CLIMATE

- is broad concept
- study of climate of a place or region over long period of time : Climatology
- ggregate weather conditions more than thirty years
- Has broader Implications it influence natural ecosystem, agriculture, water resources and human societies over a extended period.

WEATHER

- is narrow concept
- study of weather : Meteorology
- refers to short-run atmospheric conditions that exist for a given time in a specific area.
- day , week , season or perhaps a year phenomenon,
- weather is highly variable and unpredictable

DIFFERENCE BETWEEN CLIMATE AND WEATHER

Parameters	Weather	Climate
Timescale	Weather refers to the short-term atmospheric conditions occurring over a relatively short period, typically hours to days.	Climate refers to long-term patterns and averages of weather conditions over a specific region or the entire Earth, usually spanning decades to centuries.
Variability	Weather conditions can change rapidly and are influenced by daily and seasonal fluctuations in temperature, precipitation, wind, humidity, and atmospheric pressure.	Climate represents the average or typical weather conditions of a region, considering the long-term trends and variations.
Spatial Scope	Weather conditions can vary from one location to another over small distances. For example, it can be raining in one area while being sunny in a neighbouring area.	Climate describes the general patterns and characteristics of weather over a larger geographical area, such as a city, region, or even the entire planet.
Predictability	Weather is highly variable and can be challenging to predict accurately beyond a few days due to its sensitivity to small-scale atmospheric processes.	The climate is more predictable on longer timescales as it is influenced by larger-scale factors such as oceanic circulations, solar radiation, and greenhouse gas concentrations.
Impact	Weather affects our day-to-day activities and immediate conditions, such as deciding what to wear or planning outdoor events.	Climate has broader implications as it influences the natural ecosystems, agriculture, water resources, and human societies over an extended period. Changes in climate can have significant long-term impacts on habitats, agriculture, and the frequency of extreme weather events.

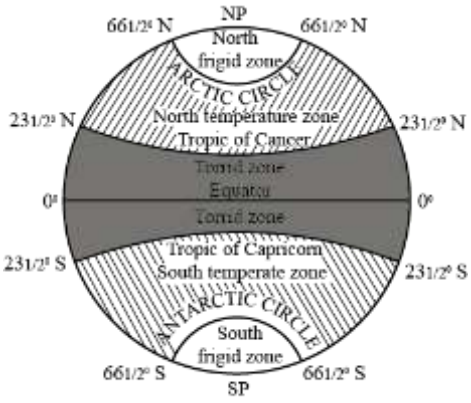
ELEMENTS AND CONTROLS OF CLIMATE AND WEATHER

The Elements and Controls of Weather and Climate

Elements of Weather and Climate	Controls of Weather and Climate
Temperature	Latitude
Pressure	Distribution of land and water
Wind	General circulation of the atmosphere
Moisture content	General circulation of the oceans
	Altitude
	Topographic barriers
	Storms

Be Noted :
three of the four weather elements—temperature, pressure, and moisture content—generally decrease upward in the troposphere and are therefore under the influence of the control altitude.

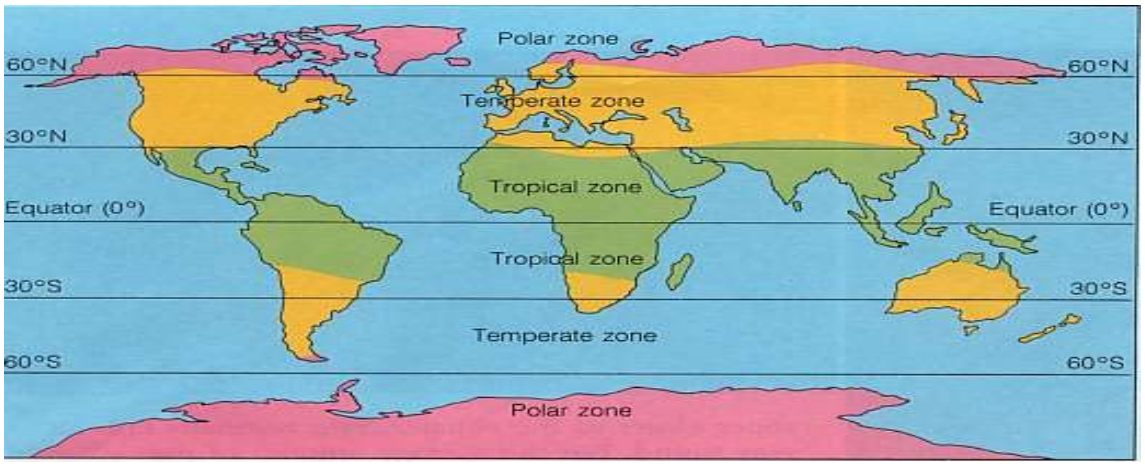
HEAT ZONES OF THE EARTH :



Heat zones.

- On the basis of latitudinal extent, the globe is divided into three broad heat zones

HEAT ZONES	lOCATION	TEMPERATURE
Tropical Zone / Torrid	Between Tropic of Cancer and Capricorn in both Hemisphere	Hot and warm Zone covers 40 % Earth Area
Temperate Zone / Tepid	Located in Both Hemisphere between Tropic of Cancer to Arctic Circle and Tropic of Capricorn to Antartica Circle	Moderate Heat Zone covers 52 % Earth Area
Polar Zone / Frigid	Located in Both Hemisphere beyond Arctic and Antartica Circle	Cold and Cool Zone covers 8 % Earth Area



EVOLUTION OF THE ATMOSPHRE

AEROLOGY:

- the study of earth atmosphere and its processes is called atmospheric science.

Evolution of the Earth's atmosphere:

Name of Stage	Duration of Stage	Main Constituents of the Atmosphere	Dominant Processes and Features

	(Billions of Years Ago)		
Early Atmosphere	4.4 to 4.0	H_2O, hydrogen cyanide (HCN), ammonia (NH_3), methane (CH_4), sulfur, iodine, bromine, chlorine, argon	Lighter gases like hydrogen and helium escaped to space. All water was held in the atmosphere as vapor because of high temperatures.
Secondary Atmosphere	4.0 to 3.3	At 4.0 billion H_2O, CO_2, and nitrogen (N) dominant. Cooling of the atmosphere causes precipitation and the development of the oceans. By 3.0 billion CO_2, H_2O, N_2dominant. O_2 begins to accumulate.	Continued release of gases from the lithosphere. Water vapor clouds common in the lower atmosphere. Chemosynthetic bacteria appear on the Earth some time between 3.9 and 3.5 billion years ago. Life begins to modify the atmosphere.
Living Atmosphere	3.3 to Present	N_2 - 78%, O_2 - 21%, Argon - 0.9%, CO_2 - 0.036%	Development, evolution and growth of life increases the quantity of oxygen in the atmosphere from <1% to 21%. 500 million years ago concentration of atmospheric oxygen levels off. Humans begin modifying the concentrations of some gases in the atmosphere beginning around the year 1700.

kEY LINES :

- Free oxygen did not exist in the atmosphere until about 2.4 billion years ago.
- Oxygen will be almost in negligible quantity at the height of 120 km
- Carbon dioxide and water vapour are found only up to 90 km from the surface of the earth.
- Ozonosphere lies at altitude between 20 km and 50 km from the earth surface
- Ozone found between 20 km and 30 km altitude (lower stratosphere) : greatest concentration of ozone are found .
- Water vapour: constitute 0.02 % to 4 % in cold dry air to humid tropical climate.

ATMOSPHERE :

- Mixture of several gases
- Completely surrounds the Earth .
- The atmosphere is held to the Planet by the force of gravity.
- The atmosphere is made up of different types of gases, water vapour and dust particles.
- The composition of the atmosphere is not static. It changes according to the time and place
- It forms a protective boundary between the outer space and the biosphere.
- Supplies oxygen for Human and animals survival and Carbon dioxide for plants.
- Helps to maintain water supply .
- It acts as a greenhouse by allowing short-wave radiation (from Sun) and trapping long-wave terrestrial radiation (from Earth's surface).
- **Temperature Balance**
- In the absence of the atmosphere extremes of temperature would exist between day and night over the earth's surface
- Acts as a shield from Sun UV radiation.
- It is held to Earth by gravitational attraction
- Here Density decrease with Altitude .

VARIABLE GASES :

- Atmosphere consist of Permanent Gases and Variable Gases
- Variable Gas like Carbon dioxide , water vapour , methane and ozone .
- They influence on weather and climate is significant than the Permanent Gases

DEFINE WATER VAPOUR AND ITS ROLE IN THE ATMOSPHERE :

- Water in the form of a gas is known as **water vapor**
- Water vapor has a significant effect on weather and climate:
- Water Vapour is variable gas in the atmosphere in terms of location
- It Decrease with Altitude.
- Water Vapour also decrease from the Equator towards the Poles
- Water vapor is most abundant in air in warm, moist surface areas such as tropical oceans, where water vapor may amount to as much as 4 percent of total volume.
- Over deserts and in polar regions, the amount of water vapor is but a tiny fraction of 1 percent
- It also absorbs parts of the isolation from the sun and preserves the Earth radiated heat.
- It thus, acts like a blanket allowing the Earth neither to become too cold not too hot .
- Water Vapour also contributes to the stability and instability in the air .
- Play a Key role in Anticyclone and Cyclone activities, Airmass, Fronts, Clouds Formation, Rainfall etc.

Dust

UPSC Prelims 2024
With reference to "water vapour", which of the following statements is/are correct?

1. It is a gas, the amount of which decreases with altitude.
2. Its percentage is maximum at the poles.

Ans 1 only

particles or Particulates Matter PM (Aerosols)

- They are microscopic solid and liquid particles found in the atmosphere are collectively called particulates or aerosols.
- Play a Key Role in Atmosphere, impacting weather and climate, Health and ecological processes.
- Help in Cloud Formation; Climate Regulation : light colour dust particles can reflect sunlight (Cooling Effect) while dark colour dust particles can absorb heat (Warming Effect)
- Dust and Salt particles act as hygroscopic nuclei around which water vapour condenses to produce clouds.
- Help in Transportation of nutrients ex Dust from Sahara Desert can fertilize the Amazon Rainforest and the Ocean playing key role in ecosystem productivity .
- **Sources :**
  Sources :
- **Man Made** : industrial and automotive emissions and smoke & soot from fires
- **Natural :** Volcanic ash, windblown soil and pollen grains, meteor debris, smoke from wildfires, and salt spray from breaking waves are examples of particulates from natural sources.
- **The Higher concentration of dust particles is found** in Subtropical and temperate regions due to dry winds in comparison to equatorial and polar regions

Topic : Composition and Structure of Atmosphere

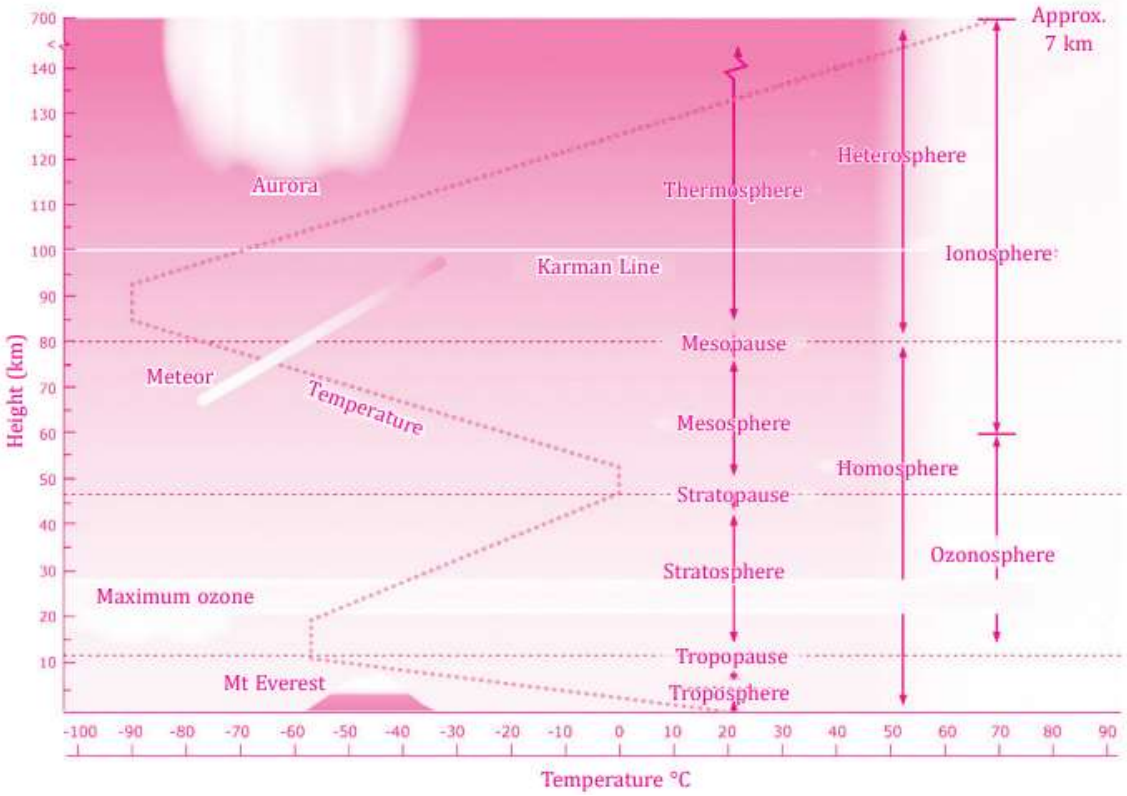
Atmosphere comprises a mixture of gases, water vapor, and dust particles. 99% of the atmosphere's total mass is concentrated within a range of 32 kilometers from the Earth's surface.

COMPOSITION OF THE ATMOSPHERE

Table 8.1 : Permanent Gases of the Atmosphere

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

-
- the three principal atmospheric gases—nitrogen, oxygen, argon- have minimal effect on weather and climate
- Carbon dioxide(0.04%): Transparent to incoming solar radiation (short wave radiations) but acts as a greenhouse gas (opaque to long wave radiation).
- Argon: A noble gas; third most abundant gas in earth's atmosphere.
- Ozone: Present in the stratosphere; absorbs ultraviolet rays from the sun.
- Water vapour is a variable gas that decreases with altitude. Water vapor also decreases from the equator towards the poles. Water vapour is the most abundant greenhouse gas in the atmosphere which absorbs inf rared rays emitted from the earth's surface. [UPSC 2023].
- Dust particles are more concentrated in subtropical and temperate regions due to dry winds.



Pause term is very shallow transition zone.

Kármán line, boundary separating Earth's atmosphere and outer space.

The Earth's Atmosphere is Divided into Distinct Layers

1. Troposphere:

- Lowest layer with an average height of 13 km. It extends up to approximately 8 km near the poles and about 18 km at the equator
- All weather changes and biological activities occur in this layer.

- Temperature decreases with height at a rate of 1°C for every 165 meters of height.

2. Stratosphere:
   - Located above the tropopause and extends to a height of 50 km. It contains the ozone layer, which absorbs UV rays.
   - Temperature increases with height
   - Ideal for aircraft flying due to the minimal presence of water vapour & clouds except polar stratospheric clouds (responsible for ozone depletion). •

3. Mesosphere:
   - Extends up to 80 km. •
   - Decreasing temperatures with altitude. •
   - Upper limit of mesosphere is known as the mesopause (minimum temperature).
   - Meteors and Shooting Stars occur here; Green House Gases are absent

4. Ionosphere:
   - Spans from 80 - 400 km above the mesopause; contains electrically charged particles and reflects radio waves back to Earth.
   - • It further has a D-Layer (lowest), an E-Layer and a F-Layer (F1 and F2 layers).

