above the earth surface. In the Figure below (Figure 6.10), the pressure at point 'X' increases as the weight of the air increases. The atmospheric pressure is not distributed uniformly over the earth. The amount of pressure increases or decreases, according to the amount of molecules, that exerts the force on the surface.

When temperature of the air increases, the air expands and reduces the number of molecules over the unit area. It leads to reduction in pressure. Similarly, when the temperature falls, the air contracts and the pressure increase. Therefore, the temperature and atmospheric pressure are inversely related.

Atmospheric pressure is measured by an instrument called **'Barometer'**.

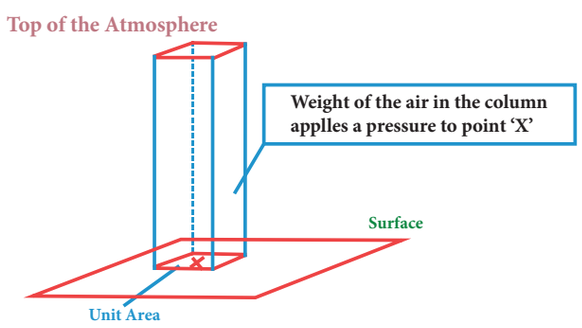


Figure 6.10 Atmospheric Pressure

6.4.1 Vertical Distribution of Atmospheric Pressure

The relationship analysis between altitude and atmospheric pressure is very peculiar. The upper atmosphere is thin and less dense. The pressure at sea level is highest and keeps decreasing rapidly with increasing altitude because of the progressive reduction of the mass above the point where it is measured (Figure 6.11).

Isobar is an imaginary line connecting the places of uniform atmospheric pressure reduced to mean sea level

Brain Storming

People feel discomfort to breathe when they go to the places of higher altitude (mountain sickness). Why?

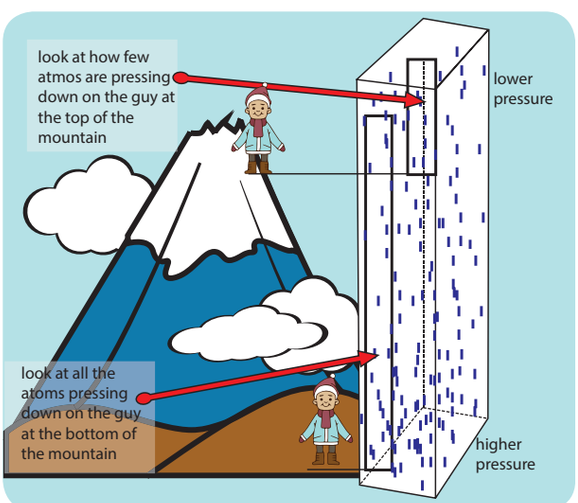


Figure 6.11 Relationship between altitude and pressure

Altitude in m	Atmospheric pressure in m b
Sea level	1013.25
1,000	898.76
2,000	795.01
3,000	701.01
4,000	616.60
5,000	540.48
10,000	264.0

6.4.2 Horizontal Distribution of the Atmospheric Pressure

When the air gets heated it expands, becomes light and rises vertically. As air rises, the pressure it exerts on the earth surface is reduced, causing a low pressure area (Figure 6.12).

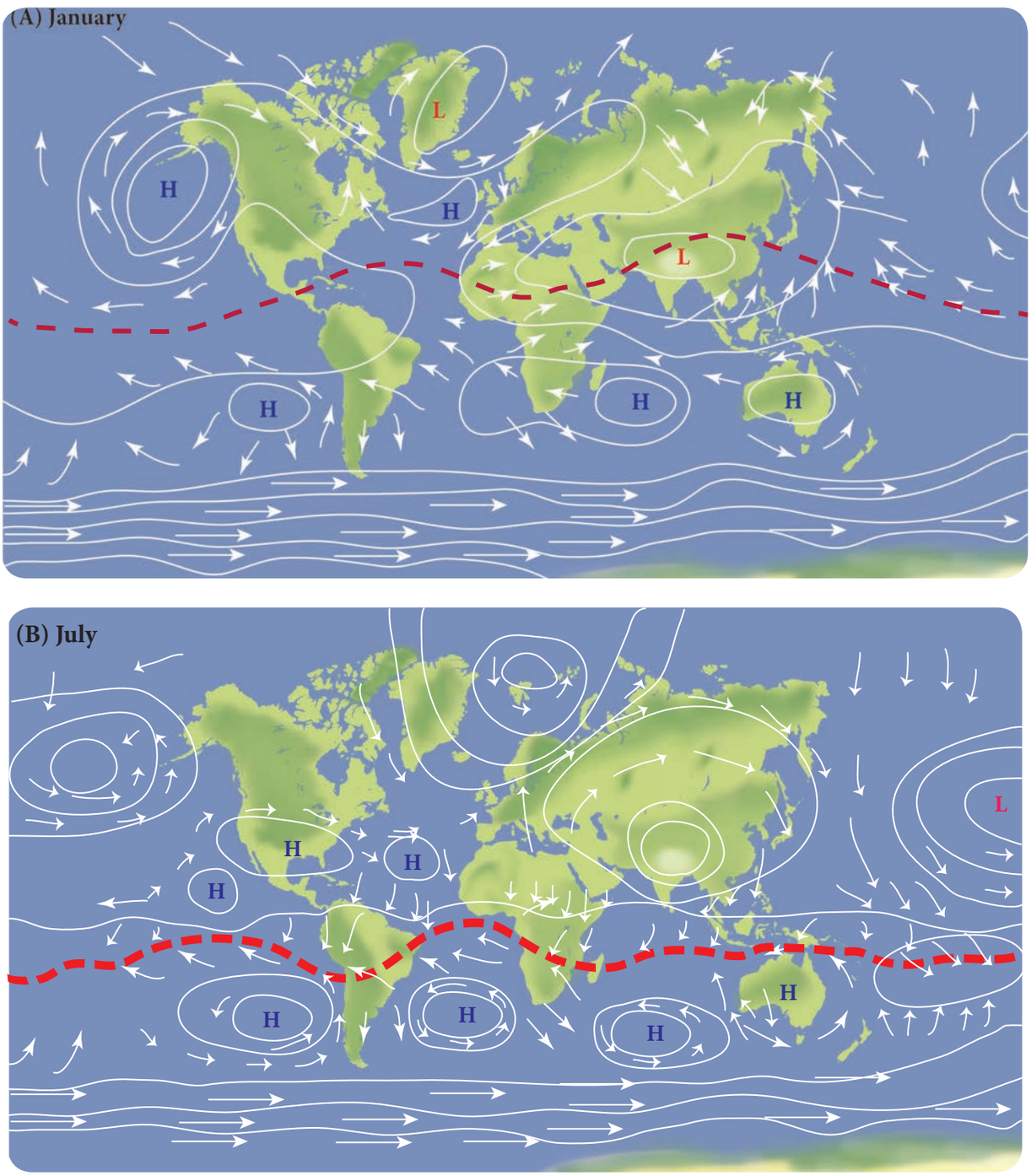


Figure 6.12 Horizontal distribution of temperature

On the other hand, cool air is dense and heavy. As a consequence it sinks vertically. It results in additional weight and pressure which cause a high pressure area to occur on the ground.

6.4.3 Pressure Belts of the Earth

The atmospheric pressure belts envelope on the surface of the earth. They are equatorial low pressure belt, sub tropical high pressure belts, sub polar low pressure belts and polar high pressure belts.

6.4.4 Wind Systems

Wind is the horizontal movement of air molecules from areas of high pressure to areas of low pressure to maintain the atmospheric equilibrium. The wind always moves perpendicular to isobars. If the earth did not rotate, the winds would blow in a straight path. Then the rotation of the earth results in corilois effect and it deflects the direction of the wind. Wind direction is identified by an instrument called Wind Vane and wind speed is measured by Anemometer.

Coriolis Effect

The rotation of the earth affects the moving objects on the earth surface. Free moving objects, affected by the rotation of the earth, do not follow a straight line. In the northern hemisphere they drift towards right and towards left in the southern hemisphere. A car travelling down a straight road at 95 km/hr in northern hemisphere would drift to the right of the path if the friction between surface and tyre is absent. The tendency is called as Coriolis Effect as it was discovered by G.G. Coriolis. This is the reason why racket launching stations are located on the east coastal areas. Example: Sriharikota, French Guyana.

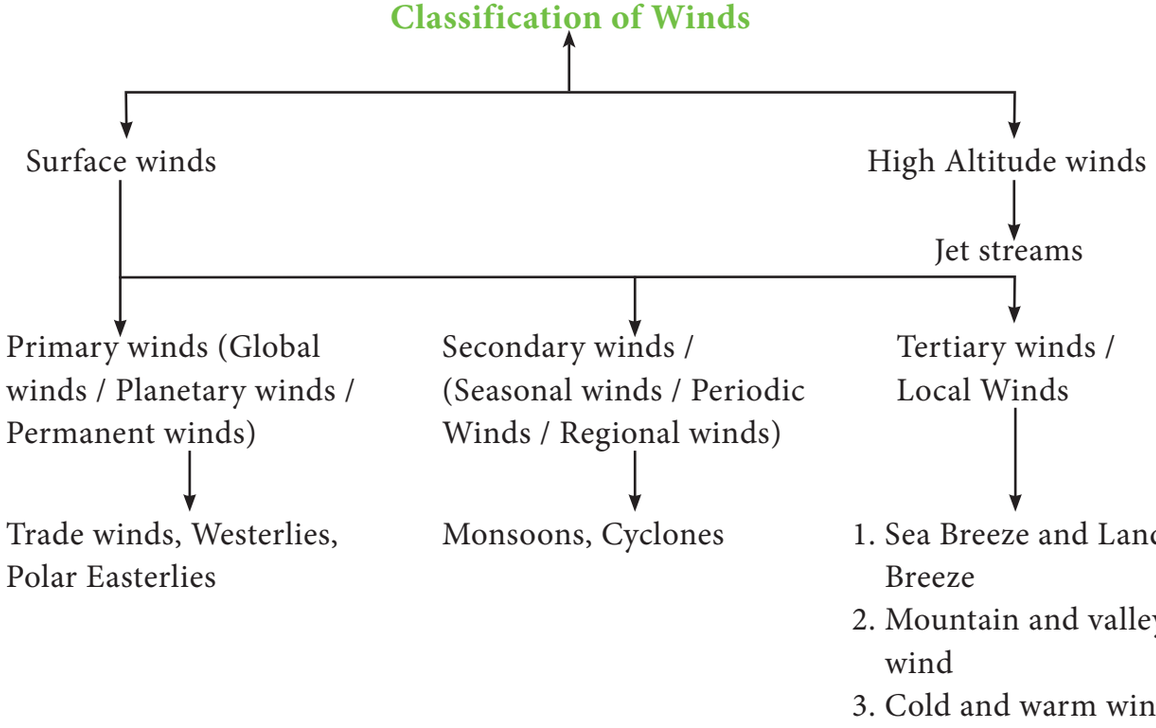
Types of Winds

Winds are classified based on the nature and area of influence as follows;

6.4.5 General Atmospheric Circulation, Pressure Belts and Primary Wind System

From the equator to the poles, each hemisphere has four pressure belts and totally there are seven belts on the globe. The pressure belts lead to formation of primary wind system as follows:

a. **The equatorial low pressure belt (between 5°N and 5°S):** This is the region of calm, weak and changeable winds. Due to the high temperature over this region, the air gets heated expands and become lighter and rises upward and creates low pressure over the region. This region is a belt of calm and referred to as the 'Doldrums'. The winds blow from the sub tropical high pressure belt towards the equatorial low pressure belt. Due to Coriolis Effect these winds are deflected to the right in the northern hemisphere and to the left in the southern hemisphere. As winds are named after the direction from which they originate they are called as the North East and South east trade winds. As the winds favoured trading ships they are called as 'Trade winds'.



b. **The sub tropical high pressure belt (25° to 35° N and S):** Air begins to cool when it reaches higher altitude over equatorial region and flows towards the poles. This wind collides with the wind coming from the polar region at higher altitude and subsides down over sub tropical latitudes. This leads to formation of high pressure belt along the sub tropical region. It is said that to avoid the slowing down of ship due to high pressure the horses were thrown into the sea. So this belt is called as 'Horse latitude'. The sinking air bifurcated in to two branches towards the equator and poles, they are called as trade winds and westerly respectively. Westerlies flow towards the pole from sub tropics and turn towards right and left in northern hemisphere and southern hemisphere respectively.

c. **The sub polar low pressure belt (50° to 60° N and S):** The warm westerly wind from sub tropical region moves towards the pole and collide with the cold polar easterly wind from polar high pressure region and raises up to form sub polar low pressure belt.

d. **Polar high pressure belt (80° N and 80° S pole):** The constant low temperature at the poles due to inclined solar radiation and reduced insolation leads to the formation of polar high pressure belt on both poles (Figure 6.13).

The high pressure on the surface always coincide with the low pressure at higher altitude while the low pressure on the surface always coincide with higher pressure on the higher altitude. High pressure always has divergence of air masses from the centre but low pressure has convergence of air.

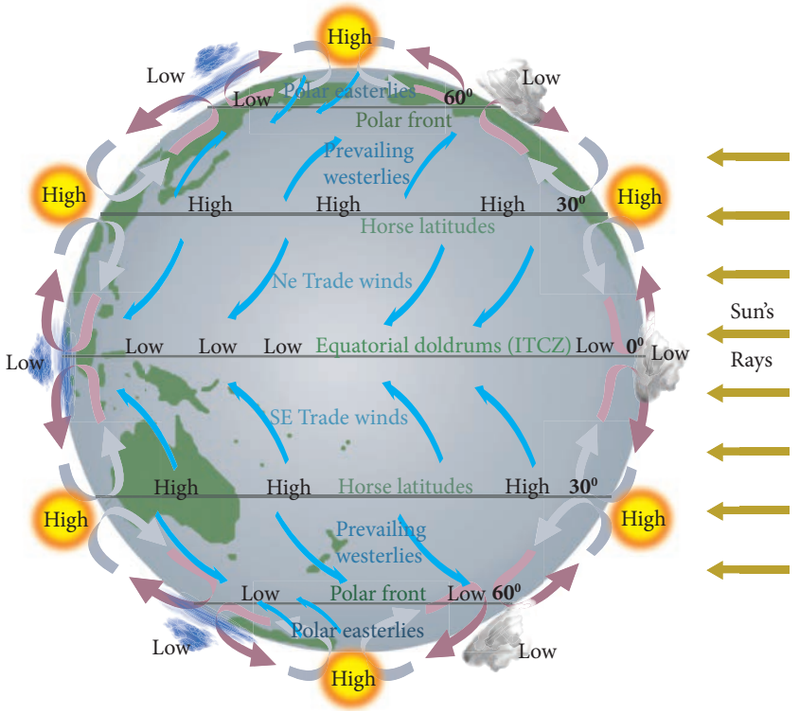


Figure 6.13 Pressure Belts and Primary Winds

6.4.6 Basis of Formation of Pressure Belts

There are two important bases on which the pressure belts are formed. They are;

a. Temperature: The equatorial low pressure and polar high pressure belts are formed due to high and low temperature respectively. So they are called as 'Thermally formed pressure belts'.

Ocean is dominant in the southern hemisphere between the latitudes 40°S and 60°S. Hence the westerlies are so powerful and persistent that the sailors used such expressions as **"Roaring Forties", "Furious Fifties"** and "**Screaming or Shrieking Sixties"** for these high velocity winds in the latitudes of 40°, 50° and 60° respectively.

b. Dynamism: The sub tropical high and sub polar low pressure belts are formed due to movement and collision of wind system. So they are called as 'Dynamically formed pressure belt system'.

6.4.7 Meridional Cell System

The cell along with trade winds, equatorial low and sub tropical high pressure belts is called as 'Hadley cell', meanwhile the cell formed by westerly wind along with sub tropical high and sub polar low pressure belt is called 'Ferrell's cell'. The cell at polar formed by polar easterlies with polar high and sub polar low pressure belt is called as 'Polar cell' (Figure 6.14).

ITCZ – Inter Tropical Convergent Zone

The region where both trade wind systems meet is known as 'Inter Tropical Convergent Zone'.

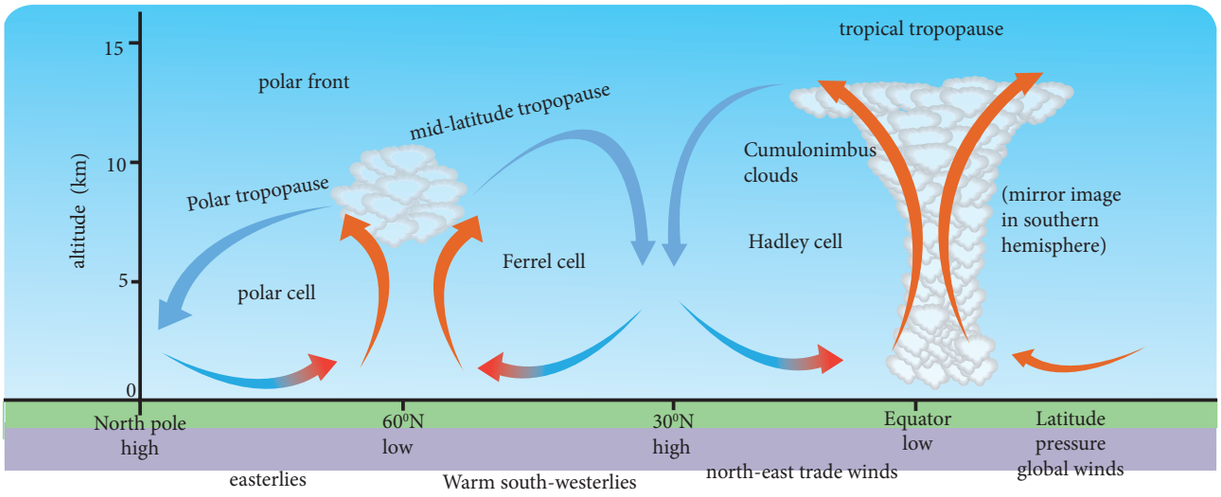


Figure 6.14 Meridional circulation

Shifting of Pressure Belts and Primary Wind System

These pressure belts and primary wind systems are dynamic in character as they shift 5° north and 5° south from their position along with the apparent movement of the sun.

6.4.8 Secondary Wind System

Both monsoon and cyclones are considered as secondary or regional wind systems.

Monsoons

The word 'Monsoon' is derived from the Arabic word, 'Mausim' which means 'Season'. Monsoons are seasonal winds which reverse their direction due to unequal heating and cooling of the land and the water.

Mechanism of Monsoon

The land absorbs more heat energy during summer, which leads to the formation of low pressure over continent. But the ocean will have relatively lower temperature than the continent leading to the formation of high pressure system over ocean. So, the wind blows from sea to land during summer season. Meanwhile the land reradiates more heat energy to space during winter leading to the formation of high pressure above the continent. But the ocean will have relatively higher temperature than the continent leading to formation of low pressure system over ocean. So, wind blows from land to sea during the winter season. This mechanism has an important effect on rainfall received over the region.

Nature of Monsoon System

There are three distinct characteristics related to monsoon wind system which differentiates it from other wind systems. They are;

1. Minimum 160° reversal of wind direction between seasons.
2. They affect a large part of the continents and oceans.
3. The formation of low and high pressure systems over land and water and their interchange between the seasons.

DO YOU KNOW?