5. Exosphere: uppermost layer of the atmosphere.

Thermosphere is the Earth's layer from 90 to 500-1,000 km. Marked by the thermopause at 500-1,000 km. Solar-driven temperature variations; has low density resembling space; has auroras.

Earth's atmosphere is divided into homosphere and heterosphere

- Homosphere, up to 60 miles, uniform mixture of air, well-mixed layers (Troposphere, Stratosphere) •
- Heterosphere, beyond 60 miles, varying composition with distinct layers (Thermosphere, Exosphere) with minimal mixing, influenced by solar radiation, and transitions into space

Structure of Atmosphere

Layer	Description	Height Range (km)	Temperature Trend	Key Features
Troposphere	The lowest layer, where we live and experience weather.	0 - 13 (Thicker at equator, thinner at poles)	Decreases with height (normal lapse rate)	Contains 75% of **atmospheric mass.** Responsible for all weather phenomena. Clouds, precipitation, wind all occur here
Stratosphere	The calm layer above the troposphere.	13 - 50	Increases with height due to ozone absorption	Contains the ozone layer, which protects us from harmful UV radiation. Ideal for air travel due to stable conditions. Some cirrus clouds may be present
Mesosphere	The middle layer where temperatures plummet.	50 - 85	Decreases with height	Most meteors burn up here due to thin air. Polar mesospheric noctilucent clouds form due to extreme cold
Thermosphere	The upper layer where temperatures soar due to solar radiation.	85 - 600	Increases with height due to UV and X-ray absorption	The International Space Station and satellites orbit here. **Kármán Line** (100 km) defines the edge of space
Ionosphere (Within	A region with charged	80 - 400	Varies	Electrically charged particles (ions) present.

Thermosphere)	particles that affect radio waves.			Reflects radio waves, enabling communication
Exosphere	The outermost layer, where particles escape to space.	400+	Gradually increases	Very thin and sparse atmosphere. Transition zone to outer space pen_spark

TOPIC : Solar Radiation, Heat Balance and Temperature

Solar radiation:

- Solar radiation is radiant energy emitted by the Sun as a result of nuclear fusion reaction.
- The earth's surface primarily receives energy in short wavelengths, which is termed as "incoming solar radiation" or "insolation."
- On an average the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere . OR aprrox 2 langley ((2 units out of 1,00,00,00,000 units of energy radiated by the sun).
-
- Plank's law states that the hotter body radiates more energy and short wavelength radiation
- The amount and intensity of insolation vary during a day, in a season and a year.
- The red colour of the rising and setting sun and the blue colour of the sky are the result of scattering of light within the atmosphere

The factors that cause these variations in insolation are :

- The rotation of the earth on its axis
- The angle of inclination of the sun's rays
- The length of the day
- The transparency of the atmosphere
- The configuration of land in terms of its aspect.

Distribution of Solar Radiation

Factors influencing insolation variability

- Rotation of earth on its axis causing day and night; poles experience continuous daylight or darkness.
- Changing distance between the Earth and the Sun: Aphelion position (farthest from the sun) on 4th July and Perihelion position (nearest to the sun) on 3rd January. Thus the annual insolation on 3rd January is slightly more than on 4th July.
- Earth's axis is angled at 66 1⁄2° with its orbital plane that influences insolation received at different latitudes.
- Angle of the sun's rays depends on the latitude of a place - Higher the latitude, lesser the angle. Net energy received per unit area decreases with latitude. Moreover, slant rays pass through a greater depth leading to more absorption, scattering, and diffusion.
- Transparency of the atmosphere: Higher transparency leads to higher insolation.
- Albedo: Measure of surface reflectivity (0 to 1 scale) The reflected amount of radiation is called the albedo of the earth.
- Albedo effect reduces temperatures (Decreasing Order of the Albedo: Fresh Snow (0.80) > Ocean ice > Sand > Green gross > Soil > Forest > Open ocean (0.06) > Charcoal (0.04))
- Configuration of land: Aspect (land orientation) influences sunlight reception; south-facing slopes are warmer and north-facing cooler in the Northern hemisphere and reverse is true for the Southern hemisphere.

Spatial Distribution of Insolation on Earth's Surface

- The insolation received at the surface varies from about 320 Watt/m2 in the tropics to about 70 Watt/m2 in the poles

- Subtropical deserts receive the highest insolation due to minimal cloudiness
- Equator receives less insolation compared to the tropics.
- At the same latitude, continents generally receive more insolation than oceans as clouds over the ocean reflect back the sunlight.
- The Equator receives 5 times more insolation than polar regions
- The specific heat capacity of water is much greater than that of land; it slowly warms in the summer and slowly cools in the winter. The temperature contrast between continents and oceans is greater during summer than in winter.

UPSC Prelims 2023 Question:

With reference to the Earth's atmosphere, which one of the following statements is correct?

a) The total amount of insolation received at the equator is roughly about 10 times of that received at the poles.

b) Infrared rays constitute roughly two-thirds of insolation.

c) Infrared waves are largely absorbed by water vapour that is concentrated in the lower atmosphere.

d) Infrared waves are a part of visible spectrum of electromagnetic waves of solar radiation.

Correct Answer: Option c)

SOLAR CONSTANT

- Is a fixed value representing the solar energy received at the top of the Earth Atmosphere .
- The value of solar constant i.e. rate of radiation from sun is **2gm calories per square cm per minute (2cal/cm2/min)**
- about 1372 watts per square meter
- **Solar Constant is measured at the distance of 1 astronomical unit (AU)**
- Insolation varies by location, time of year , and weather conditions , representing the actual solar energy received on the surface of the Earth

Length of the Day :

Note the variations in the duration of the day at different latitudes on solstices given in Table

Table 9.1 : Length of the Day in Hours and Minutes on Winter and Summer Solstices in the Northern Hemisphere

Latitude	0°	20°	40°	60°	90°
December 22	12h 00m	10h 48m	9h 8m	5h 33m	0
June 21	12 h	13h 12m	14h 52m	18h 27m	6 months

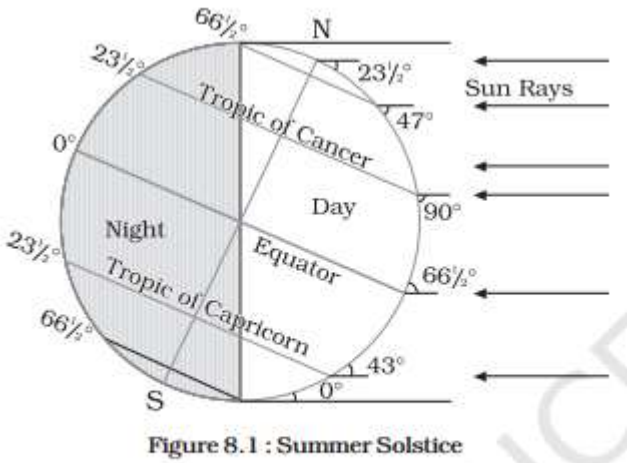


Figure 8.1 : Summer Solstice

The Passage of Solar Radiation through the Atmosphere

In which one of the following cities, are the days the longest in Summar?
a)Chandigarh.
b)Hyderabad.
c)Thiruvananthapuram.
d)Nagpur.

Correct answer is option 'A'.

In summer (March to September), in the northern hemisphere, as we move northwards, the length of the day increases. But in winter (September to March) the length of the night increases as we move northwards. since Chandigarh is northernmost among the options

Stations	Latitude	Altitude (Metres)	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Rainfall
Bengaluru Temperature (°C)	12°58'N	909	20.5	22.7	25.2	27.1	26.7	24.2	23.0	23.0	23.1	22.9	18.9	20.2	
Rainfall (cm)			0.7	0.9	1.1	4.5	10.7	7.1	11.1	13.7	16.4	15.3	6.1	1.3	88.9
Mumbai Temperature (°C)	19° N	11	24.4	24.4	26.7	28.3	30.0	28.9	27.2	27.2	27.2	27.8	27.2	25.0	
Rainfall (cm)			0.2	0.2	–	–	1.8	50.6	61.0	36.9	26.9	4.8	1.0	–	183.4
Kolkata Temperature (°C)	22°34' N	6	19.6	22.0	27.1	30.1	30.4	29.9	28.9	28.7	28.9	27.6	23.4	19.7	
Rainfall (cm)			1.2	2.8	3.4	5.1	13.4	29.0	33.1	33.4	25.3	12.7	2.7	0.4	162.5
Delhi Temperature (°C)	29° N	219	14.4	16.7	23.3	30.0	33.3	33.3	30.0	29.4	28.9	25.6	19.4	15.6	
Rainfall (cm)			2.5	1.5	1.3	1.0	1.8	7.4	19.3	17.8	11.9	1.3	0.2	1.0	67.0
Jodhpur Temperature (°C)	26°18' N	224	16.8	19.2	26.6	29.8	33.3	33.9	31.3	29.0	20.1	27.0	20.1	14.9	
Rainfall (cm)			0.5	0.6	0.3	0.3	1.0	3.1	10.8	13.1	5.7	0.8	0.2	0.2	36.6
Chennai Temperature (°C)	13°4' N	7	24.5	25.7	27.7	30.4	33.0	32.5	31.0	30.2	29.8	28.0	25.9	24.7	
Rainfall (cm)			4.6	1.3	1.3	1.8	3.8	4.5	8.7	11.3	11.9	30.6	35.0	13.9	128.6
Nagpur Temperature (°C)	21°9' N	312	21.5	23.9	28.3	32.7	35.5	32.0	27.7	27.3	27.9	26.7	23.1	20.7	
Rainfall (cm)			1.1	2.3	1.7	1.6	2.1	22.2	37.6	28.6	18.5	5.5	2.0	1.0	124.2
Shillong Temperature (°C)	24°34' N	1461	9.8	11.3	15.9	18.5	19.2	20.5	21.1	20.9	20.0	17.2	13.3	10.4	
Rainfall (cm)			1.4	2.9	5.6	14.6	29.5	47.6	35.9	34.3	30.2	18.8	3.8	0.6	225.3
Thiruvananthapuram Temperature (°C)	8°29' N	61	26.7	27.3	28.3	28.7	28.6	26.6	26.2	2.6.2	26.5	26.7	26.6	26.5	
Rainfall (cm)			2.3	2.1	3.7	10.6	20.8	35.6	22.3	14.6	13.8	27.3	20.6	7.5	181.2
Leh 34° N Temperature (°C)	34°N	3506	−8.5	−7.2	−0.6	6.1	10.0	14.4	17.2	16.1	12.2	6.1	0.0	−5.6	
Rainfall (cm)			1.0	0.8	0.8	0.5	0.5	0.5	1.3	1.3	0.8	0.5	–	0.5	8.5

TEMPERATURE DISTRIBUTION ON EARTH

The Sun stands as the primary source of heat for our planet. The varying amounts of solar energy received by different regions of the Earth result in the diverse climatic features we observe. This differential heating is fundamental to the formation of wind systems, pressure zones, precipitation patterns, and other weather phenomena.

Factors Affecting Distribution of Temperature

- The Angle of Incidence or the Inclination of the Sun's Rays: Areas at higher latitudes receive sunlight at an angle and heats the ground less effectively. This is the primary reason why the tropics are hot and the Polar Regions are cold.
- Transparency of Atmosphere: Aerosols like smoke, dust, and clouds influence how much solar radiation reaches Earth's surface by scattering, reflecting, or absorbing it.
- Land-Sea Differential: Land heats and cools faster than water due to its lower specific heat capacity. This, combined with the varying reflectivity (albedo) of land and water, creates temperature differences between continents and oceans. Oceans moderate coastal temperatures through water circulation.
- Prevailing Winds: Winds transport heat from warm regions to cooler ones, influencing regional temperature patterns. Oceanic winds, in particular, bring the moderating influence of the sea to coastal areas.
- Ocean Currents: Warm or cold ocean currents can significantly impact the temperature of nearby landmasses.
- Altitude: As altitude increases, air pressure decreases, weakening the greenhouse effect and leading to a general decrease in temperature.
- Earth's Distance from the Sun: Earth's slightly elliptical orbit causes a small variation in the amount of solar radiation received throughout the year. However, this variation has a lesser impact compared to other factors affecting temperature distribution.

WHY WINDS TRANSFER HEAT FROM ONE REGION TO OTHER ?

- **Due to Earth Axial Tilt** (With respect to the vertical plane, the Earth has an axial tilt of 23.5°. With respect to the orbital plane or the horizontal plane, the Earth's axis is tilted at an angle of 66.5°)
- So 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 t**ransfer** of heat from one region to the other by winds

When air is heated, it expands, becomes lighter and goes up. Cold air is denser and heavy. That is why it tends to sink down. When hot air rises, cold air from surrounding area rushes there to fill in the gap. That is how air circulation takes place.

HEATING AND COOLING OF ATMOSPHERE

The four different ways of heating and cooling of the atmosphere are:

Conduction: Process in which heat flows from objects with higher temperature to objects with lower temperature through molecular movement. It primarily heats the atmosphere's lower layers.

Convection: Transfer of heat by the movement of a fluid (liquid or gas) between areas of different temperatures. Air in contact with the earth rises vertically when heated, forming currents that transmit atmospheric heat. It is limited to the troposphere

Advection: Transfer of heat through horizontal movement of air. In middle latitudes, most diurnal (day & night) variations in daily weather and in tropical regions effects of loo are the result of the advection process.

Terrestrial Radiation: Heat transfer from one body to another without actual contact or movement. Earth absorbs shortwave radiation (UV and Visible portion of electromagnetic spectrum) warming the surface; it emits long wave radiation (Infrared rays) which heats up the atmosphere.

Consider the following statements: UPSC Prelims 2024

Statement-I: The atmosphere is heated more by incoming solar radiation than by terrestrial radiation

Statement-II: Carbon dioxide and other greenhouse gases in the atmosphere are good absorbers of long wave radiation

Which one of the following is correct in respect of the above statements?