If any wind system has all the above mentioned characters of monsoon in one season but absence of at least one in the other season then is called as 'Pseudo monsoon'. The other names are 'Monsoon tendency' or 'false monsoon'.

Monsoon system is classified into two groups based on the location. They are;

a. Asian Monsoon

b. South Asian Monsoon

a. Asian Monsoon

The Asian monsoon system is divided into two components based on season it flows. The presence of high temperature with low pressure in the lake Baikal region and low temperature with high pressure in the Aleutian islands region leading to flow of wind from Pacific Ocean to interior part of Asia during summer is called 'Summer Monsoon of Asia'. This leads to rainfall in the east coast of Asia.

Meanwhile, in winter the low temperature and high pressure in the Lake Baikal region and high temperature and low pressure in the Aleutian Island region leading to flow of wind from Central Asia to Pacific Ocean is known as 'Winter Monsoon of Asia'. As the wind system flows off shore, the rainfall does not occur in the continent of Asia except western coast of Japan.

b. South Asian Monsoon

South Asian Monsoon includes the countries in the southern part of Himalayas, that is India, Pakistan, Bangladesh, Sri lanka, Maldives, Nepal and Bhutan. This monsoon system has been classified into two groups based on the direction of origin of wind namely south west monsoon and north east monsoon (Figure 6.15).

South West Monsoon

During summer the Indian peninsula is heated more than the sea around it. Intense low pressure is formed in the region of Peshawar of Pakistan. At the same time, the Indian Ocean has higher pressure due to relatively low temperature. So the wind

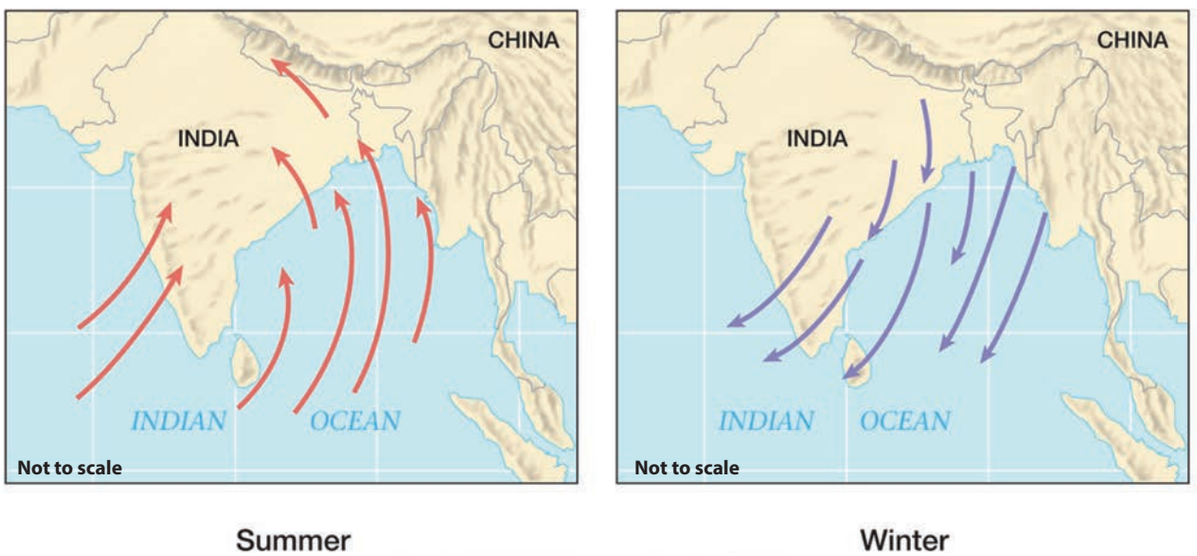


Figure 6.15 South Asia Monsoon

blows from Indian Ocean towards South Asia as Southeast Winds. The wind turns towards right due to Coriolis Effect and blows as south west winds which bring heavy rains around four months of the year. This is known as south west monsoon in Indian Sub continent. This wind system bifurcates into two branches as Arabian Sea branch and Bay of Bengal branch.

Arabian Sea Branch

The Arabian Sea branch strikes the Western Ghats at perpendicular direction and rises over it. The orographic effect by the Western Ghats results in heavy rainfall in the windward side and low rainfall in the leeward side. So the west coast of India receives high rainfall when compared to the eastern side of the Western Ghats. Kerala is the first state to receive rainfall from the south west monsoon in India, which occurs during first week of June. Then, the wind gradually moves towards the north of the western coast and leads to gradual development of the monsoon in parts of Karnataka, Goa, Maharashtra, Gujarat and Rajasthan. The wind further advances towards foot hill of the Himalayas and creates orographic rainfall in the Himalayan states, Punjab and Haryana. The other part of the Arabian Sea branch moves towards the east and results in onset of monsoon in Uttar Pradesh and Bihar. Here, it unites with the Bay of Bengal branch and leads to heavy rainfall and flood.

Bay of Bengal Branch

Bay of Bengal branch flows from south west which results in orographic rainfall in Sri Lanka and reaches Andaman and Nicobar Islands and results in orographic rainfall. Indira point in the Great Nicobar is the first place which receives rainfall during south west monsoon in India during middle of May. The wind flows parallel to the east coast of India and Eastern Ghats. So Coromandel Coast of India doesn't get enough rainfall during south west monsoon. The wind strikes Arakanyoma Mountain in Myanmar and results in heavy rainfall in western coast of Myanmar. The wind funnels towards north eastern part of India after deflected by the Arakanyoma Mountain in Myanmar. This wind strikes Meghalaya plateau which leads to heavy rainfall in Bangladesh and North eastern part of India. Mawsynram, the wettest place (highest annual rainfall) in the world, is located in the windward side of Meghalaya plateau.

The wind further advances towards the Himalayas where it creates heavy rainfall in the southern slopes. This leads to flood in River Brahmaputra. The wind gradually moves towards the west and results in onset of monsoon in Bhutan, Sikkim, West Bengal, Nepal and Bihar. It joins with Arabian Sea branch in Bihar and results in heavy rainfall and flood.

The south west monsoon gradually withdraws from south Asian continent due to apparent movement of the Sun towards the southern hemisphere. This is called as 'Withdrawal of South West Monsoon'.

North East Monsoon

During winter the Indian Subcontinent becomes colder than the Indian Ocean. As a result the wind blows from Northeast to South West direction. This is dry wind system and it does not produce rainfall in the coastal region of south Asia except the Coromandel Coast of India and Sri Lanka. This is known as North East Monsoon or Retreating Monsoon in South Asia.

CASE STUDY

Mawsynram, world's wettest place!

''It was the kind of rain you wouldn't see anywhere else. We could barely see four feet ahead of us. We could touch the clouds, smell the clouds, and taste the clouds" said a local resident. Yes, it is about Mawsynram which is located in Meghalaya's East Khasi Hills, with the cluster of about 1,000 homes. It holds the Guinness Record for "the wettest place on earth". The average annual rainfall is 11,861mm, according to the Guinness website.

However, the soil in the limestone plateau doesn't absorb water. There is barely any forest cover, so a lot of erosion of top soil happens. All of it flows down into Bangladesh. The irony is that "the wettest place on earth" grapples with an acute water shortage after monsoon ends around October. Hence, people call world's rainiest place Mawsynram, which is also world's wettest desert.

Agriculture in India mostly depends on the rainfall brought by the monsoons.

During the El Nino year the temperature of the ocean water increases. This weakens the high pressure over Indian Ocean thereby reduces the strength of south west monsoon over south Asia. However during winter, it induces the low pressure over the ocean resulting in severe depressions and cyclones.

6.4.9 Tertiary Winds

The tertiary winds are formed due to pressure gradients which may develop on a local scale because of differences in the heating and cooling of the earth's surface.

Sea and Land Breezes

During daytime, land heats up much faster than water. The air over the land warms and expands leading to form low pressure. At the same time, the air over the ocean becomes cool because of water's slower rate of heating and results in formation of high pressure. Air begins to blow from high pressure over ocean to the low pressure over the land. This is called as

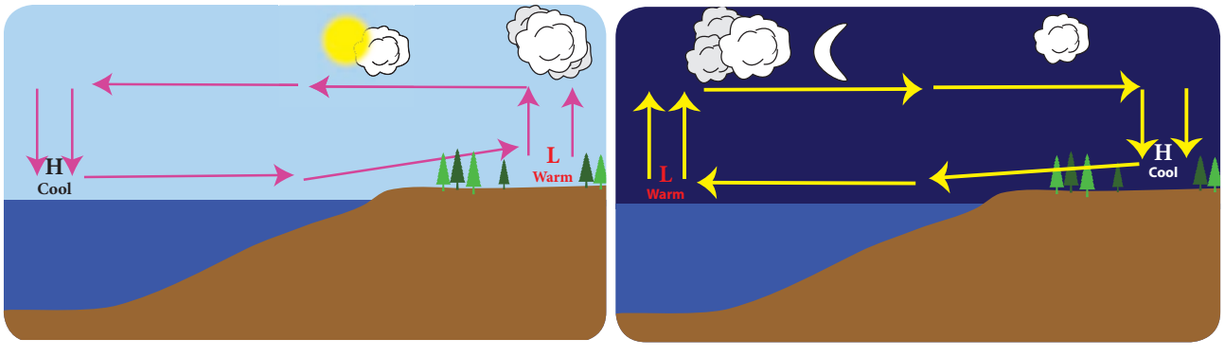


Figure 6.16 Sea breeze and Land breeze

'Sea breeze'. During night time, the wind blows from land to sea and it is called as 'Land breeze' (Figure 6.16).

Mountain and Valley Breezes

A valley breeze develops during the day as the sun heats the land surface and air at the valley bottom and sides. As the air gets heated it becomes less dense and begins to blow gently up the valley sides. This is called as 'valley wind'. This process reverses at night leading to blow of wind from mountain top to valley bottom referred to as 'mountain wind' (Figure 6.17).

Local Winds

Local wind systems influence the weather pattern where ever they blow (Figure 6.18). Some important local winds are;

Bora: North easterly from eastern Europe to north eastern Italy

Chinook: Warm dry westerly off the Rocky Mountains

Sea breeze and land breeze influence the movement of boats near the coastal region and fisher men use these winds for their daily fish catching. Fishermen go for fishing at early morning along the land breeze and return to the shore in the evening with the sea breeze.

Fohn: Warm dry southerly off the northern side of the Alps and Switzerland.

Harmattan: Dry northerly wind across central Africa

Karaburan: 'Black storm' a spring and summer katabatic wind of central Asia

Khamsin: South easterly from North Africa to the eastern Mediterranean

Loo: Hot and dry wind which blows over plains of India and Pakistan.

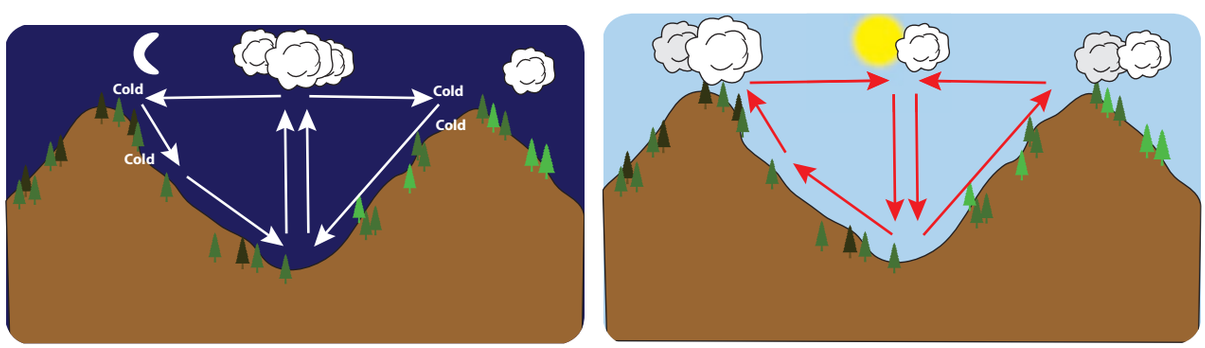


Figure 6.17 Mountain and Valley breeze

Figure 6.18 Local winds of the world

Mistral: Cold northerly from central France and the Alps to Mediterranean.

Nor'easter: Strong winds from the northeast in the eastern United States, especially New England

Nor'wester: Wind that brings rain to the West Coast, and warm dry winds to the East Coast of New Zealand's South Island, caused by the moist prevailing winds being uplifted over the Southern Alps, often accompanied by a distinctive arched cloud pattern.

Pampero: Argentina, very strong wind which blows in the Pampa.

Simoom: Strong, dry, desert wind that blows in the Sahara, Israel, Jordan, Syria, and the desert of Arabia.

Sirocco: Southerly from North Africa to southern Europe.

Zonda wind: On the eastern slope of the Andes in Argentina.

Mountain and valley wind systems influence the weather pattern of the mountain top and valley bottom. Mountain top can be seen clearly at early morning and valley bottom at evening. But mountain top will be covered with clouds at evening due to rising of valley wind system and valley bottom would be covered by clouds at early morning due to arrival of mountain wind system. These clouds are sometimes called as 'fog' which is used for cultivation in the dry regions like Yemen.

6.4.10 Jet Streams

Jet streams are high altitude westerly wind system blows at a height of 6 to 14 km, with very high speed up to 450 km/hr in wavy form at both hemispheres. As they encircle the poles they are called as 'Circum polar wind system' (Figure 6.19).

Although the jet streams flow at higher altitude they also influences the surface weather pattern of the Earth.

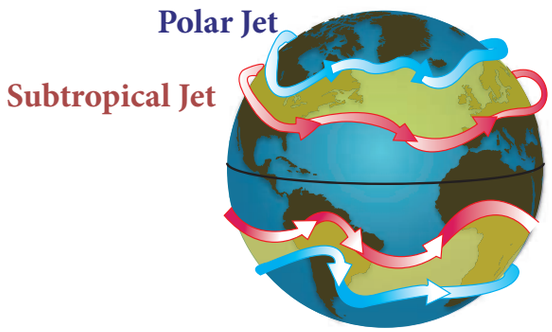


Figure 6.19 Jet Stream

The Major impacts of Jet streams

1. **Creation of Polar Vortex:** Polar westerly jet stream will carry cold polar air masses towards temperate region which creates severe cold waves in North America and Eurasia during winter.
2. **Sudden burst of South west monsoon:** Sudden withdrawal of polar westerly jet stream from Indian sub continent to northern part of Pamir, leads to sudden burst of South west monsoon into Indian Sub continent.
3. **Late and early monsoon in South Asia:** Rate of with drawl of polar westerly jet stream decides the onset of south west monsoon. Slower and faster rate of with drawl leads to late and early onset of south west monsoon.
4. **Intensity of monsoon rainfall:** The arrival of tropical easterly jet stream influences the intensity of south west monsoon. This leads to increasing intensity of rainfall during south west monsoon.

DO YOU KNOW?

Jet streams were discovered during the Second World War as the jet pilots felt the strong obstruction in the higher altitudes.

Student Activity

Mark the direction of the primary winds in the given world map.

Not to scale

The wavy structure of the Jet stream is represented as 'Rossby waves'.

5. **Bringing rainfall to India by western disturbances:** Polar westerly jet stream carries rainy clouds from cyclones formed over Mediterranean Sea during winter towards India. These clouds piles up on the Himalayas and results in rainfall over the states of Punjab and Haryana. This assists in the cultivation of wheat in India.
6. **Development of super cyclone:** The condition at which the speed of the jet stream is transferred to tropical cyclone may leads to development of super cyclone.

6.5 Humidity, Condensation and Clouds

Humidity is the amount of water vapour in the atmosphere. Temperature of the air controls the capacity of the air to hold moisture. The maximum amount of moisture that can be hold by the air in the particular temperature is called as Humidity Capacity. As the volume increases with the temperature of the air, it can hold more moisture. So, humidity capacity increases with temperature. It is measured as weight of humidity or volume of the air.

Humidity of the air can be expressed in the following ways.

a. **Absolute Humidity:** This measures the total amount of water vapour present in the air at particular time. It is highly variable based on the surface on which the air moves. It is measured as weight of humidity/ volume of the air.

b. **Relative Humidity (RH %):** This is the ratio of Absolute humidity and humidity capacity in term of percentage. It reveals the condition of air to get saturated. This is controlled by both temperature and moisture content of the air. The condition is that when the temperature increases RH% decreases. But when absolute humidity increases RH% increases.

6.5.1 Process of Condensation

Condensation is the change of the physical state of water vapour (gas state) into water (liquid state). The following process explains mechanism of condensation in the atmosphere.

If an air reaches 100% relative humidity, it means that the air is completely filled with moisture content. It indicates that both the absolute humidity and the humidity capacity of the air are in same level. This condition is called 'saturation of air' which can be attained by reducing the temperature of the air or increasing the moisture content. The temperature at which the air gets saturated is called as 'dew point'. The RH crosses the 100% when the temperature of the air drops below its dew point. This condition is called as 'super saturation' of the air. In this condition the air releases the excess moisture out of it in the form of tiny water droplets which floats and form clouds in the atmosphere.

If the same process occurs on the surface of the earth, it is called as 'fog' or cloud on the ground.

Hygrometer is used to measure the relative humidity of a region.

Student Activity

The cup filled with ice cubes has tiny water droplets on its outer surface (Figure 6.20). Identify why.

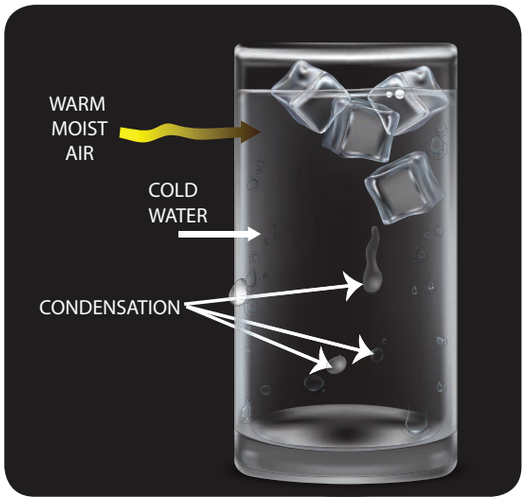


Figure 6.20 Process of Condensation

The moisture in the atmosphere is based on the following processes:

a. Evaporation – Water changes from liquid state to gaseous (vapour) state.
b. Transpiration – Water state changes from liquid in to (gas) vapour state due to the activity of plants.
c. Evapotranspiration – This denotes that the total amount of (liquid) water state changed in to (gas) vapour state due to evaporation and the activity of plants transpiration.

Isonephs – The imaginary line connecting the places having equal amount of cloudiness.

6.5.2 Clouds and its Types

Clouds are tiny water droplets suspended in the air formed due to the condensation (Figure 6.21).

The clouds can be classified based on their form, height and appearance as follows:

a. **High clouds:** Mainly cirrus (Ci) which are feathery form at 6 km above the ground.
   i. Cirrus (Ci) – This looks fibrous and appears as wisps cotton in the blue sky. It indicates fair weather and gives brilliant sun set.
   ii. Cirro Cumulus (Cc) – This appears as white globular masses, forming a mackerel sky.
   iii. Cirro Stratus (Cs) – This resembles a thin white sheet. The sky looks milky and the sun and moon shines through this clouds and form a 'halo'.
b. **Middle Clouds:** Mainly Alto (Alt) clouds at 2 km to 6 km above the ground.
   iv. Altocumulus (Alt-Cu): These are woolly, bumpy clouds arranged in layers appearing like waves in the blue sky. They indicate fine weather.
   v. Altostratus (Alt-St): These are denser and have watery look.
c. **Low Clouds:** Mainly Stratus or sheet clouds below 2 km height.
   vi. Stratocumulus (St-Cu): This is rough and bumpy clouds with wavy structure.
   vii. Stratus (St): This is very low cloud, uniformly grey and thick, appears like highland fog. It brings dull weather and light drizzle. It reduces the visibility and is a hindrance to air transportation.