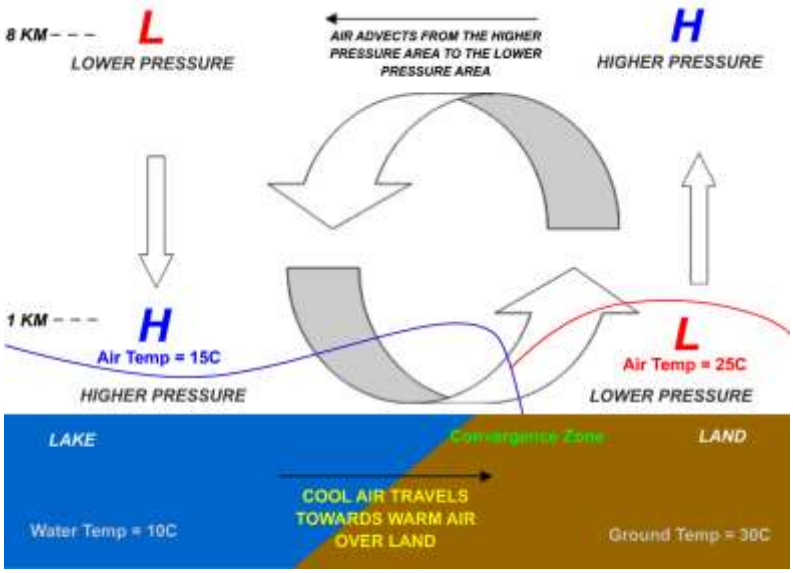
Ans **Statement-I is incorrect, but Statement-II is correct**

WHAT IS ADIABATIC COOLING AND ADIABATIC WARMING :

- Adiabatic : Change in Pressure and Latent Heat : Change in Temperature
- **Adiabatic Cooling** : —cooling by expansion (*adiabatic* means without the gain or loss of energy). In the atmosphere, any time air rises, it cools adiabatically. it is Key process involved in the cloud development and precipitation.
- **Adiabatic warming**—warming by compression. In the atmosphere, any time air descends, it warms adiabatically

Example :

- **More Temperature** = LP region: Ascending Winds / Upward winds /rising winds / Less dense winds
- **Cold Temperature** = HP region : Descending winds/ downward winds/ subsidence winds/ moredense. Brings Atmospheric Stability .
- **Convection:** Vertical winds : upward and downward winds
- **Advection:** Horizontal winds



THE EARTH NEITHER WARMS UP NOR DOES IT GET COOLED OVER A PERIOD OF TIME - Due to Heat Budget Balancing Mechanism

Concept of Heat Budget

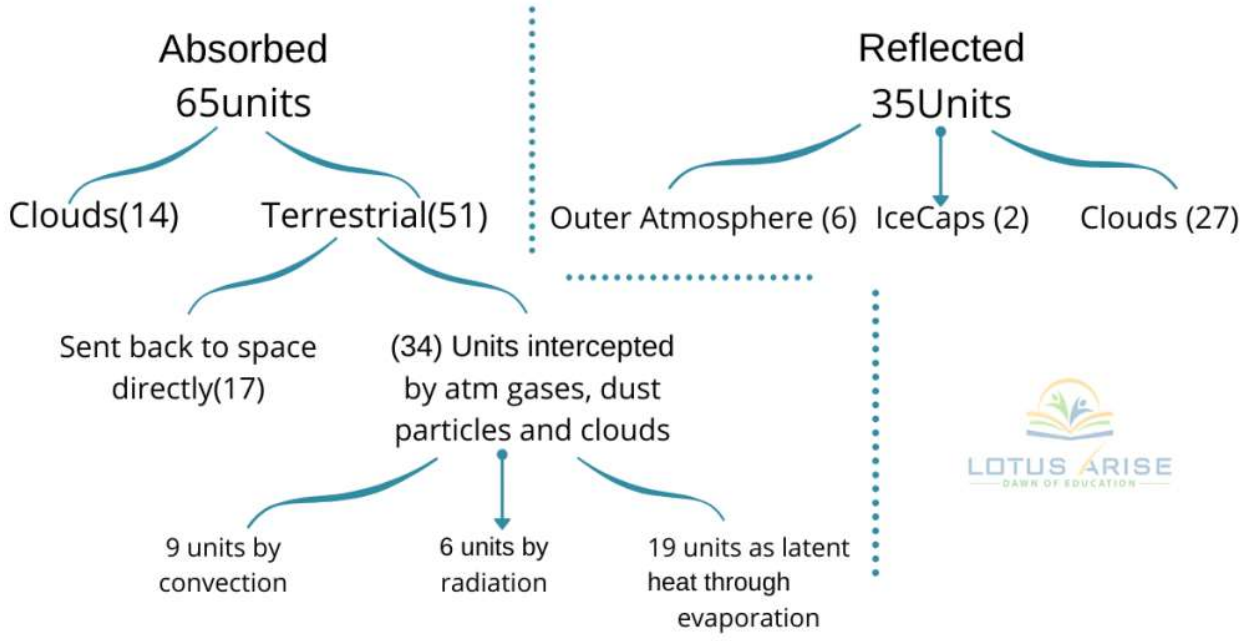
- Refers to Balance between Incoming Solar Radiation and Outgoing Terrestrial infrared radiation from the Earth
- Through this the Earth maintains its temperature .
- thus average surface temperature of earth is maintained around 15 degree Celsius

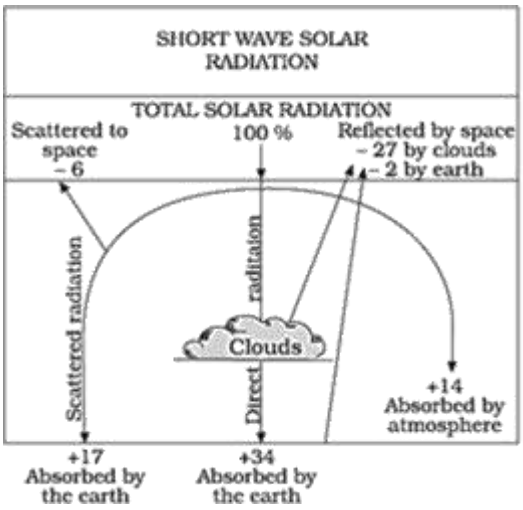
Two Aspects :

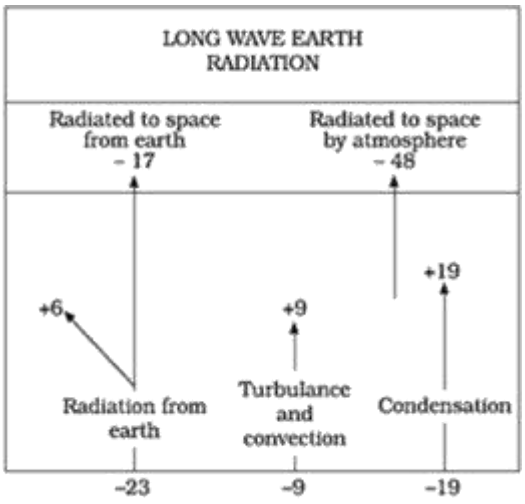
1. **VERTICAL BUDGET** OR PLANETARY BUDGET
2. **HORIZONTAL BUDGET** OR LATITUDINAL BUDGET

VERTICAL BUDGET OR PLANETARY BUDGET :

- it explains why the Earth neither warms up nor cools down despite the huge transfer of heat takes place.
- it explains the Balance Between Short wave Solar Radiation and Long wave Earth radiation.
- it is basically Reflected, Scattered , Absorbed Mechanism of the Earth







Incoming shortwave solar radiation: equals to 100 units

100 : 35(Reflection+ Scattered) + 65 (Absorption by Earth and atmosphere)

a) Amount lost to space through scattering and reflection equals to 35% comprises of

- Clouds = 27%
- Reflected by ground/ earth = 2%
- Scattered by dust particles = 6%

b) Absorb by Earth equals to 51% comprises of

- Through direct radiation = 34%
- Through indirect radiation /Received as diffuse day light = 17%

c) Absorb by atmospheric gases and water vapour equals to 14%

Outgoing long-wave terrestrial radiation (100)

a) Reflected by earth which was equal to 51 per cent as shown above

- 23% from radiation from the Earth (17 + 6)
- 9% through convection
- 19% through evaporation/ condensation

b) 48% or 49 % absorbed in atmosphere moved through radiation back into space.

Hence Total Heat Received = Total Heat Radiated

HORIZONTAL **BUDGET** OR LATITUDINAL BUDGET

Variation in the Net Heat **Budget at the Earth's Surface** :

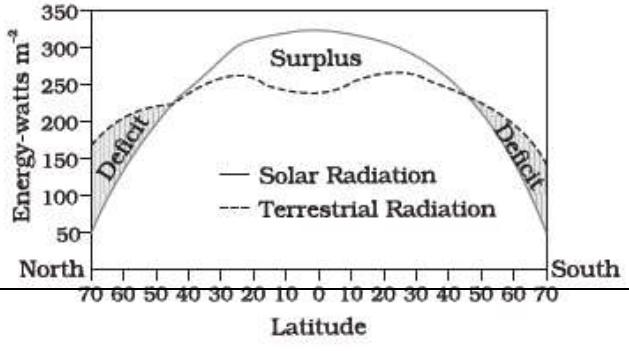


Figure depicts the latitudinal variation in the net radiation balance of the earth – in Atmosphere system.

Explanation

- There are variations in the amount of radiation received at the earth's surface. Some part of the earth has surplus radiation balance while the other part has deficit.
- . Regions within the equator and 40° N and S latitudes receive abundant sunlight and hence they are energy surplus regions.
- . Regions beyond 40° N and S latitudes lose more heat than that gained from sunlight and hence they are energy deficit regions.
- There is a surplus of net radiation balance between 40 degrees north and south and the regions near the poles have a deficit.
- The surplus heat energy from the tropics is redistributed pole wards and as a result the tropics do not get progressively heated up due to the accumulation of excess heat or the high latitudes get permanently frozen due to excess deficit.

So Energy is transferred from area of surplus to deficit areas in two related ways:

1. Atmospheric circulations(Apprx 80% of heat transfer)
2. Oceanic Currents(20%)

FOR MAINS:

FACTORS INFLUENCE HEAT BUDGET

- **Solar Radiation:** The amount of solar energy received by different regions varies based on factors like latitude, season and cloud cover etc.
- **Albedo: refers** to reflectivity of the surface. Higher Value Albedo , reflect more radiation back into space , leading to lowering the temperature. (low albedo -rising temp)
- **Heat Transfer:** Heat is transferred through various process , including conduction, convection, and radiation. These Processes affect the distribution of heat within the atmosphere ,Oceans and Land Surfaces.
- **Greenhouse Effect: Certain** gases in the Earth atmosphere, known as greenhouses gases , trap heat and contribute to the greenhouse effect. This effects help to regulate Planet Temperature, but human activities increased the concentration of GHG, leading to Global Warming .
- **Atmospheric Circulation:** The movement of air masses and the distribution of Heat through AC play a crucial role in the HB. Factors like prevailing winds, Ocean currents and pressure systems influence the transfer of Heat across different regions.
- **Climatic Patterns :** Heat Budget influences Climatic Patterns like formation of different climatic zones ,the occurrence of weather phenomenon like Monsoons or El Nino, and the development of Specific Systems.

It is important to note that Heat Budget is a complex topic with many interconnected factors. Understanding these factors helps in studying climate change, weather patterns and the overall functioning of Earth Systems.

SIGNIFICANCE OF THE HEAT BUDGET

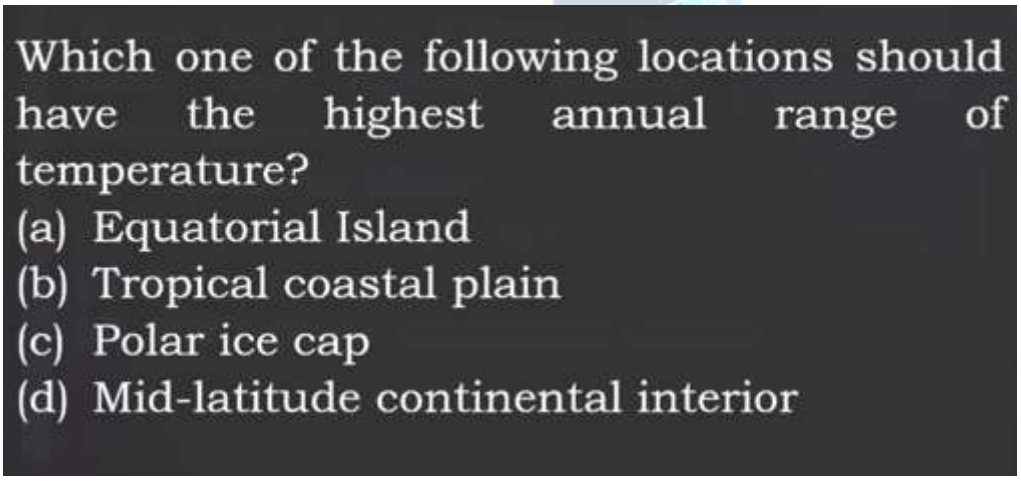
Climate Regulation: The heat budget helps in regulating the Earth's climate by maintaining a balance between the energy received and the energy emitted. Any imbalance can lead to climate changes, such as global warming if more energy is retained or cooling if more energy is lost.

Weather Patterns: The distribution of solar energy across the Earth influences weather patterns and ocean currents. Understanding the heat budget helps in predicting weather and understanding climate phenomena.

Life Sustenance: A balanced heat budget ensures that Earth's temperatures remain within a range that supports life. It influences the availability of water and the distribution of ecosystems around the planet.

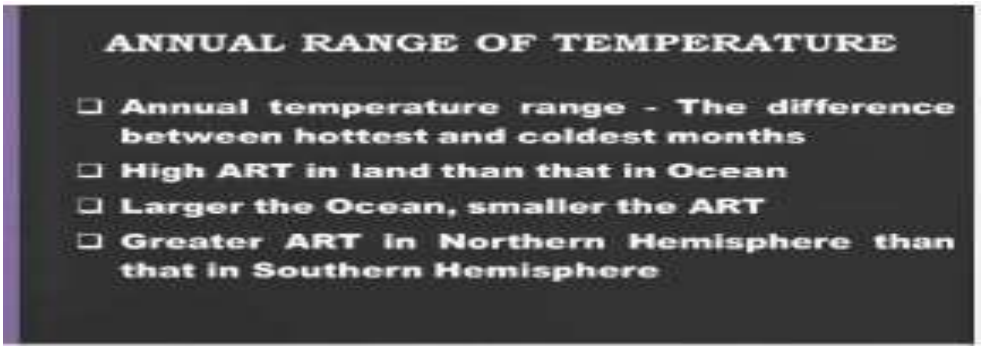
Diurnal /Daily Range of Temp:

- **difference between Max temp during day and minimum temp during at night.**
- DRT is high at **equator and decrease towards the poles.**
- **DRT is minimum near Seacoast due to the moderating effect of the sea and gradually increase towards continental interior.**
- High desert regions typically have the greatest diurnal-temperature variations, while low-lying humid areas typically have the least
- Diurnal temperature variation is of particular importance in viticulture. Wine regions situated in areas of high altitude experience the most dramatic swing in temperature variation during the course of a day. In grapes, this variation has the effect of producing high acid and high sugar content as the grapes' exposure to sunlight increases the ripening qualities while the sudden drop in temperature at night preserves the balance of natural acids in the grape



Annual Range of Temperature: difference between average temp of hot month and cold month of year. ART is minimum near equator and **increase towards poles. but seasonal changes are minimum at equator and maximum at poles.**
Ex: ART high in Siberian plains because Mean January temp between 80 degree N and 50 degree N is minus 20 degree C and temp in july is more than 10 degree C

At the Same Latitudes ART much on Land than Ocean .
Larger Ocean takes more time to Heat up and Heat will be lost very slowly .
Smaller Oceans takes less time to Heat up and Heat will be lost very Fast .
PO has less ART than AO (Atlantic Ocean)



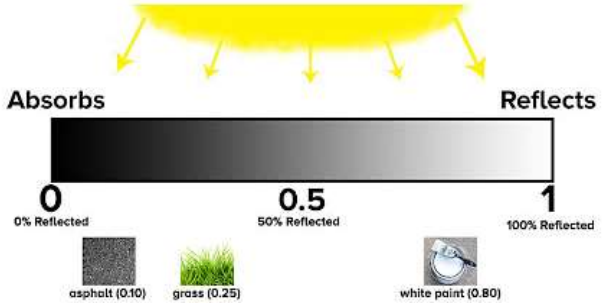
Thermal Anomaly: the difference of observed temperature of a place and the mean temp of latitude passing through that place is called thermal anomaly. if observed temp of a particular place is more than mean temp of latitude of that place then thermal anomaly called is **positive T.A and** if less **negative TA.**

Equal thermal anomaly of several places called Isanomalous temp and lies drawn on world map joining places of equal TA are called **Isanomals.**

During ---Summer anomalies: **Positive TA = Continent (High temp)** **Negative TA= Ocean (Low temp)**	**Winter anomalies** **Positive TA= Ocean(High temp)** **Negative TA= Continent (Low temp)**

ALBEDO

- is the amount of solar radiation reflected back into space from the Earth's surface.
- The average albedo of the Earth from the upper atmosphere(planetary albedo), is 30–35%.
- it is reflection coefficient and having value less than one .
  - On a scale of 0-1, albedo is measured:
  - 1 on the albedo scale equals 100% reflection.
  - 0 indicates that there is no reflection.