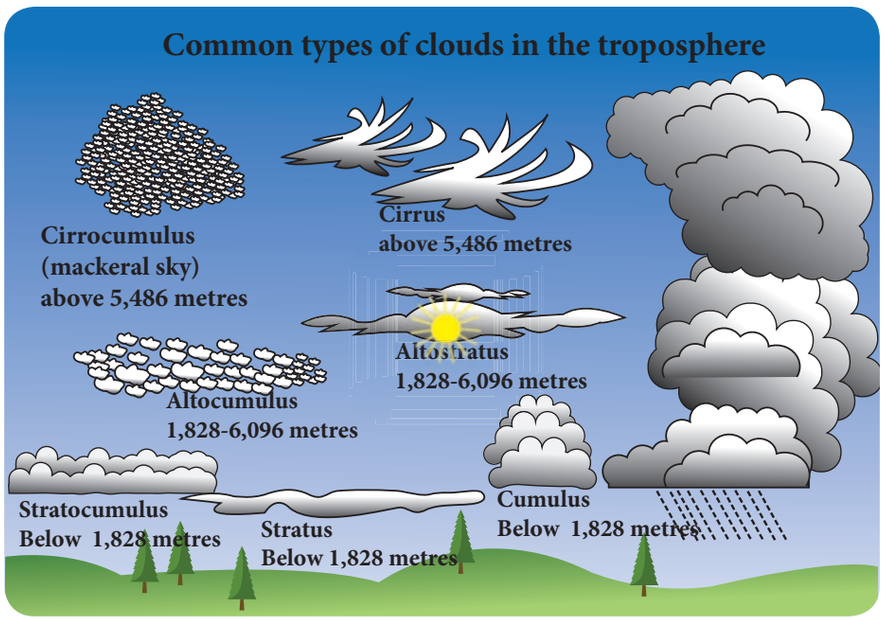


Figure 6.21 Types of Clouds

viii. Nimbostratus (Ni-St): This is dark dull cloud, clearly layered, as it brings rain, snow and sleet and it is called as rainy cloud.

6.5.3 Fog, Mist and Smog

- **'Fog'** is defined as almost microscopic droplets of water condensed from super saturated air and suspended over or near the surface of the earth. Fogs reduce the visibility to less than 1 km. Fog occurs during calm or light wind conditions. It is more common in the areas near to the ocean due to the supply of more moisture by sea breeze. In the interior of the continents fog is formed due to reduction of temperature to extreme low during the winter nights.
- If the fog has higher visibility due to lesser water drops near the surface it is termed as **'mist'.**
- In large industrial areas the air is more polluted. If the fog forms in that area it mixes with the pollutants and turns into smog (smoke + fog = smog) which is more hazardous to the health of the people.(Figure 6.22).

Figure 6.22 Smog at New Delhi

Student Activity

Collect the information regarding the smog in the cities of London (Great London Smog), Bhopal, Beijing and New Delhi.

Identify the precautionary steps to be followed in the regions of smog.

6.5.4 Hydrological Cycle

Continuous movement of water among the three spheres is known as **Hydrological Cycle**. Hydrological cycle involves evaporation, condensation, precipitation, advection, interception, evapo-transpiration, infiltration, percolation and runoff to the ocean (Figure 6.23).

Evaporation is the process by which water in liquid state changes into vapour state using heat energy from Sun. Evaporation is maximum when the temperature is high, on the large expanse of water and when dry winds blow over water surface.

Condensation is the process by which water vapour cools to form water droplet by loosing temperature. The condensation occurs when dew point is reached in the atmosphere.

Precipitation is the process by which all forms of water particles fall from the atmosphere and reach the ground.

The rain drop that falls may get evaporated before it reaches the ground in an extremely arid region.

6.6 Precipitation

Precipitation is the product of condensation of atmospheric water vapour that falls under gravity and reaches the surface of the earth. In order to fall as rain drop or snow, the tiny drop lets in a cloud must grow larger. The droplets accumulate over the nuclei and combine to grow large enough to fall and reach the surface of the earth due to gravity.

If the drop is smaller it falls slowly so that it evaporates before it reaches the ground. Ice crystals in cloud also cause precipitation. Each ice crystal grows by cooling so that they become large in size and fall to the ground. They melt on the way due to friction with the atmosphere and fall as rain.

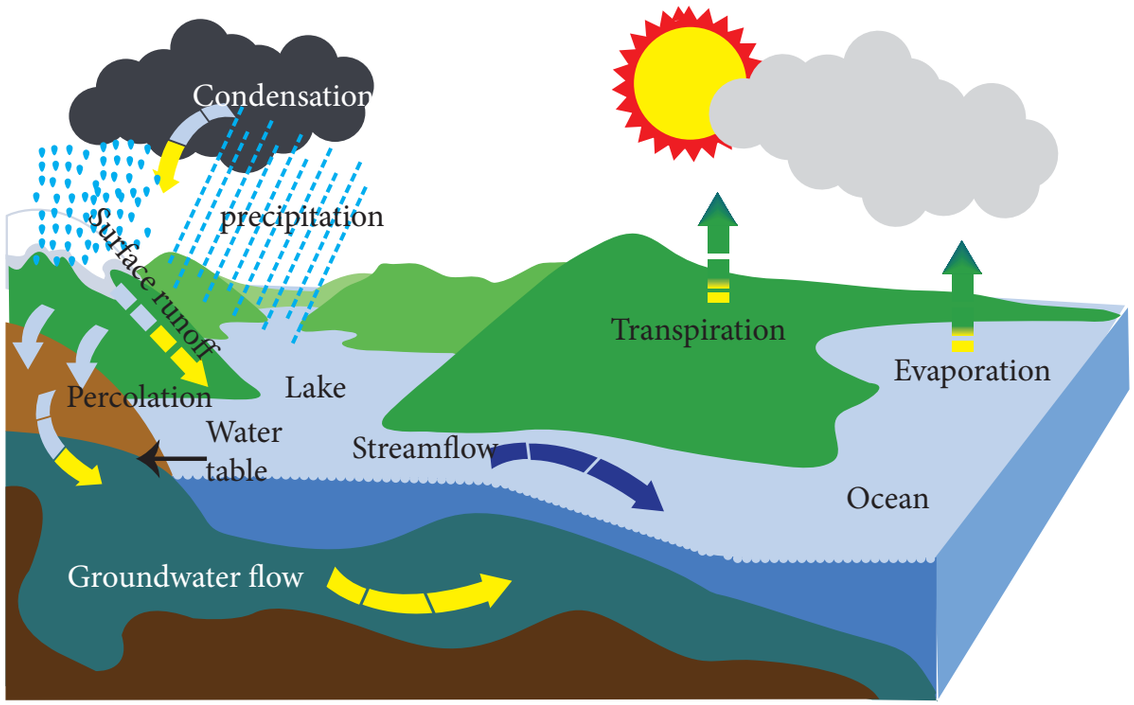


Figure 6.23 Hydrological cycle

6.6.1 Forms of Precipitation

The precipitation has various forms based on the condition of occurrence (Figure 6.24). The various forms are;

Rainfall: When water droplets of more than 0.5 mm diameter falls from the atmosphere to the ground it is called as 'Rainfall'. If the diameter is less than 0.5mm, it is called as 'Drizzle'.

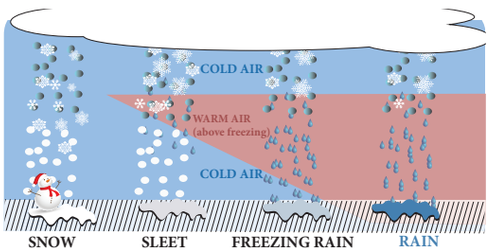


Figure 6.24 Form of precipitation

Hail: When precipitation occurs at sub zero temperature, the water droplets crystallise and fall as ice pellets with the size of 5 to 50 mm or some times more. This is called as 'Hail'.

Sleet : Precipitation occurs as falling of raindrop along with ice pellets less than 5 mm diameter or snow, called as 'Sleet'.

Snow: Precipitation occurs at below freezing point and falls as thin ice flakes or powdery ice, called as 'Snow'.

Dew: Condensation of water droplets on the objects at the surface of the earth such as leaves and grasses are called as 'Dew'.

6.6.2 Types of Precipitation (Rainfall):

Precipitation can be classified based on the causes for the rising up of air,

1. Convectional rainfall
2. Orographic or Relief rainfall
3. Cyclonic or Frontal rainfall

1. Convectional Rainfall: As a result of heating of the surface air, the warm moist air expands and is forced to rise to a great height. As the air rises, it cools, reaches dew point and condenses to form clouds. This process influences the upper tropospheric circulation. By further cooling, precipitation takes place as rainfall. This rainfall occurs throughout the year near the equator in the afternoon. It is called as 4 'O' clock rainfall region. In middle latitudes, convectional rainfall occurs in early summer in the continental interiors (Figure 6.25).

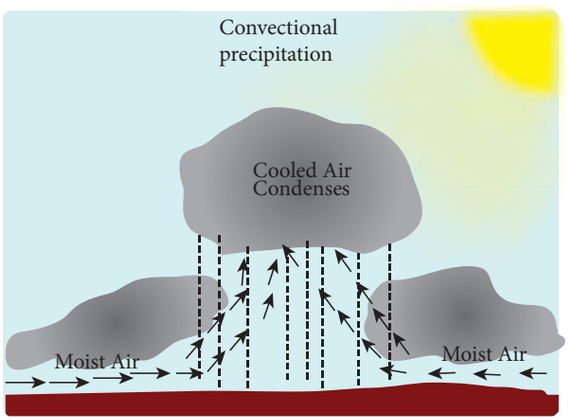


Figure 6.25 Convectional rainfall

2. Orographic or Relief Rainfall

It occurs when large mass of air is forced to rise across land barriers, such as high mountain ranges, plateaus, escarpments, or over high hills. On the windward side of the region the warm moist air raises, temperature of the air falls below its dew point, forming clouds which give subsequent rainfall. As the wind moves to the leeward side it has emptied itself of moisture and thus descends the slope as warm dry winds. The leeward side of the mountain therefore

is called as the **rain shadow region (Figure 6.26)**.