How does the Albedo of Earth affect Climate?

Albedo and Global Warming

- Human activities (e.g., deforestation, farming, and urbanization) change the albedo of various areas around the globe which contributes to 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.

Where this Concept Used? and its Role

- 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.
- It is crucial to the energy balance of the earth's surface because it determines the rate at which **incident solar radiation** is absorbed.
- Different surfaces have different values.
- Albedo is higher in snow or Ice

Surface	Albedo
1. Fresh Snow	80-90%
2. Thick cloud	70-80%
3. Water at the horizon (upper troposphere)	50-80%
4. Old Snow	45-50%
5. Concrete	40-50%
6. Desert	30-45%
7. Light soil	20-45%
8. Thin cloud	25-35%
9. Grasses	20-25%
10. Soil	20-25%
11. Crops	10-25%
12. Forest	10-20%
13. Oceans & Water bodies	06-10%
14. Asphalt (used in road construction)	5%

Planet	Albedo
1. Mercury	0.14
2. Venus	0.84
3. Earth (Moon)	0.37 (0.11)
4. Mars	0.15
5. Jupiter	0.34
6. Saturn	0.34
7. Uranus	0.30
8. Neptune	0.29
9. Pluto (dwarf planet)	0.44-0.61

- *Numbers are not important. Just remember the descending order of Albedo.*
- *Albedo is 0 for a black (darker) object that absorbs all light and reflects none.*
- *Albedo is 1 for a white (lighter) object that reflects all light and absorbs none.*

- Isolines are lines drawn to link different places that share a common value.
- The prefix 'iso' is a greek word meaning equal, so an isoline must be a line joining equal points.

Ex

Contour Line:

- A contour line is an imaginary line that connects all points having the same **height above sea level** Counter line a type of isolines helps to indcate topography of land.

Other types of Isolines

- Isobath: Joins points of the same depth below water. (Bathemetry : means ocean depth studies)
  ocean (vertical distance) depth count in Fathom 1ft: 1.8 m
  ocean (Horizontal distance) count in nautical miles. 1 NM: 1852 m / 1.852 km
- Isobar: Joins points with the same atmospheric pressure.
- Isotherm: Joins points with the **same temperature.**
- Isohaline: Joins points where the **salinity (amount of salt) of sea water** is the same.
- Isohel: Joins points where the amount of **sunshine** is the same.
- Isohume: Joins points where the humidity (amount of water in the air) is the same.
- Isyhyet: Joins points where the **amount of precipitation (rainfall, snow** etc) is the same.
- Isotach Joins points representing points of equal wind speed.
- Isoneph: Joins points where the amount of cloud cover is the same
- study of clouds : Nephalogy

TEMPERATURE

- Temperature is the measurement in degrees of how hot (or cold) a thing (or a place) is

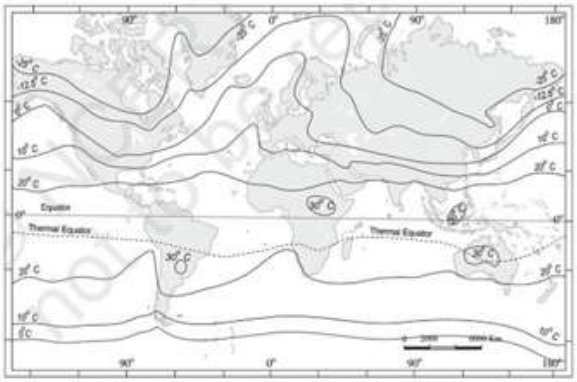


Figure 9.4 (a) : The distribution of surface air temperature in the month of January

Seasonal Surface Air Temperature Distribution – January and July

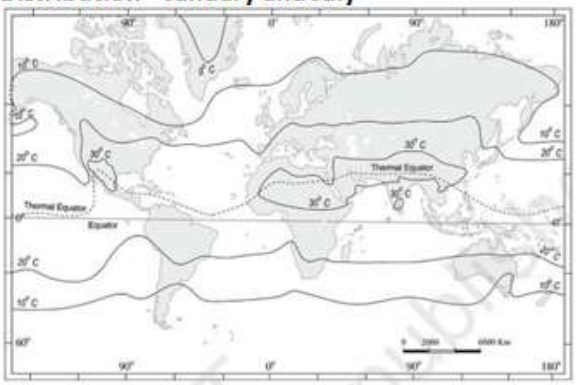


Figure 9.4 (b) : The distribution of surface air temperature in the month of July

- Isotherms are lines connecting places with equal temperatures.
- Isotherms shift with the apparent movement of the sun across the equator.
- In the Northern Hemisphere, isotherms are irregular and closely spaced.
- In the Southern Hemisphere, they are more regular and widely spaced
- Isotherms, meant to align with latitudes on a uniform Earth, bend due to land-water heat differences. •
- The general rule is that isotherms crossing from land to sea bend towards the pole (In winter) / equator (In summer).
- ITCZ Movement Deviate Isotherms in NH and SH . And the Effects of Land Mass and Ocean Currents are well Pronounced .

Isotherms bends

- ITCZ in SH : January - Sea to Land - Southwards
- ITCZ in NH : July - Sea to Land - Northwards

Isotherms bends from sea to land behaviour is opposite in January and July

Due to ITCZ Movement	January	July
North Hemisphere	Winter	Summer
South Hemisphere	Summer	Winter

Summary :

- ITCZ Movement Deviate Isotherms in NH and SH . And the Effects of Land Mass and Ocean Currents are well Pronounced .
- When Isotherms = Close Spaced : High Thermal Gradient or rapid temperature shift
- When Isotherms = Widely Spaced : Low Thermal Gradient
- Ocean- Continent Boundary - Isotherms Bends due to differential Heating of Land and Sea.

ITCZ Location	**Month**	**Isotherms deviate**	**Isotherms bends**
NH	**July**	**North (Continent) - South (Ocean)**	**Northwards (Sea to Land)**

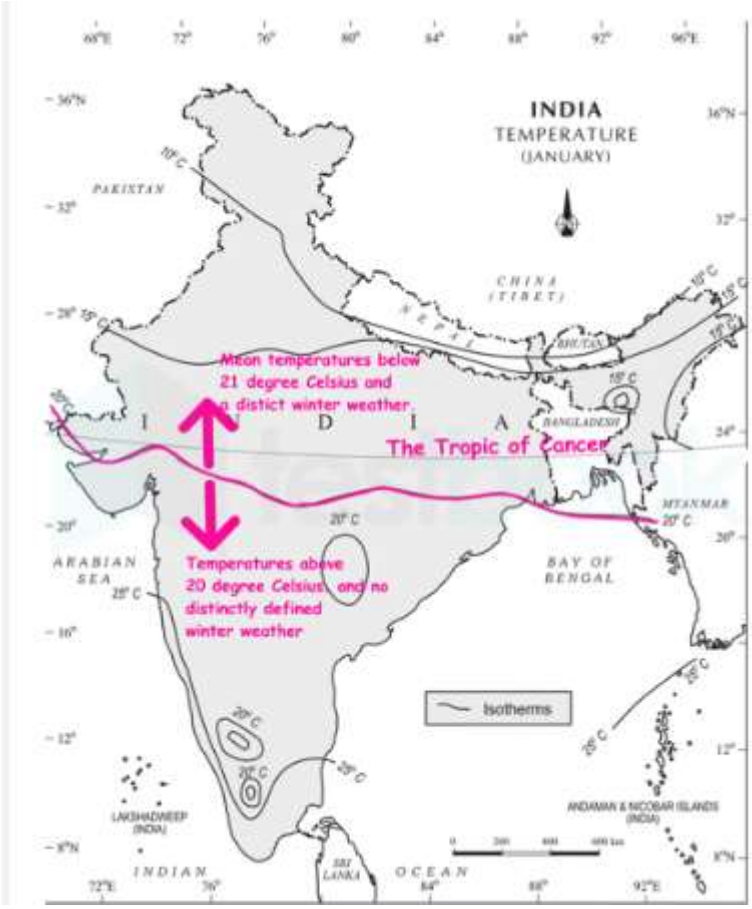
SH	**January**	**South (Continent)-North (Ocean)**	**Southwards (Sea to Land)**

The Isotherm Line, which divides India North- South in almost two equal parts in the month of January , is ?

a) 10°C
b) 25 °C
c) 15°C
d) 20°C

Ans D

The Isotherm of 20°C roughly parallel to the Tropic of Cancer .



Located Isotherms of July Which Divide India?

In July, the isotherm that roughly divides India into two parts is the **30°C isotherm**. This isotherm runs approximately between 10°N and 40°N latitudes.

- Temperature anomaly indicates a place's temperature differing from its latitude's mean, with positive anomaly (e.g., Sahara Desert, temp > mean) and negative anomaly (e.g., Mt. Everest, temp < mean).

FACTORS CONTROLLING TEMPERATURE DISTRIBUTION

Factors Affecting Temperature Distribution on the Earth

1) latitudes
2) Altitudes
3) Distance from the Coast

4) Ocean Currents
5) Prevailing Winds
6) Nature of Ground Slope
7) Nature of land and water distribution
8) Albedo/ reflectivity of the Surface

Factors Controlling Temperature Distribution

The temperature of air at any place is influenced by

- Latitude It has direct control on temperature as the insolation is inversely proportional to the latitude.
- Altitude: Higher the altitude, lower is the temperature. 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
- Albedo effect reduces temperatures (Decreasing Order of the Albedo: Fresh Snow (0.80) > Ocean ice > Sand > Green gross > Soil > Forest > Open ocean (0.06) > Charcoal (0.04))
- Distance from the sea: The places situated near the sea come under the moderating influence of the sea and land breezes
- Air-mass circulation and ocean currents- Warm air-masses/ocean currents: Higher temperature. Cold air-masses/cold currents: Low temperature. Similarly, the places located on the coast where the warm ocean currents flow record higher temperature than the places located on the coast where the cold currents flow.
- Prevailing Winds: Wind origin and speed affect temperature distribution.
- Aspect of Slope: Orientation of slopes influences sunlight exposure, affecting temperature
- Day-Night Cycle: Rotation-induced temperature variations

Consider the following statements :

Statement-I : The temperature contrast between continents and oceans is greater during summer than in winter.
Statement-II : The specific heat of water is more than that of land surface.

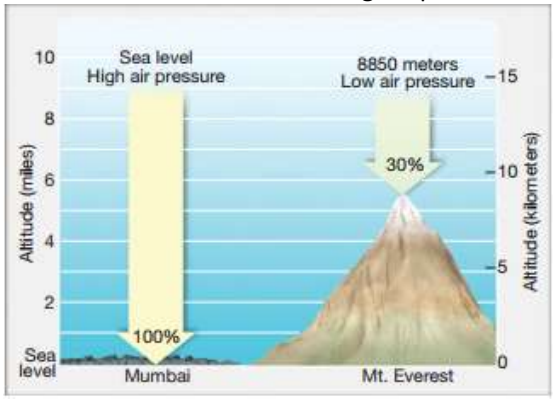
Answer: (a) Both Statement-I and Statement-II are correct and Statement-II is the correct explanation for Statement-I

- **Summer:** Land heats up faster than oceans, leading to a greater temperature difference between the two.
- **Winter:** Land cools down faster than oceans, reducing the temperature contrast.

Therefore, the temperature contrast between land and oceans is indeed greater during summer than winter.

Concept of Atmospheric Pressure

- The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the atmospheric pressure.
- The atmospheric pressure is expressed in units of milibar.
- At sea level the average atmospheric pressure is 1,013.2 milibar.
- Due to gravity the air at the surface is denser and hence has higher pressure



- Air Pressure or Atmospheric Pressure and Temperature Decrease with Increasing Altitude.
- Measured by : mercury barometer or the aneroid barometer.

- The pressure decreases with height. At any elevation it varies from place to place and its variation is the primary cause of air motion, i.e. wind which moves from high pressure areas to low pressure areas
- Atmospheric pressure also determines when the air will rise or sink

Atmospheric Pressure affects boiling point and cooking time ?

- At higher altitudes, atmospheric pressure is lower. As a Result , water boils at lower temperature than the standard 100°C, so the boiling point of water decreases.
- But longer cooking time at High altitudes- foods cooking by boiling (like pasta or vegetables) may take longer to cook. this means that the heat may not be sufficient to fully cook food that typically relies on boiling water. To counteract this issue may people use pressure cookers.

WHY we do not experience strong upwards winds ?

Vertical Variation of Pressure In the lower atmosphere the pressure decreases rapidly with height. The decrease amounts to about 1 mb for each 10 m increase in elevation. It does not always decrease at the same rate. Table gives the average pressure and temperature at selected levels of elevation for a standard atmosphere

Level	Pressure in mb	Temperature °C
Sea Level	1,013.25	15.2
1 km	898.76	8.7
5 km	540.48	-17. 3
10 km	265.00	- 49.7

The vertical pressure gradient force is much larger than that of the horizontal pressure gradient. But, it is generally balanced by a nearly equal but opposite gravitational force. Hence, we do not experience strong upward winds

Horizontal Distribution of Pressure

Small differences in pressure are highly significant in terms of the wind direction and velocity.

Horizontal distribution of pressure is studied by drawing isobars at constant levels.

Isobars are lines connecting places having equal pressure

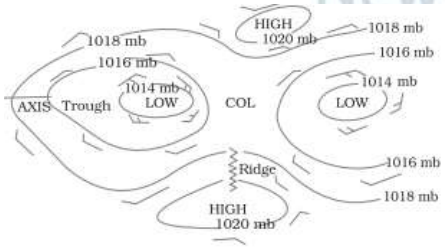


Fig : Isobars, pressure, wind systems in the North Hemisphere

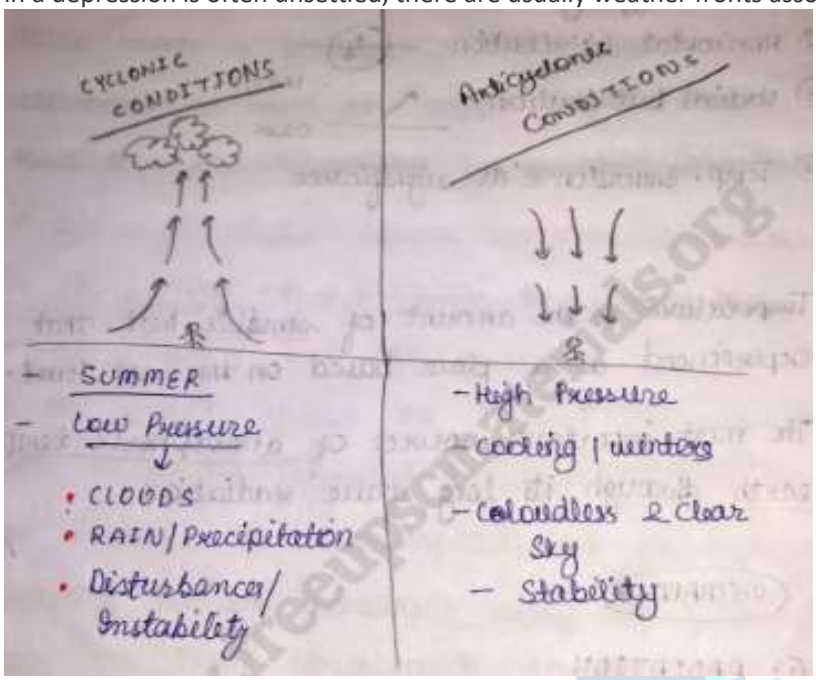
See the Patterns of isobars corresponding to pressure systems. Lowpressure system is enclosed by one or more isobars with the lowest pressure in the centre. High-pressure system is also enclosed by one or more isobars with the highest pressure in the centre.

- Pressure Gradient : rate of change in the air pressure between the two places on the Earth Surface.
- Wind Moves from HP to LP area. So this helps in understanding advection of the Winds .
- Close Spacing of Isobar indicates strong PGF
- Wide Spacing of Isobar indicates weak gradient or weak PGF.

The Atmosheric Pressure classified into Lp and HP

Areas of high and low pressure are caused by ascending and descending air. As air warms it ascends, leading to low pressure at the surface. As air cools it descends, leading to high pressure at the surface.

Anticyclone (high pressure)
In an anticyclone (high pressure) the winds tend to be light and blow in a clockwise direction (in the northern hemisphere). Also, the air is descending, which reduces the formation of cloud and leads to light winds and settled weather conditions.
Depression (low pressure)
In a depression (low pressure), air is rising and blows in an anticlockwise direction around the low (in the northern hemisphere). As it rises and cools, water vapour condenses to form clouds and perhaps precipitation. This is why the weather in a depression is often unsettled, there are usually weather fronts associated with depressions.



World Distribution of Sea Level Pressure:
The world distribution of sea level pressure in January and July

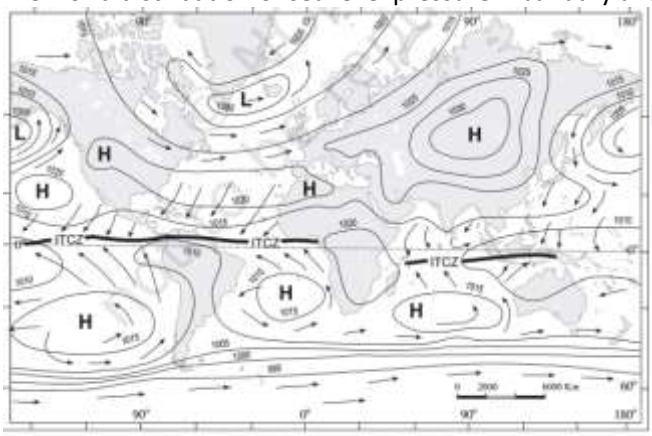


Figure 10.2 : Distribution of pressure (in millibars) — January

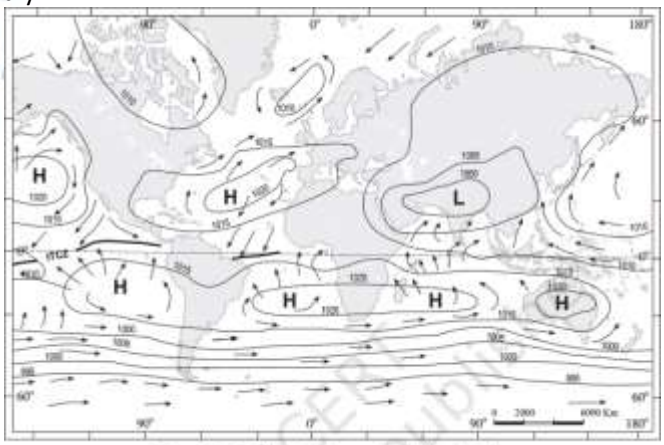


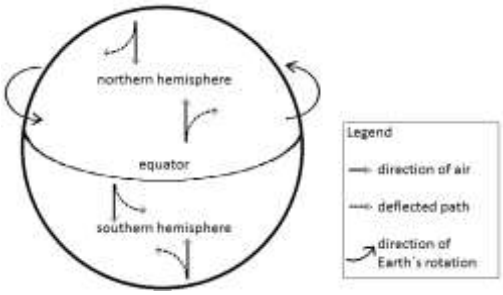
Figure 10.3 : Distribution of pressure (in millibars) — July

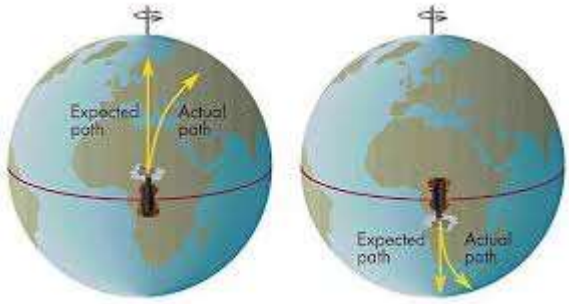
World Distribution of Sea level Pressure

- Near Equator the Sea level pressure is low called " Equatorial Low"
- Along 30 Degree N and S: HP Belt called " Subtropical Highs"
- Along 60 Degree N and S: LP Belt called " Sub polar Low"
- Along 90 Degree N and S: HP Belt called " Polar High "

But this Pressure Belt movement is not permanent in nature . They oscillate with the apparent movement of the sun . In the Northern Hemisphere in winter they move southwards and in the summer northwards

CONCEPT OF CORIOLIS FORCE



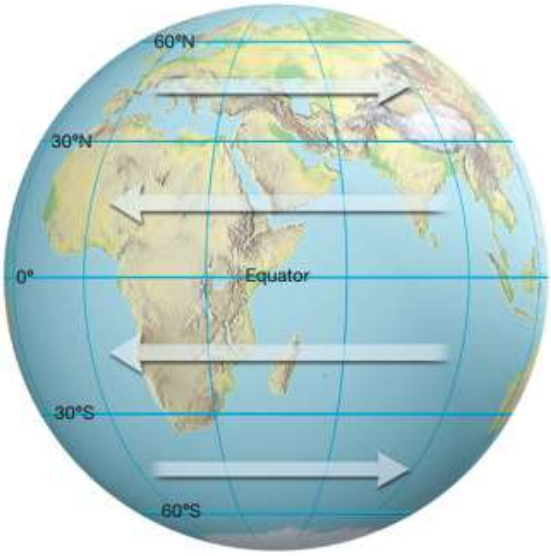


Define Coriolis Force:

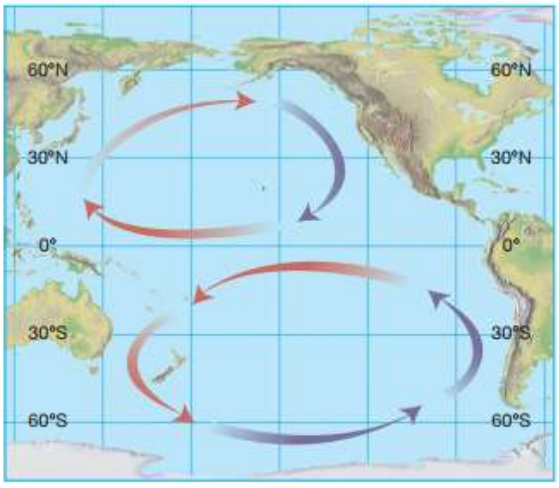
- i**s an apparent force caused by the earth's rotation**. The Coriolis force is responsible for deflecting winds towards the right in the northern hemisphere and towards the left in the southern hemisphere. This is also known as 'Ferrel's Law' or Coriolis Effect

- French engineer-mathematician Gustave-Gaspard Coriolis described the Coriolis effect in 1835.
- **Background :** George Hadley described this apparent deflection in the 1730s, but it was not explained quantitatively until Gaspard G. Coriolis (1792–1843), a French civil engineer and mathematician, did so a century later. The phenomenon is called the Coriolis effect in his honor

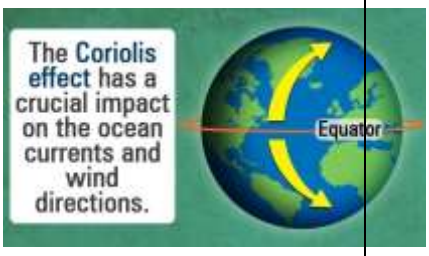
Applications : Influence Movement of Airmasses, Watermasses , Cyclonic movements ; , deflection of Permanent wind ; Ocean currents(Gyre circulation), Trajectories of projectiles (Launch vehicles or missile movement)

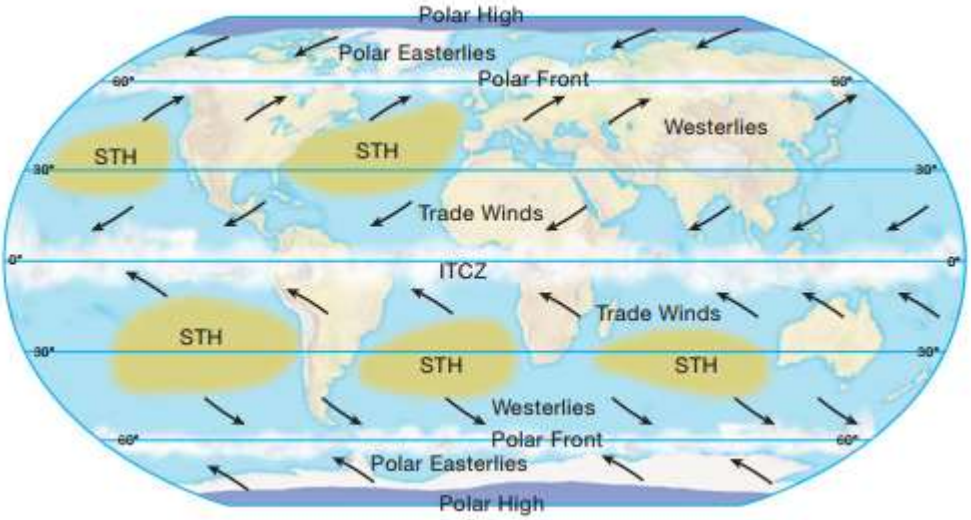


▲ **Figure** The general circulation of the atmosphere is an important climatic control. This highly simplified diagram shows that surface wind generally blows from the east in the tropics, and from the west in the midlatitudes; the complete patterns of atmospheric wind and pressure are discussed in Chapter 5.

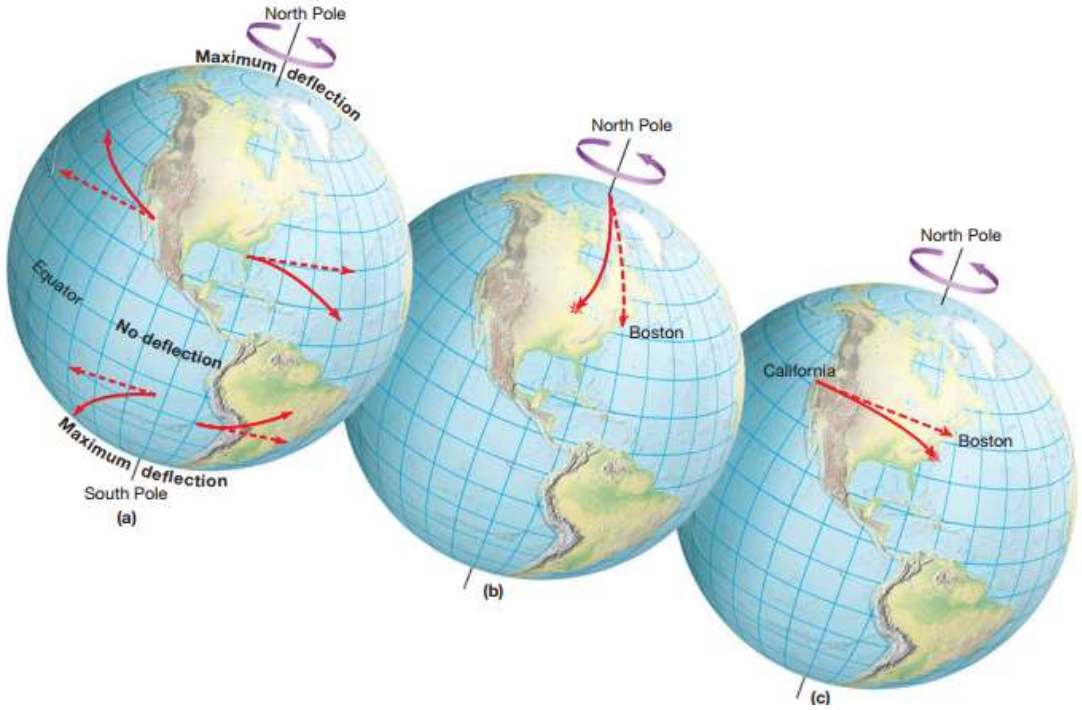


▲ **Figure** The general circulation of the oceans involves the movement of large amounts of warm water (red arrows) and cool water (blue arrows). These surface ocean currents have a significant climatic effect on neighboring landmasses.





Roaring Forties, Furious fifties and Shrieking Sixties are Westerlies in the South Hemisphere all these blow in 35 and 60 degrees latitudes



Earth Rotational Velocity is Greatest At Equator ? Why ?

Speed of the Earth's Rotation at the Equator:

- Circumference of the Earth at the Equator = **40,000 kilometers**
- Time to complete one Rotation = **24 hours**
- Speed of Rotation = Distance/Time = 40,000 km / 24 hr = **1670 km/hr**
- Earth Rotational velocity is 1670 km/hr at Equator .
- so due to more rotational velocity , less centripetal force(inward force) and more centrifugal force (outward force). so Coriolis force is weak, low , absent or zero**.**

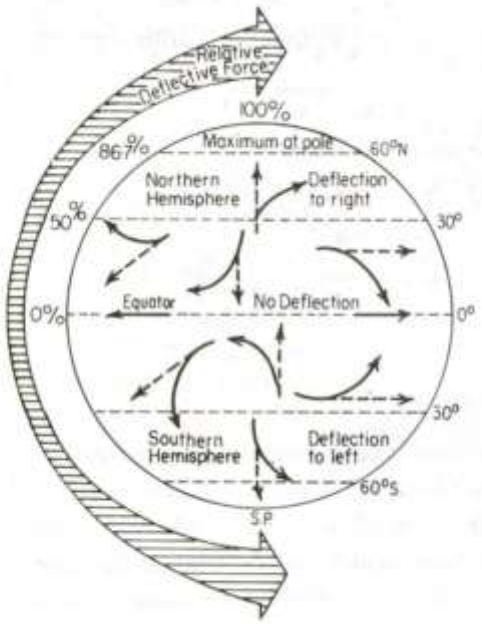


Fig. Deflection of Winds by Coriolis Force

Characteristics of Coriolis Force : Key Inferences or Significant Aspects :

- **As latitude increases and the speed of the earth's rotation decreases, Coriolis force or effect increases.**
- As the Earth spins on its axis from west to east, the Coriolis force acts north-south. At the Equator, the Coriolis force is zero.
- The Earth rotates faster at the Equator than it does at the poles. Hence,coriolis effect is zero at equator and maximum at poles
- The Coriolis effect is greatest at the poles and zero at the equator because of the earth's spherical shape and difference in circumference of the Earth
- Coriolis Force directly proportional to the angle of latitude.
- The Coriolis force becomes greater as the altitude increases if there is lesser friction and air resistance.
- Coriolis force is directly proportional to the velocity of wind.
- The deflection is more when the wind velocity is high.
- The Coriolis force acts perpendicular to the pressure gradient force
- Coriolis force is perpendicular to the object's axis.

UPSC Prelims 2024 With reference to "Coriolis force", which of the following statements is/are correct?