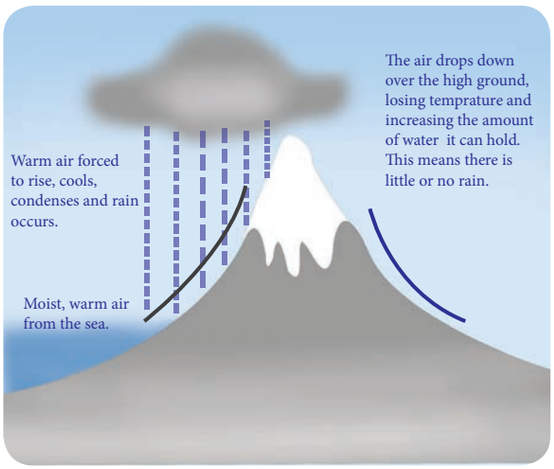


Figure 6.26 Orographic Rainfall

When altitude increases, the rainfall also increases in orographic pattern. But the rainfall decreases with altitude, once the amount of moisture reduces in the air after a point where it reaches maximum rainfall which is called as 'Maximum Rainfall Line'. This condition where the rainfall decreases with altitude is called 'Inversion of Rainfall'.

3. Cyclonic or Frontal Rainfall

This type of precipitation is associated with a cyclonic activity (Tropical and Temperate) and also occurs along the frontal zone. Cyclonic rainfall is associated with Cumulo Nimbus (CuNi) clouds. The rainfall is very heavy and accompanied with lightning and thunder and high speed winds which has the potential to cause damage.

'Frontal rainfall' is associated with fronts which form due to collision of different air masses. Warm front is formed due to advent of warm air masses which leads to

Fact File

Acid Rain

Acid rain is a rain that is unusually acidic, it has elevated levels of hydrogen ions. It is caused by a chemical reaction of compounds like sulphur dioxide and nitrogen oxides that are released into the air from anthropogenic activities and from volcanic eruptions. These substances can rise very high into the atmosphere, where they mix as hygroscopic nuclei and react with water vapour, oxygen, and other gases to form more acidic water which falls to the ground as acid rain. It is harmful for plants, animals, human and environment.

Normally the rainfall is slightly acidic because of the presence of dissolved carbonic acid. The pH of normal rain has been given a value of 5.6. Acid rain has the pH value of less than 5.6. A great way to reduce acid rain is by using renewable energy resources, such as solar and wind power and reducing the use of fossil fuels.

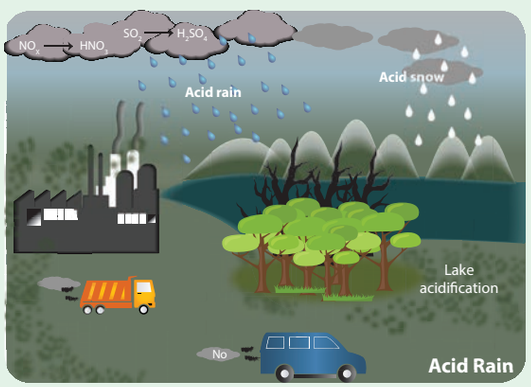


Figure 6.27 Acid rain

moderate rainfall. In the same way cold front is formed due to advent of cold air mass which leads to heavy rainfall with lightning and thunder.

6.6.3 Cloud Burst

A 'cloud burst' is a sudden aggressive rainstorm falling in a short period of time limited to a small geographical area. Meteorologists say that the rain from a cloud burst is usually of the heavier rain with a fall rate equal to or greater than 100 mm (3.94 inches) per hour. Generally cloudbursts are associated with thunderstorms. The air currents rushing up words in a rain storm hold up a large amount of water. For example cloud bursts in the region of Uttarkhand (2013) and Chennai (2015).

6.7 Atmospheric Disturbances (Cyclone and Anti Cyclone)

The atmospheric disturbances which involve a closed circulation of air around a low pressure at centre and high pressure at periphery, rotating anticlockwise in northern hemisphere and clockwise in southern hemisphere is called 'Cyclones' (Figure 6.28). Cyclones may be classified into two types based on latitude of its origin.

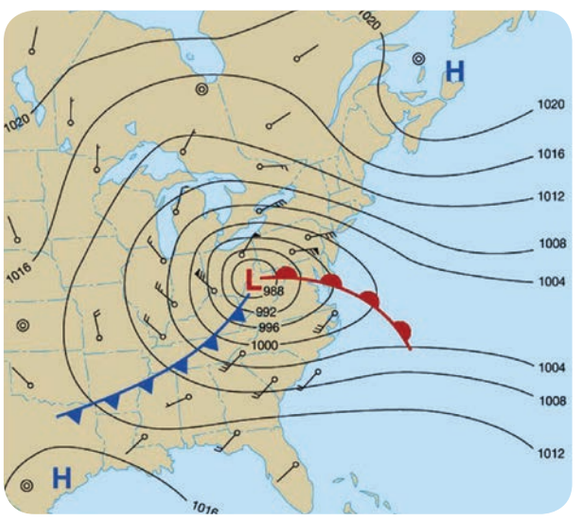


Figure 6.28 Cyclone

They are:

A. Tropical cyclone B. Temperate cyclone.

A. Tropical Cyclone

Cyclone formed in the low latitudes is called as Tropical cyclone. They form over warm ocean waters in the tropical regions. The warm air rises, and causes an area of low air pressure.

6.7.1 Stages of Development of Tropical Cyclone

As per the criteria adopted by the World Meteorological Organisation (W.M.O.), India Meteorological Department classifies the low pressure systems in to vary classes based on wind speed.

1. Tropical Disturbances
2. Tropical depressions Low winds with a speed between 31 and 61 km ph.
3. Tropical cyclone wind speed from 62 to 88 km ph and it is assigned a name.
4. Severe Cyclonic Storm (SCS) wind speed is between 89 to 118 km ph
5. Very SCS wind speed between 119 to 221 km ph and
6. Super Cyclonic Storm when wind exceeds 221 km ph.

6.7.2 Origin of Tropical Cyclone

Tropical cyclones have certain mechanism for their formation. These are

A source of warm, moist air derived from tropical oceans with sea surface temperature normally near to or in excess of 27 °C (Figure 6.29).

Wind near the ocean surface is blowing from different directions converging and causing air to rise and storm clouds to form.

Winds which do not vary greatly with height are known as low wind shear. This allows the storm clouds to rise vertically to high level;

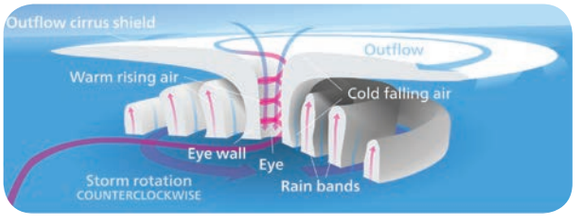


Figure 6.29 Structure of Tropical Cyclone

Coriolis force is induced by the rotation of the Earth. The mechanisms of formation vary across the world, but once a cluster of storm clouds starts to rotate, it becomes a tropical depression. If it continues to develop it becomes a tropical storm, and later a cyclone/ super cyclone.

Characteristics of the Tropical Cyclone

The centre of the cyclone where the wind system converges and vertically rises is called as Eye. The eye is a Calm region with no rainfall and experiences highest temperature and lowest pressure within the cyclonic system (Figure 6.30).

Cyclone wall is made up of Cumulo Nimbus clouds with no visibility, higher wind velocity and heavy rain fall with lightning and thunder.

Tropical cyclones mostly move along with the direction of trade wind system. So they travel from east to west and make land fall on the eastern coast of the continents (Figure 6.31).

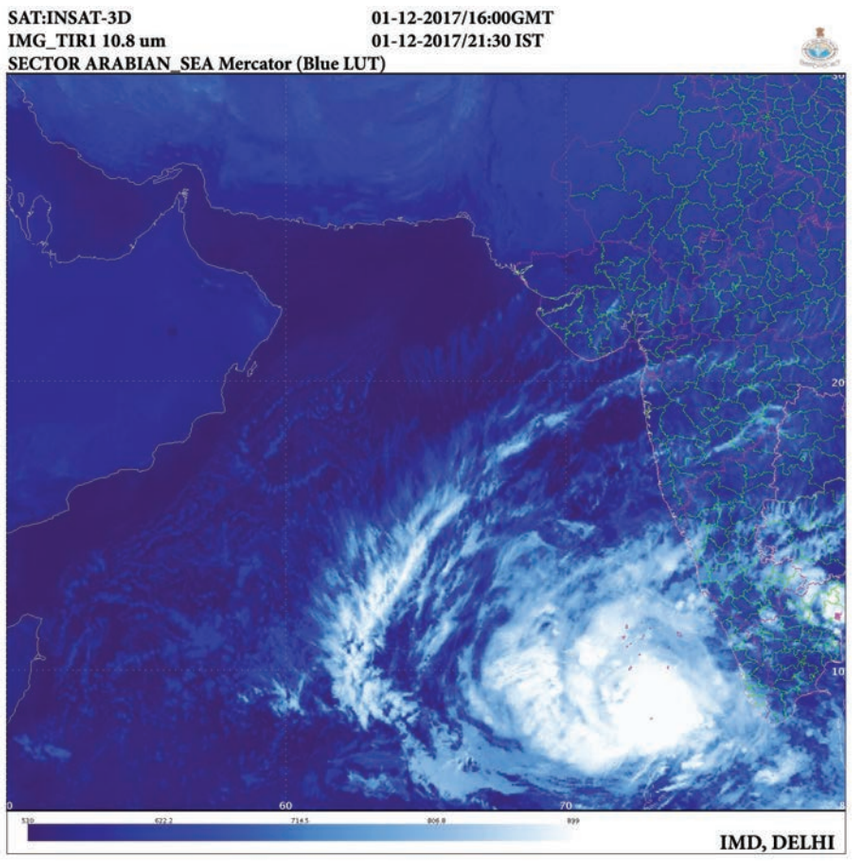


Figure 6.30 Track of Tropical cyclone

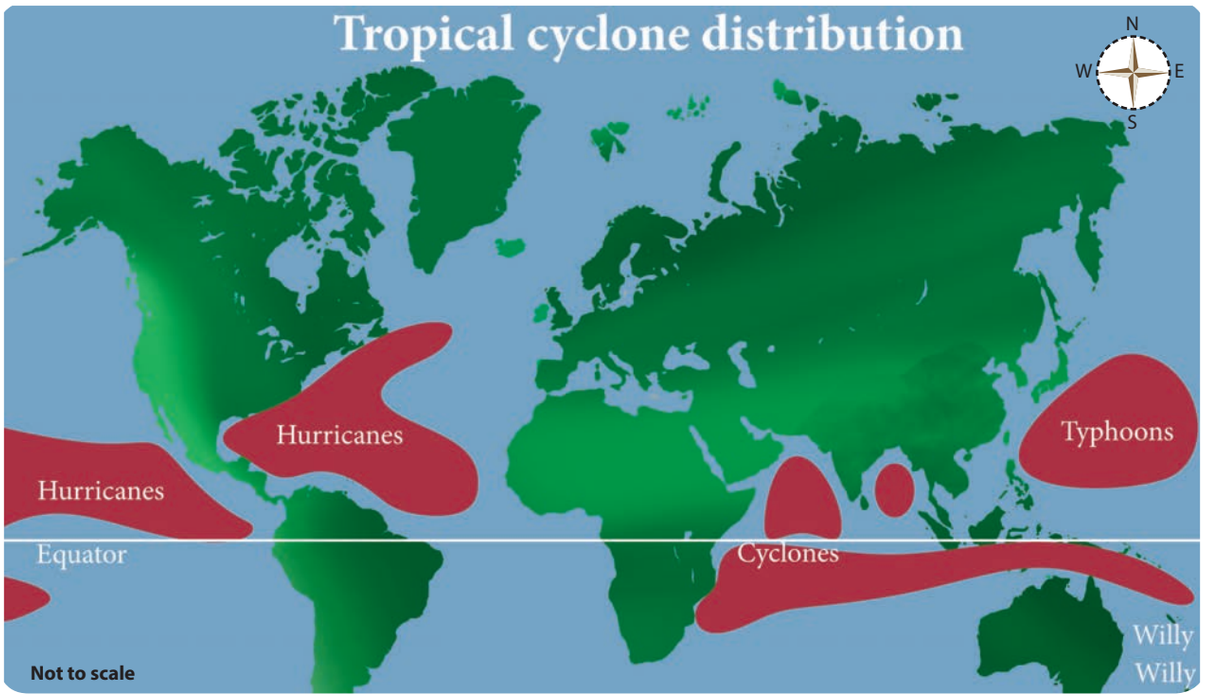


Figure 6.31 Distribution of Tropical Cyclone

Landfall: The condition at which the eye of the tropical cyclone crosses the land is called 'Land fall' of the cyclone (Figure 6.32).

Figure 6.32 Landfall of tropical cyclone

Naming of Tropical Cyclones

The practice of naming storms (tropical cyclones) began years ago, in order to help in the quick identification of storms in warning messages because names are presumed to be far easier to remember than numbers and technical terms

In the pursuit of a more organized and efficient naming system, meteorologists later decided to identify storms using names from a list arranged alphabetically. Since 1953, Atlantic tropical storms have been named from lists originated

Lightning and Thunder are caused by differences in the electrical charge of different parts of the cloud. The top of the cloud becomes positively charged and the bottom is mostly negatively charged. When the difference is great lightning occurs. Differences in the charge between cloud and the earth surface also cause lightning.

Thunder is caused by rapid expansion of the air that is heated as the lightning passes through it.

Fact File

Cloud Seeding or Artificial Rainfall

People have always wanted to create rain, so that they would not suffer from drought. Modern science has been successful in causing rain in a limited way through cloud seeding. This method is based on the knowledge of growing ice crystals in clouds.

One method to cause rainfall from clouds is to introduce particles of dry ice (solid CO_2) into the cloud from an air plane. The dry ice causes ice crystals to form in the cloud. These ice crystals coalesce, grow, melt and fall as rain. Cloud seeding will not be successful unless the cloud is already saturated with water vapour.

by the National Hurricane Centre. They are now maintained and updated by an international committee of the World Meteorological Organization (WMO).

Large scale destruction caused by Odisha cyclone in 1999, triggered the issue of naming tropical cyclones developed in the North Indian ocean. As a result, naming conventions for storms that develop in the Indian Ocean began in 2004. WMO (World Meteorological Organisation)had informed each of the eight South Asian member countries to submit a list of their own eight names for the cyclones.

DO YOU KNOW?

An isohyets or isohyetal **line** is a **line** joining points of **equal rainfall** on a map in a given period. A map with isohyets is called an isohyetal map.

6.7.3 Tornado and Water Spouts

It is a very small intense, funnel shaped very speed whirl wind system. Its speed and direction of the movement are erratic (Figure 6.33). The winds are always as fast as 500 km ph. The fast moving air converges in the middle and rises up. The uplift is capable of rising dust, trees and other weaker objects in its path. South and western part of Gulf States of USA experiences frequent tornados.

Water spouts are formed over water body similar to tornados in the formation and structure. This sometimes leads to fish rain, if the mass of fish comes under the water spout.

Web link for Water spout at Chennai, Tamil Nadu https://www.youtube.com/watch?v=v0RubwHxlgM

Figure 6.33 Tornado

B. Temperate Cyclone

The cyclone formed in the mid latitudes is called as temperate cyclone. As they are formed due to movement of air masses and front, they are called as 'Dynamic cyclone' and 'Wave cyclone'. This cyclone is characterised by the four different sectors, which are varied with their weather patterns (Figure 6.34).

Student Activity

Students have to collect the recent names of the hurricanes, typhoons and cyclones and date and location of landfall in last 5 years.