1. It increases with increase in wind velocity.
2. It is maximum at the poles and is absent at the equator.

Ans Both

TOPIC : ATMOSPHERIC CIRCULATION AND WEATHER SYSTEMS

- Atmospheric pressure is the weight of a column of air contained in a unit area. It decreases with height;
- Wind is the horizontal movement of air that flows from high pressure to low pressure areas.
- Air current is the vertical or nearly vertical movement of air
- Pressure gradient is the ratio between the pressure difference and the actual horizontal distance between two points.

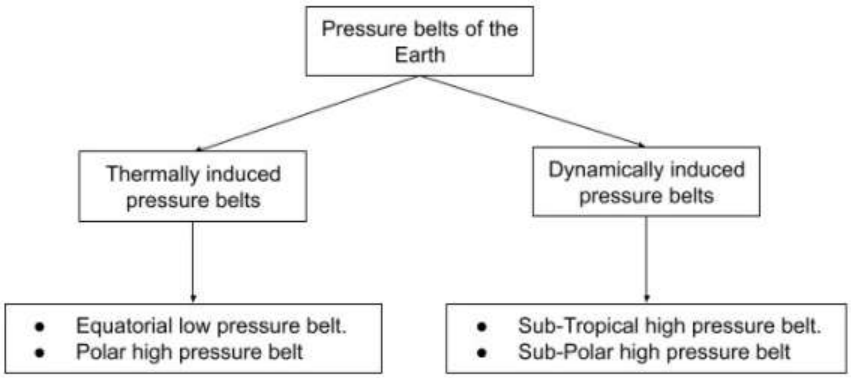
Forces Affecting the Velocity and Direction of Wind

- Pressure Gradient Force from high pressure to low pressure; closely spaced isobars indicate strong pressure gradients and hence stronger winds.
- Frictional Force: affects the speed of the wind due to Earth's surface irregularities; greatest at the surface and minimal over the sea surface and generally extends up to an elevation of 1 - 3 km.

- Coriolis Force: The rotation of the earth about its axis produces a pseudo force affecting the direction of the wind; deflects the wind to the right direction in the northern hemisphere and to the left in the southern hemisphere (Buy Ballot Law), which depends on the wind velocity; It is directly proportional to the angle of latitude; maximum at the poles and is absent at the equator (thus cyclones are not formed at the equator)
- Acts perpendicular to the pressure gradient force creating cyclonic conditions, higher the pressure gradient force, higher the velocity of the wind and the larger is the deflection of the wind.

PRESSURE BELTS

Pressure belts are areas on the earth's surface where the same pressure is distributed differently depending on latitude



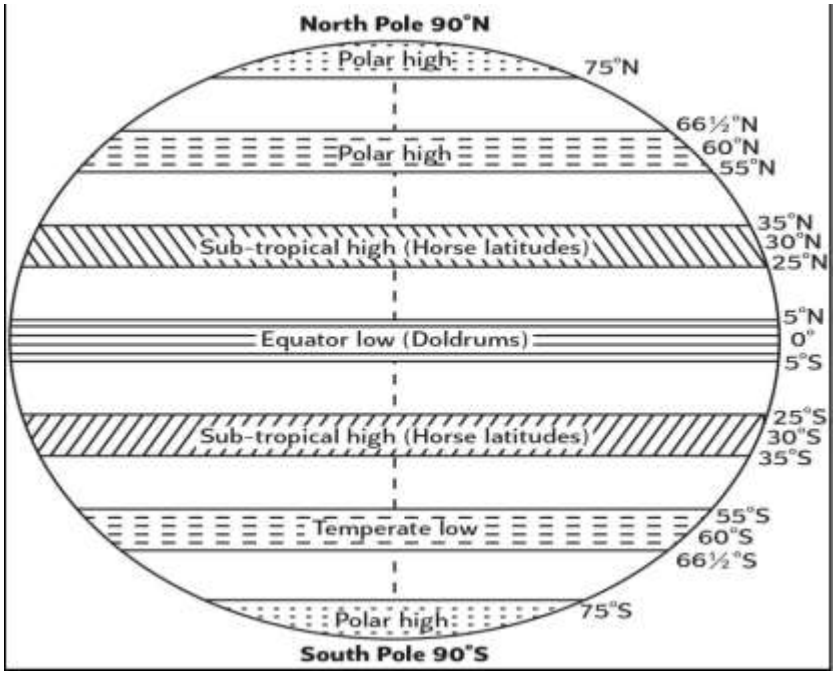
Thermally induced pressure belts

Thermally-induced pressure belts are regions of the Earth's atmosphere where variations influence the air pressure in temperature. These belts are formed due to solar radiation's uneven heating of the Earth's surface.

The Thermally Induced Pressure Belts are further divided into two types:

1. Equatorial Low-Pressure Belts

2. Polar High-Pressure Belts



1. Equatorial Low Pressure Belt or 'Doldrums'

- This belt happens to be the zone of convergence of trade winds from two hemispheres from sub-tropical high pressure belts. It lies between 10°N and 10°S latitudes.
- This belt is also called the Doldrums, because of the extremely calm air movements. This is because of the absence of Surface winds since winds approaching this belt begin to rise near its margin. Thus, only vertical currents are found.
- Vertical winds (convection) carrying moisture form cumulonimbus clouds and lead to thunderstorms (convectional rainfall).
- In spite of high temperatures, cyclones are not formed at the equator because of 'zero' coriolis force

2. Polar High pressure belt-

• The polar high pressure belts are at 90° N and 90° S latitudes. This zone is commonly referred to as the polar highs.

• Since the Polar Regions receive only slanting rays of the sun, the temperature remains low throughout the year. Thus high pressure is developed over this zone.

• Also, the subsidence of cold and dry air in this zone increases the pressure. Due to the Coriolis Effect, the subsiding air gets converted into anticyclones and forms gales (very strong winds).

DYNAMICALLY INDUCED PRESSURE BELTS

Dynamically induced pressure belts are regions in the Earth's atmosphere where air pressure is influenced by dynamic factors, particularly the movement and interaction of air masses and the Earth's rotation. Dynamically induced pressure belts are shaped by atmospheric circulation patterns and the Coriolis Effect.

The Dynamically Induced Pressure Belts are further divided into two types:

1. Sub-Tropical High-Pressure Belts

2. Sub-Polar Low-Pressure Belts

Subtropical High Pressure Belt or Horse Latitudes

- The subtropical highs extend from near the tropics to about 35°N and S.
- High pressure along this belt is due to subsidence of air coming from the equatorial region which descends after becoming heavy. The high pressure is also due to the blocking effect of air at upper levels because of the Coriolis force.
- The subsiding air is warm and dry, therefore, most of the deserts are present along this belt, in both hemispheres. For example Sahara Desert (North Africa): The world's largest hot desert, the Sahara exemplifies the impact of descending air currents.
- A calm condition (anticyclone) with feeble winds is created in this high pressure belt.
- The descending air currents feed the winds blowing towards adjoining low pressure belts. This belt is frequently invaded by tropical and extra-tropical disturbances

Sub-Polar Low-Pressure Belts

- The sub-polar low-pressure belts are between 60° to 65° latitudes in both hemispheres.
- This belt is known as the temperate convergence zone because the warm and cold air masses from the sub-tropical and polar high pressure belts converge at this zone. This, in turn, produces cyclonic storms.
- It is a dynamically induced pressure belt which is evident from the low pressure over this zone, despite the temperature being low.
- In the northern hemisphere, the sub-polar low-pressure belts become discontinuous during the summer and continuous during the winter.

WINDS SCALE :

To Measure Wind : Two Type of Scale:
1. Beaufort Scale
2 Saffir -Simpson Scale:

BEAUFORT SCALE: By Britain's Admiral Sir Francis Beaufort , in 1805 to help sailors estimate the winds via visual observations. The scale starts with 0 and goes to a force of 12. The Beaufort scale is still used today to estimate wind strengths.

Beaufort Scale

Beaufort number	Wind Speed (mph)	Seaman's term		Effects on Land
0	Under 1	Calm		Calm; smoke rises vertically.
1	1-3	Light Air		Smoke drift indicates wind direction; vanes do not move.
2	4-7	Light Breeze		Wind felt on face; leaves rustle; vanes begin to move.
3	8-12	Gentle Breeze		Leaves, small twigs in constant motion; light flags extended.
4	13-18	Moderate Breeze		Dust, leaves and loose paper raised up; small branches move.
5	19-24	Fresh Breeze		Small trees begin to sway.
6	25-31	Strong Breeze		Large branches of trees in motion; whistling heard in wires.
7	32-38	Moderate Gale		Whole trees in motion; resistance felt in walking against the wind.
8	39-46	Fresh Gale		Twigs and small branches broken off trees.
9	47-54	Strong Gale		Slight structural damage occurs; slate blown from roofs.
10	55-63	Whole Gale		Seldom experienced on land; trees broken; structural damage occurs.
11	64-72	Storm		Very rarely experienced on land; usually with widespread damage.
12	73 or higher	Hurricane Force		Violence and destruction.

THE SAFFIR-SIMPSON HURRICANE WIND SCALE is a 1 to 5 rating based on a hurricane's sustained wind speed. The scale – originally developed by wind engineer Herb Saffir and meteorologist Bob Simpson – has been an excellent tool for alerting the public about the possible impacts of various intensity hurricanes

CLASSIFICATION OF WINDS

Permanent Winds	Periodic Winds (meso scale)	Local Winds	
		Hot Winds	Cold Winds
• Trade winds • Westerlies • Polar easterlies	• Monsoon • Land and Sea Breezes • Mountain & Valley winds	• Loo • Foehn • Chinook • Zonda	• Bora • Pampero • Gregale • Tramontane • Mistral

ATMOSPHERIC CIRCULATION

World atmospheric circulation is the large-scale movement of air around the planet. This circulation is primarily driven by the uneven heating of the Earth's surface by the sun. The structure of atmospheric circulation remains consistent annually, despite variations in specific details

Atmospheric circulation is classified into three types:

1. **Primary or General Circulation:**
   - Primary winds, also known as **planetary, permanent, global, invariable, or prevailing** winds, blow constantly throughout the year.
   - Three types of primary winds: **Trade Winds, Westerlies, and Easterlies.**
2. **Secondary Circulation**
   - This circulation is also called **seasonal, periodic, variable, and regional winds**.
   - These winds change direction with different seasons, exemplified by monsoons.
3. **Tertiary Circulation:**
   - Formed due to local pressure gradients resulting from differences in the Earth's **surface heating and cooling**, tertiary winds, such as **Harmattan and Chinook**, blow only during specific periods in a small area, confined to the lower levels of the troposphere.

Planetary Winds :

Primary winds or Permanent Winds

- because they remain the same throughout the year and are distributed across the globe.
- These winds are related to thermally and dynamically induced pressure belts and rotation of the earth.

Tropical Easterlies:'

- They blow from the sub-tropical highpressure areas towards the equatorial lowpressure belt. They flow as the northeastern trades in the northern hemisphere and the south-eastern trades in the southern hemisphere.
- The trade winds from two hemispheres meet at the inter tropical convergence zone, and due to convergence, they rise and cause heavy rainfall.
- Their off – shore nature on the western side of the continents are one of the reasons behind formation of deserts in those areas.

Subtropical Westerlies:

- They blow from the subtropical high - pressure belts towards the sub polar lowpressure belts. They blow from southwest to north-east in the northern hemisphere and north-west to south-east in the southern hemisphere.
- These winds produce wet spells and variability in weather.

Polar Easterlies:

They blow from the polar high-pressure areas of the sub-polar lows. The Polar easterlies are dry, cold prevailing winds blowing from north-east to south-west direction in the Northern Hemisphere and south-east to north-west in the Southern Hemisphere.

Significance of Planetary Winds

Climatic significance

- **Balances the heat budget** by transporting the excessive heat of tropics towards poles.
- Form the **dynamic pressure belts** – Sub Polar low-pressure belt is formed due to convergence and upliftment of sub-tropical westerlies and Polar easterlies.
- **Cyclone formation and movement** – Their convergence form the fronts at sub polar low-pressure belt and thus create extra tropical cyclone. Trade winds move the Tropical cyclones from west to East.
- **Regional Climate**- Monsoon in Indian subcontinent is caused due to eastward shift of SE trades after crossing the equator under the effect of Coriolis force.

Oceanic significance

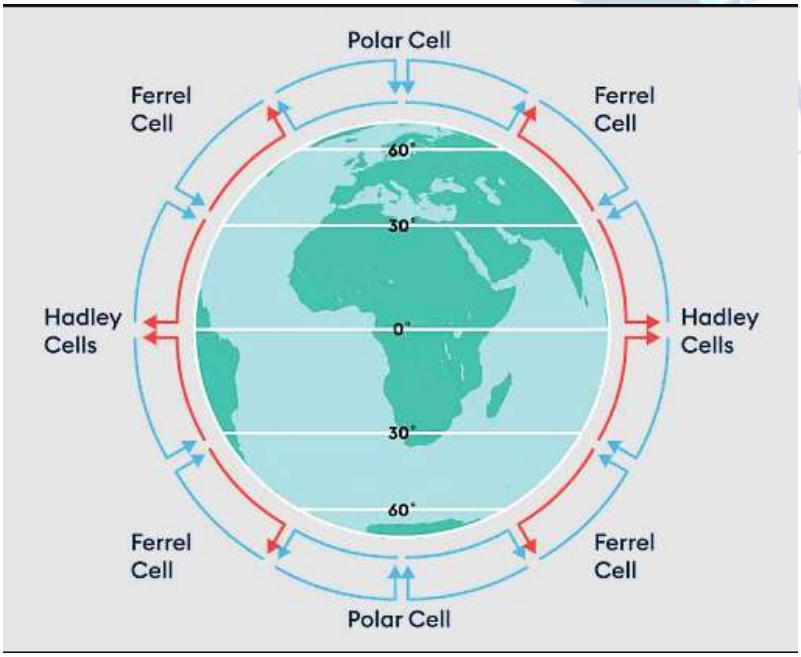
- **Movement of oceanic currents**- North and South Equatorial currents move east to West under the influence of Trade winds. Gulf Stream moves toward the North-east and hit the NW coast of Europe under the influence of Sub-tropical Westerlies.
- **Formation of gyres**- Primary winds affected by Coriolis form the circulatory motion of current thereby forming the Gyres.

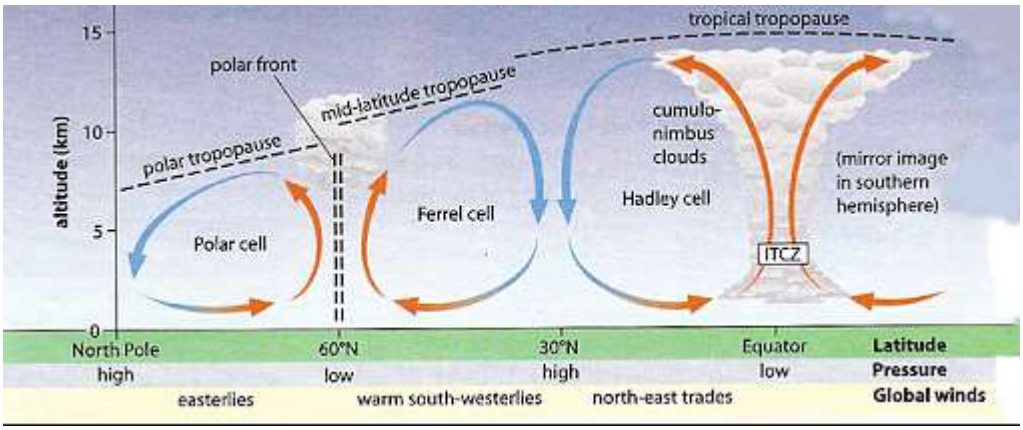
Geomorphic significance:

- **Formation of deserts**- Tropical Easterlies form the desert on the western margins of the Continents as they become dry when they reach there and act as offshore winds.

Ecological significance:

- Their effect on Oceanic current movement allows transport of nutrients and thriving biodiversity in the form of fisheries, planktons, and corals.





ATMOSPHERIC TRICELLULAR CIRCULATION

Atmospheric Tricellular Circulation refers to the three-cell system in each hemisphere: Hadley, Ferrel, and Polar cells. These cells involve large-scale air movement from the equator to the poles and back, driving global wind patterns and influencing climate by distributing heat and moisture across the Earth's surface

Three Cells Based on Thermal and Dynamic Factors:

Hadly Cell:

- At the equator, the warm air ascends because of high insolation, moves towards the poles, and descends in the subtropical regions around 30°N and 30°S latitudes
- At the surface near the land, the air flows back toward the equator due to the pressure gradient, generating the easterly winds.

Ferrel Cell:

- Extending from 30 to 60° latitude, a thermally indirect cell induced by dynamic forces, with warm air ascending from the polar front and subsidence in the horse latitudes.
- Completed by Westerly winds on the surface

Polar Cell:

- Extending from 65° to 90° latitudes, a thermally direct cell is strongest during winter, with sinking air along the poles moving towards sub-polar lows as the Easterly wind.

The interaction of Easterly and Westerly winds in sub-polar lows leads to rising air, completing the polar cell circulation.

Why Are Deserts Found Between 20-30 Degrees North and on Western Sides of Continents?

The formation of major hot deserts in the Northern Hemisphere, primarily between 20-30 degrees north and on the western side of continents, is influenced by several factors:

Atmospheric Conditions

- **Subtropical High-Pressure Belts:** These belts, situated around 20-30 degrees north, are characterized by descending air masses. This descending air warms and compresses, inhibiting cloud formation and precipitation, creating arid conditions ideal for desert formation. Examples include the Sahara Desert in Africa and the Arabian Desert in Asia.
- **Trade Winds:** The easterly winds carry moisture from oceans. While they bring rain to eastern coasts, they become drier inland, contributing to the aridity of western regions.

Geographic Factors

- **Rain Shadow Effect:** Mountain ranges on western continental sides act as barriers to moisture-laden winds. As air is forced to rise over these mountains, it cools and releases precipitation. The drier air descends on the leeward side, creating desert conditions. The Mojave Desert in North America is a prime example.
- **Cold Ocean Currents:** Cold ocean currents along western coasts cool the air, reducing its moisture-holding capacity. This leads to less precipitation and contributes to desert formation.

The combination of descending air, dry trade winds, rain shadow effects, and cold ocean currents creates the perfect conditions for the development of major hot deserts in these specific geographic locations.

Seasonal Winds

Winds changing their direction with the shifting seasons are termed seasonal winds. Includes monsoon winds, which alter their direction based on seasonal changes. Other examples of periodic winds include land and sea breeze, mountain and valley breeze, cyclones and anticyclones, and air masses.

Land and Sea Breezes:

- During the daytime, the land heats up faster than the adjacent sea, creating low pressure over land and high pressure over the sea. The pressure gradient induces air movement from the high-pressure sea to the low-pressure land, known as a sea breeze
- At night, land cools rapidly, becoming cooler than the sea, resulting in a reverse pattern known as land breeze

Mountain and Valley Breezes

Mountain and valley breezes are local winds that occur due to differential heating and cooling between mountain slopes and valleys. They are not considered seasonal winds, as they occur daily

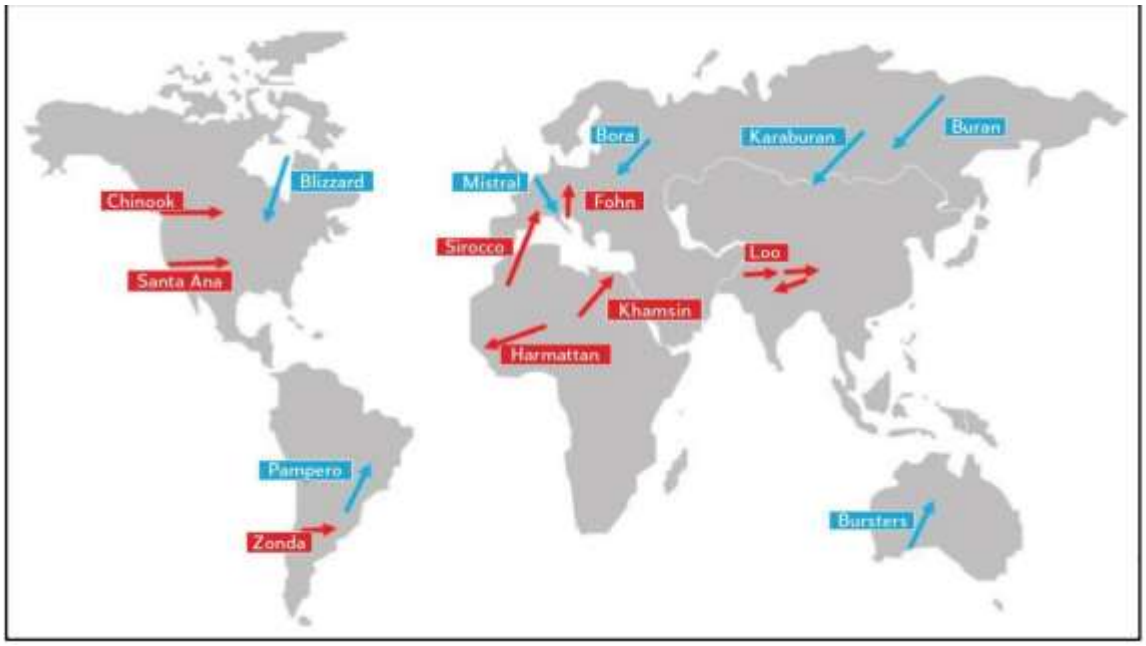
Valley Breeze: During the day, the sun heats up mountain slopes faster than valleys. This creates a low-pressure area on the mountain, drawing cooler air from the valley upwards - the valley breeze

Mountain Breeze: At night, the mountain slopes cool down rapidly, forming denser, cold air. This air flows downhill into the warmer valley, creating a mountain breeze.

These local winds influence local climate, weather patterns, and ecosystems. They can also impact human activities like agriculture and aviation.

LOCAL WINDS

Local winds are those kinds of winds that are solely caused by local conditions. Local winds are caused by the air moving between high and low-pressure systems in confined spaces. Each form of wind differs somewhat from the others since there are various sorts of winds. These local winds play an important role in the weather and climate of a particular location



Hot Local Winds

Wind Name	Region	Characteristics	Impact on Local Weather
Loo	Northern India and Pakistan	Hot, dry, strong, blows from west to east	High temperatures (45-50°C), heatwaves, reduced visibility
Foehn	Leeward side of Alps	Warm, dry, strong	Snow melt, early pasture growth, increased fire risk
Chinook	Eastern slopes of Rockies	Hot, dry, strong, "snow eater"	Rapid snowmelt, increased temperatures
Sirocco	Sahara Desert	Hot, dry, dusty	Brings hot, dry conditions, sometimes cooled by Mediterranean Sea
Harmattan	Northwest Africa	Hot, dry, dusty, strong	Relief from moist heat, health benefits, dry climate

Cold local winds

Wind Name	Region	Characteristics	Impact on Local Weather
Mistral	Alps, France	Cold, dry, high velocity	Low temperatures, freezing conditions
Bora	Adriatic Sea region	Cold, dry, high speed	Low temperatures, strong winds
Blizzard	Various regions	Freezing, wind-laden with dry snow	Severe winter conditions, low visibility, transportation disruptions

Difference betweenAir and Airmass:

a. Airmass is massive and thick, whereas Air is in thin layers

b. Airmass is homogenous with regard (distinctive characteristics)to temp and humidity, whereas Air can have diff temp and humidity

c. Airmass originate from specific source region whereas Air can start flowing from any place depending upon pressure condition

d. Airmass help in studying cyclones and anticyclones whereas air help in studying complication of the atmosphere.

- Air Mass

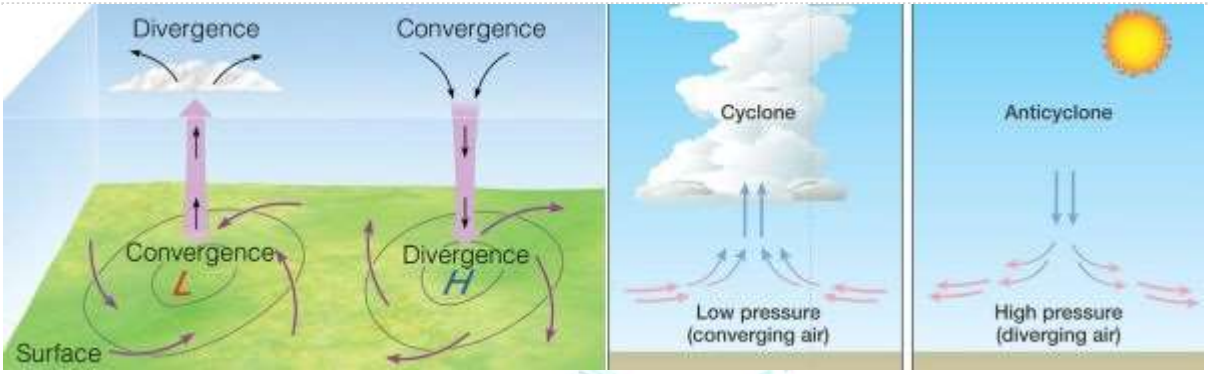
An air mass is a large area of air that has the same temperature and moisture levels throughout. It usually covers a wide region and comes from a specific place known as the source region. Air masses are grouped based on how warm or cold they are and how much moisture they contain

Define Source regions

- The homogenous surfaces, over which air masses form, are called the **source regions.**
- The main source regions are the **divergent air circulation / high pressure belts** in the **sub tropics (giving rise to tropical air masses)** and around the **poles (the source for polar air masses).**

Conditions for the formation of Air masses

1 Homogeneous surface either land or sea not marginal area
2. Isotropic Surface ie less topographical variations
3. Lack of turbulance in air, lack of convection in air
4. Subsidising air with HP, atmospheric Stability

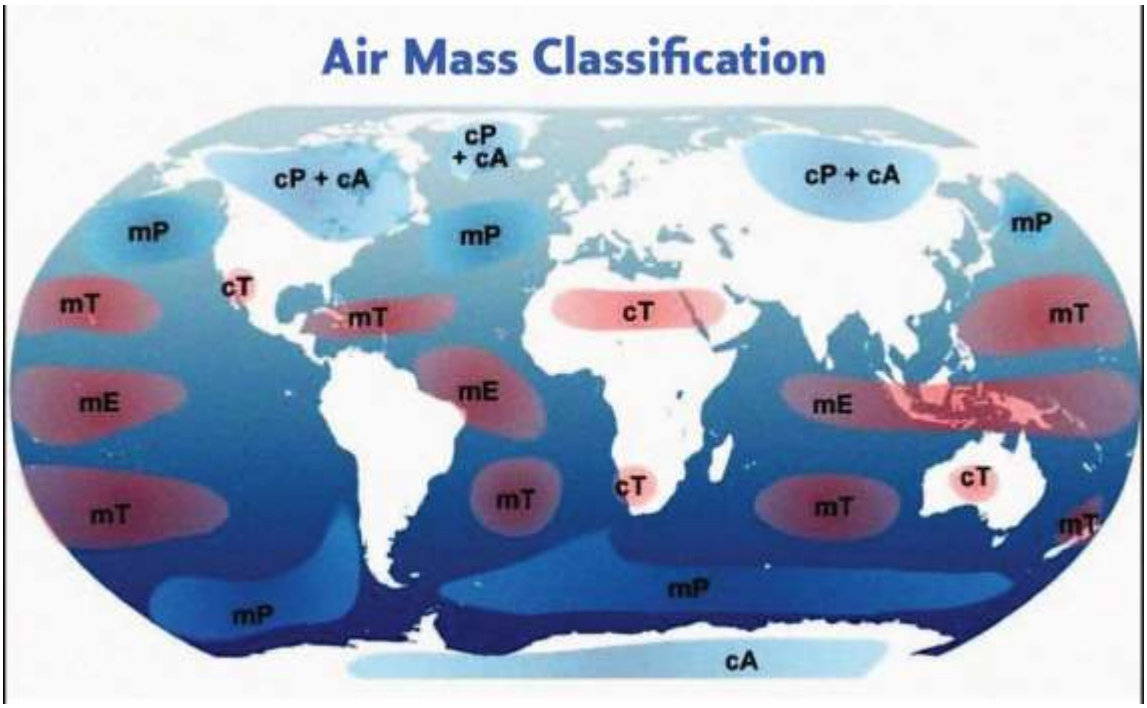


Temperature Classification:

- Polar (P) Air Masses: These are cold air masses.
- Tropical (T) Air Masses: These are warm air masses.

Moisture Classification:

- Maritime (m) Air Masses: These are humid air masses, usually formed over oceans
- Continental (c) Air Masses: These are dry air masses, typically formed over land.



FIVE MAJOR SOURCE REGIONS	PRIMARY AIR MASSES	
1. Warm tropical and subtropical oceans 2. The subtropical hot deserts 3. The relatively cold high latitude oceans 4. The very cold snow covered continents in high latitudes 5. Permanently ice covered continents in the Arctic and Antarctica	1. Maritime tropical (mT) 2. Continental tropical (cT) 3. Maritime polar (mP) 4. Continental polar (cP) 5. Continental arctic (cA) 'm' stands for Maritime; 'c' stands for continental; 'T' stands for tropical; 'P' stands for polar and 'A' stands for arctic region	

DIFFERENCE BETWEEN WARM AIRMASS AND COLD AIRMASS

Warm Air Mass	Cold Airmass
Originates from Tropical Region	Originates from Cooler regions
Having High Temperature	Low Temperature
Less Denser, pushes up;More quickly ; they are fast	More Denser , Sinks Down, Slow moving
Can hold more moisture due to warmness	Can hold less moisture
Effects : Unstable weather conditions ; clouds sky	Stable weather conditions and clear sky

Warm and Cold Airmass : Differ in Temperature; Density , Moisture content . They play a key role in development of various weather phenomenon can occur :

- Fronts
- Cyclones
- Anticyclones or Blocking Highs
- Jetstreams

The formation of Air Mass involves several key steps:

- **Source Regions**: Air masses form over specific areas called source regions. These regions are typically flat and have consistent conditions, like oceans or large plains.
- **Stagnation:** The air remains stationary over the source region, allowing it to gradually absorb the temperature and moisture characteristics of the surface.
- **Characteristics:** Once formed, an air mass can be warm or cold, and moist or dry, depending on its source region. For example, air masses over oceans are usually moist, while those over land are drier.

After formation the air masses can move with the wind, affecting weather patterns in other regions by bringing their specific characteristics with them.

Effects of Air Mass Movement on Climate Changes

- **Temperature Changes**: Air masses carry the temperature of their source regions. When a warm air mass moves into a cooler area, it can raise temperatures, while a cold air mass can cause temperatures to drop, leading to heat waves or cold spells.
- **Precipitation Patterns**: The moisture content of an air mass affects rainfall. A moist air mass can bring rain or snow, while a dry air mass can lead to dry conditions.
- **Weather Fronts**: When different air masses meet, they create fronts, which can lead to storms, heavy rain, or snow. These fronts are important for weather changes and can impact regional climates significantly.