Names	Location of Landfall	Date of Land fall
Hurricanes		
Typhoons		
Cyclones		

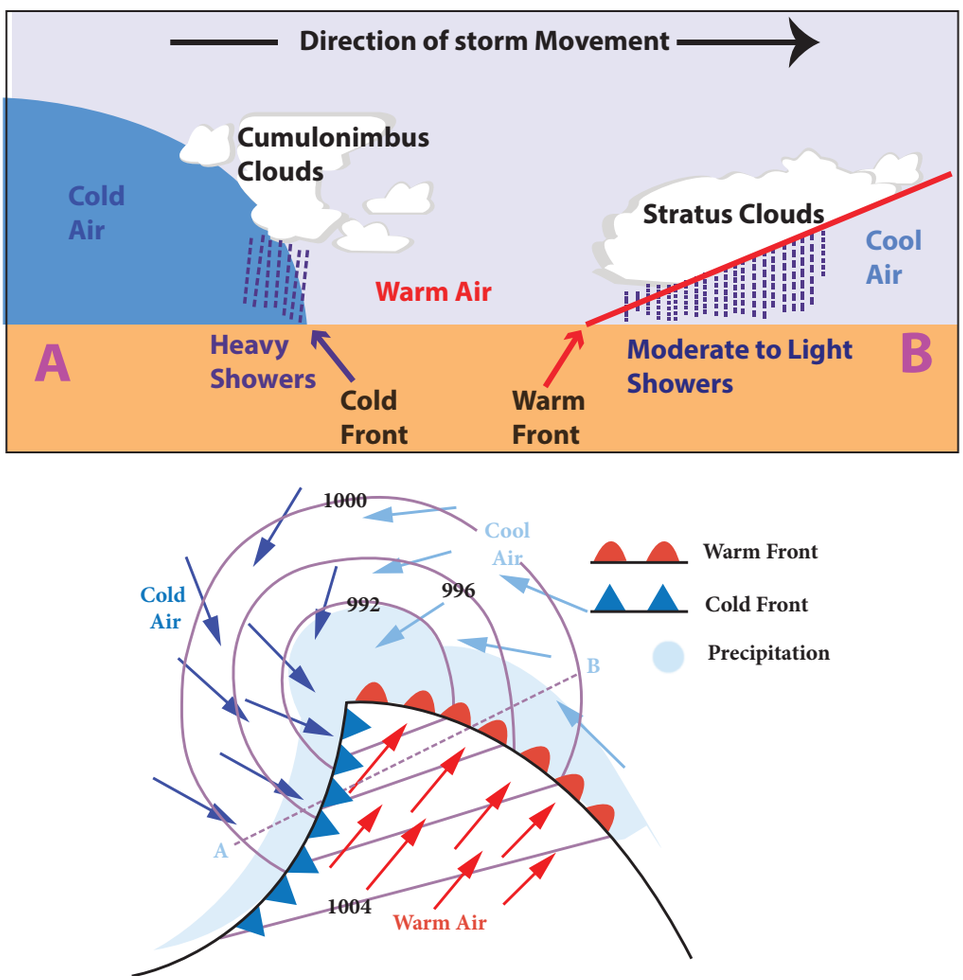


Figure 6.34 Sector structure of Temperate cyclone

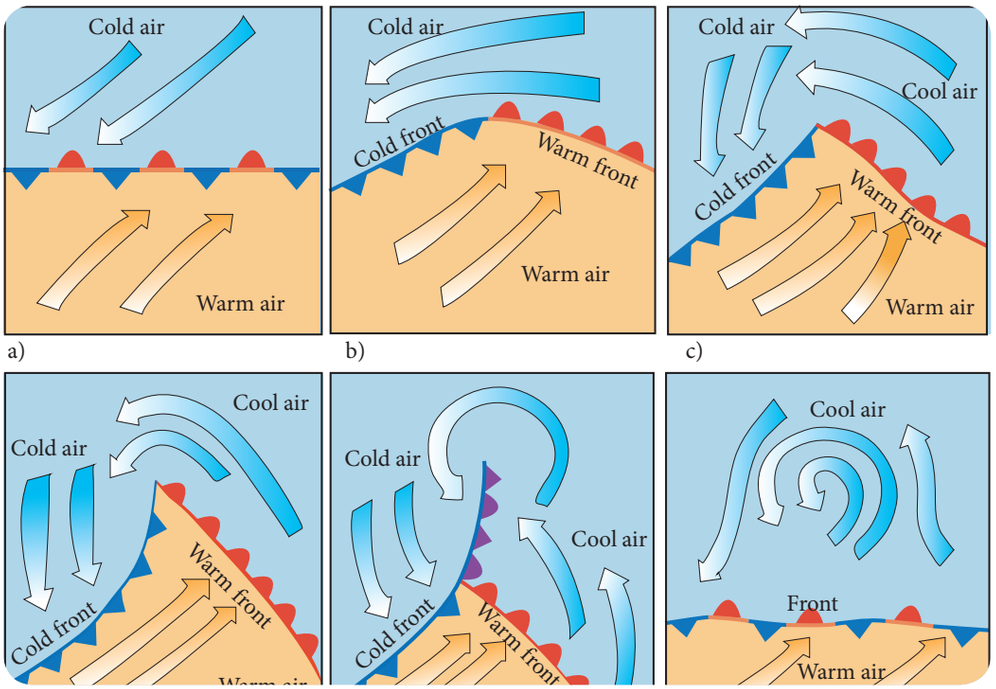


Figure 6.35 Development of Temperate cyclone

6.7.4 Stages in the Formation of Temperate Cyclone

a. Frontogenesis –Formation of front due to collision of two contrasting air masses (Figure 6.35).

b. Cyclone genesis – Formation of cyclone due to conversion of fronts into various sectors.

c. Advancing Stage – The stage where cold front advances towards warm front.

d. Occlusion stage - The stage where the cold front over takes warm front

e. Frontalysis – The last stage where fronts disappear and cyclone ends its life.

Characters

Unlike tropical cyclone, temperate cyclone forms over both land and water in all seasons. It covers larger area than tropical cyclone and stays for a longer period.

Condition of Super Cyclone Formation

1. Longer travel or stay of low pressure system over warm ocean water.
2. The speed of jet stream may influence the formation of super cyclone.

Track

Temperate cyclone moves along with the westerly wind system from west to east.

Anti Cyclones

Anti cyclone is a whirlwind system in which high pressure area at the centre and surrounded by low pressure at periphery rotating clockwise in northern hemisphere and anti clock wise in southern hemisphere(Figure 6.36).

This is the largest among the whirl wind systems. Normally, they are associated with high pressure belts of sub tropical and polar region.

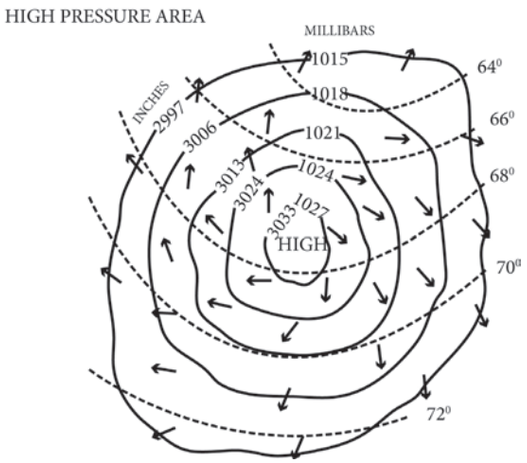


Figure 6.36 Anticyclone

Anti cyclones are classified as warm core and cold core, based on their temperature, which are resulted in aridity and cold waves respectively.

GLOSSARY

Buoyant: Able to keep afloat on the top of air or liquid.

Collision: Hit by accident when moving.

Equilibrium: A balanced state of molecules where the acting forces are equal.

Escarpment: A long, steep slope especially one of the edge of a plateau or surface.

Expansion: The action of becoming larger or more extensive.

Funnelling: Guided through the area that has widening at front and narrow at the end.

Hygroscopic: Tending to observe moisture from air.

Insolation: Amount of solar radiation reaching a given area.

Meteorology: is a branch of the atmospheric sciences with a major focus on weather forecasting.

Molecules: A group of atoms bonded together.

Permeable: Allowing liquids or gases to pass through it.

Subsistence: The gradual movement of air molecules from higher altitude to lower altitude.

Torrid: Region of Very hot and dry condition.

Vortex: A whirling or rotating mass of fluid or air.

Evaluation

I Choose the best answer

1. Which of the following atmospheric layer known as the weather layer?
   a. Troposphere b. Stratosphere
   c. Thermosphere d. Mesosphere
2. Which is the most suitable layer for flying Jet air craft?
   a. Troposphere b. Stratosphere
   c. Mesosphere d. Exosphere
3. Which of the following atmospheric structure absorbs the ultra violet rays of the sun and protect the earth from intense heating?
   a. Troposphere b. Ozonosphere
   c. Thermosphere d. Exosphere
4. An imaginary line connecting the places having equal atmospheric temperature is called
   a. Isotherm b. Isohytes
   c. Isobar d. Contour
5. Speed of the wind is measured by
   a. Barometer b. Hygrometer
   c. Thermometer d. Anemometer
6. What happens to atmospheric pressure with increase in altitude?
   a. It remains constant
   b. It increases
   c. It decreases
   d. It constantly fluctuates
7. Which one of the following winds is the example of secondary winds?
   a. Trade winds b. Westerlies
   c. Polar easterlies d. Monsoon
8. Albedo means
   a. Amount solar radiation reflected by the surface
   b. Amount moisture absorbed by the surface
   c. Amount moisture present in air
   d. Amount of molecules present in air
9. Which instrument is used to measure the relative humidity in air?
   a. Hygrometer b. Barometer
   c. Thermometer d. Altimeter
10. Convectional rainfall mostly occurs in _____?
    a. Temperate region
    b. Equatorial region
    c. Tundra region
    d. Desert region

II Very short Answer.

11. Define lapse rate.
12. What is mountain wind?
13. Draw and label the pressure belts on the globe.
14. Differentiate rainfall and snow.
15. What are the stages of formation of temperate cyclone?

III Short Answer.

16. Why is ozone layer depleting?
17. Draw the diagram for heat budget and mark the radiation emit.
18. How is an urban heat island formed?
19. Differentiate between sea breeze and land breeze.
20. List the forms of precipitation.

IV Detailed Answer.

21. Elucidate the types of clouds.
22. Discuss the mechanism of Asian monsoon.
23. How is the cyclone different from anticyclone?

References

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1. http://www.imd.gov.in/
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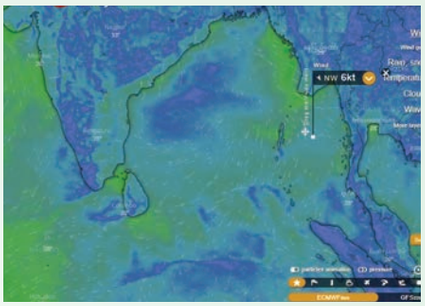
ICT CORNER

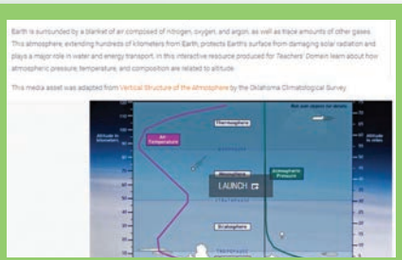
Atmosphere Vital Blanket

Through this activity you will explore atmosphere system.

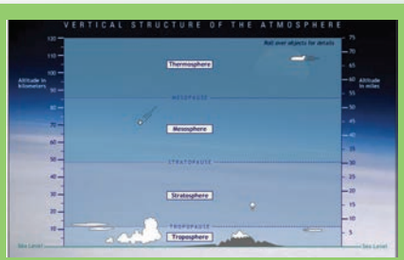


Steps

- Use the URL to reach 'Vertical Structure of the Atmosphere' page. Click launch to start the interactive atmosphere page.
- Click begin and select 'Objects' check box to observe the vertical content of the atmosphere.
- Select 'Temperature' and 'Pressure' check boxes to study physical properties of the atmosphere.
- Use https://www.windy.com to observe live wind flow of any place on the earth.



Step 1



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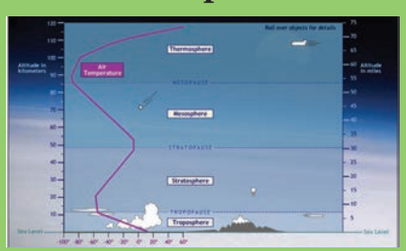
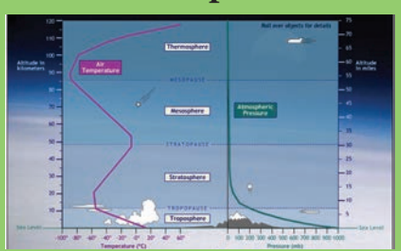


Step 3



Step 4

Interactive Atmosphere's URL:

https://www.pbslearningmedia.org/resource/ess05.sci.ess.watcyc.vertical/vertical structure-of-the-atmosphere/#.Wq-xD8OuzIU

ZCAJR

*Pictures are indicative only.