Air masses are part of the global atmospheric circulation, distributing heat and moisture around the Earth. Changes in this circulation can affect climate zones and lead to phenomena like El Niño and La Niña, which have global impacts.

FRONTS:

- It is a transition or boundary zone between two air masses of different densities and physical characteristic(temperature, humidity, pressure,density) meet.
- The boundary between the two air masses is called the front.
- Front is a three dimensional boundary zone formed between two converging air masses with different physical properties (temperature, humidity, density etc.).
- it is line of constracting weather conditions.
- Frontogenesis: The processs of formation of the front called Frontogenesis. and dissipation of a front is known as Frontolysis (one of the air masses win against the other).
- In the **northern hemisphere,** Frontogenesis happens in an **anticlockwise** direction (**clockwise** in the **southern hemisphere**) due to the Coriolis Effect.
- Front Formed in Mid latitudes because there is no Airmass
- They are uncommon (unusual) in tropical and polar regions. because there is Airmass.

Key Notes:

- Fronts are the typical features of midlatitudes weather (temperate region – 30° – 65° N /S).
- They are uncommon (unusual) in tropical and polar regions.
- Front Formed in Mid latitudes because there is no Airmass .

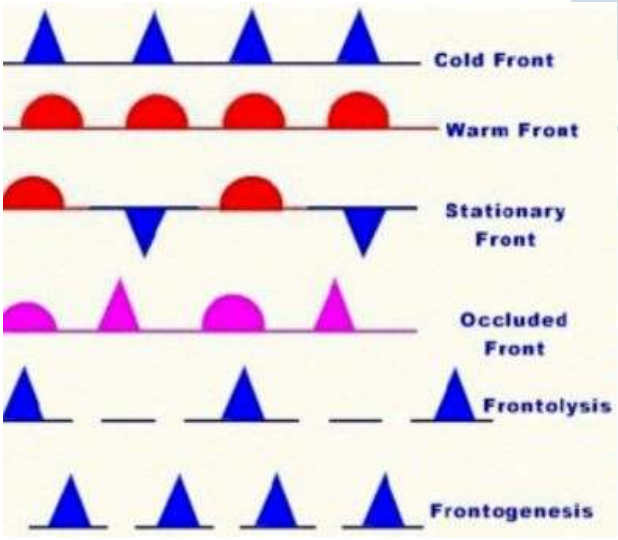
TYPES

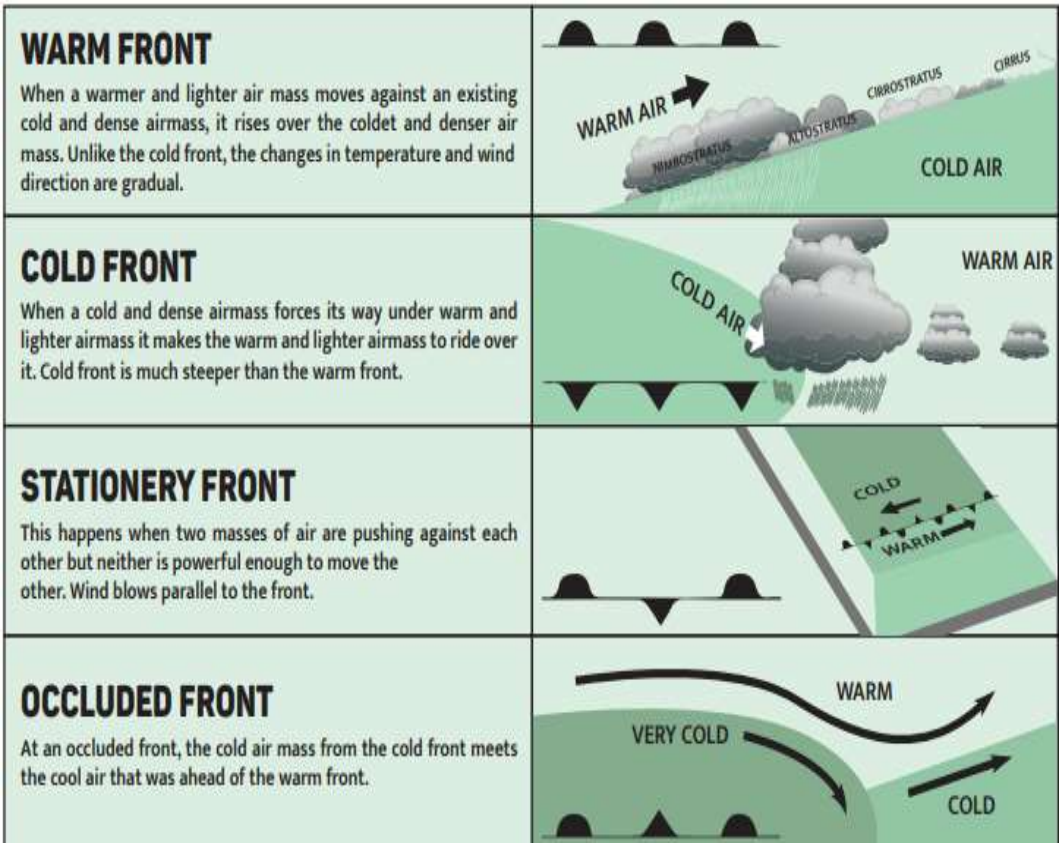
There are four types of fronts as described below:

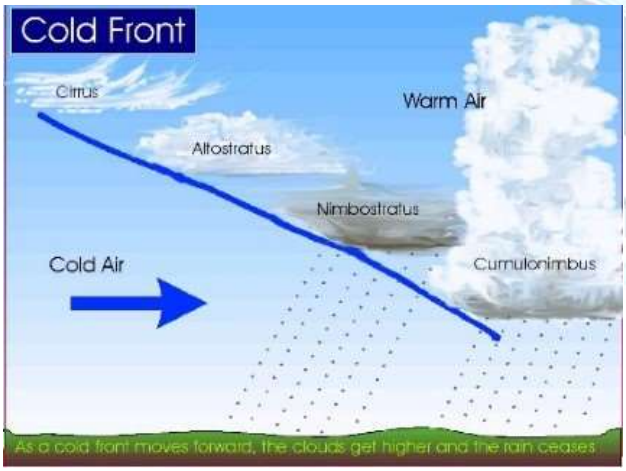
1. cold front,
2. warm front,
3. occluded front and
4. stationary front.

Cold front mapped on weather map: line marked with triangular spikes pointing in the direction of frontal movement. Whereas

Warm Front = Line marked with semi circle facing the direction of frontal movement





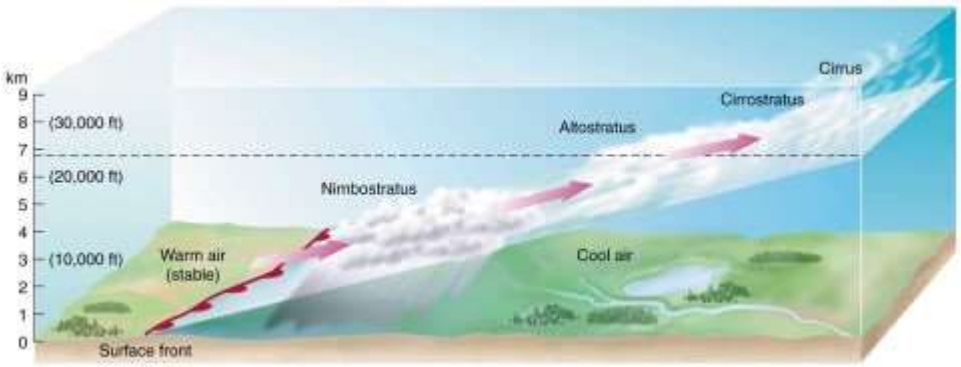


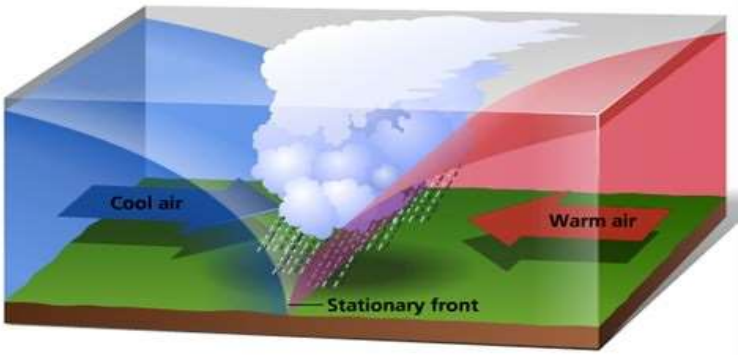
Cold Front

- Leading edge of cold Airmass
- Creating Steep Slope Boundary
- Rapid Weather changes : Sudden drop in the temperature , gusty winds
- Formation of cumulonimbus clouds and Nimbostratus and heavy rainfall
- Most violent weather patterns
- More Speed than Warm Front **up to 50 kmph and warm front : 20 kmph**

WARM FRONT :

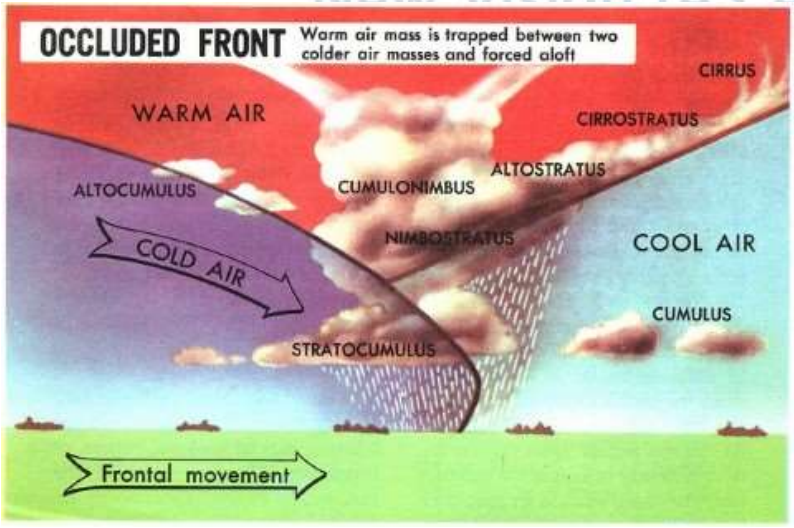
- Leading edge of warm Airmass
- Creating Gentle or Gradual Slope Boundary
- Gradual Weather changes : gradually increase the temperature,
- Formation of stratus or nimbostratus cloud ; Light Showers ; bring steady, prolonged precipitation
- Less violent weather patterns
- Less Speed than Cold Front





STATIONARY FRONT :

- Formed when two airmass are pushing against each other but neither is powerful enough to move other .
- Winds blow parallel to the Front (warm and cold Front : winds blow perpendicular)
- weather conditions : Persist in a particular area for several days
- Result in prolong period of rainfall or cloudiness Convergence zone: Along the front, air masses converge, leading to the development of clouds and precipitation.



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Occluded Fronts or Cut off Front:

- formed when cold front overtakes warm front ; warm air being lifted off the ground , Pushes upwards and cut off .
- Typically happens in complex weather systems and lead to weather changes .
- "occluded" refers to the process of the two fronts merging or closing off from each other
- it is end stage of extra tropical cyclone or temperate cyclone .

DISCUSS THE FORCES AFFECTING THE VELOCITY AND DIRECTION OF WIND

- The unequal heating in the atmosphere creates atmospheric differences
- Due to differences in atmospheric pressure , air is set in motion , called Wind .
- To balance this Wind blows from HP to LP region.

The Horizontal winds near the Earth Surface respond to combined effect of Three Forces :

- The Pressure Gradient Force
- The Frictional Force
- The Coriolis Force : the force exerted by the rotation of the Earth

Note : Gravitational force acts downward **.**

Forces affecting Wind Motion are:

1. Pressure Gradient Force 2. Coriolis Force
3. Frictional Force 4. Geostrophy.

PGF:

- unequal heating in the atmosphere creates differences.
- The differences in the atmospheric pressure produce a force
- The rate of change of pressure with respect to distance is the pressure gradient
- PGF is strong when Isobars are close to each other and Weak when Isobars are apart.(Isobars are weather map lines that connected with equal pressure)
- **PGF Increases with altitude bringing Strong winds at high altitudes.**

Frictional Force:

- it affect speed of the Wind.
- it is greatest at surface generally extend up to 1 to 3 km.
- But over sea surface it is minimal.

Coriolis Force:

- It deflects the wind to the right direction in the northern hemisphere and to the left in the southern hemisphere.
- The deflection is more when the wind velocity is high.
-
- Coriolis force is directly proportional to the velocity of wind.
- Coriolis Force is directly proportional to the angle of latitude
- CF is maximum at Poles and absent at the Equator (More : RV, Cfgl Less G)
- As latitude increases and the speed of the earth's rotation decreases, Coriolis effect increases.

KEY FACTS :

- Coriolis Force acts perpendicular to the PGF
- The pressure gradient force is perpendicular to an isobar
- The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind
- As a result of these two forces operating perpendicular to each other ,

IF WIND BLOWS PARALLEL TO THE ISOBAR CALLED ?

Geostrophy:

- is resultant force when Coriolis is so high and Frictional force is negligible .
- The velocity and direction of the wind are the net result of the wind generating forces.
- The winds in the upper atmosphere, 2 – 3 km above the surface, are free from frictional effect of the surface and are controlled by the pressure gradient and the Coriolis force.(there exact balance called geostrophic balance)
- When isobars are straight and when there is no friction, the pressure gradient force is balanced by the Coriolis force and the resultant wind blows parallel to the isobar. This wind is known as the geostrophic wind.
- The wind movement around a low is called cyclonic circulation. Around a high it is called anti cyclonic circulation. The direction of winds around such systems changes according to their location in different hemispheres.
- Geostrophic Wind parallel to isobars, Perpendicular to PGF. Flow of Ocean Water is also largely geostrophic.
- These winds can also form in a cyclonic or anticyclonic circulation.

- One important type of geostrophic wind is the Jet Stream.

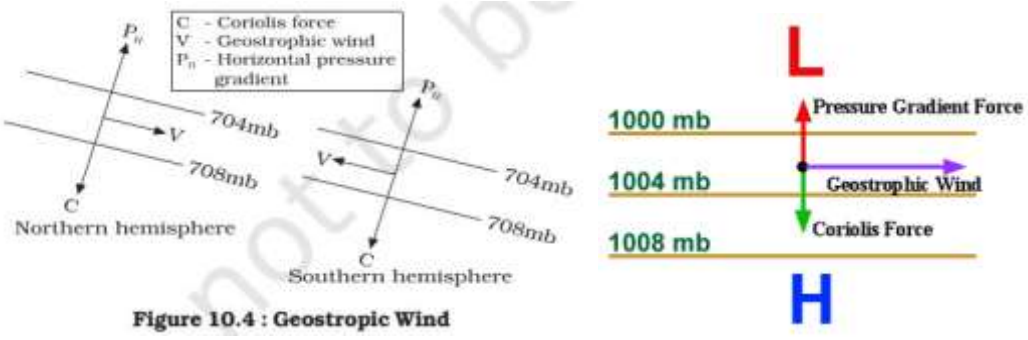


Figure 10.4 : Geostropic Wind

Note :

- The Jet Stream is a geostrophic wind blowing horizontally through the upper layers of the troposphere, generally from west to east, at an altitude of 20,000 - 50,000 feet.
- Jet Streams develop where air masses of differing temperatures meet.
- Coined: German meteorologist Heinrich Seilkopf is credited with coining a special term, Strahlströmung (literally "jet current"), for the phenomenon in 1939. in World War II Period

Define Jet stream :

- **Jet streams** are fast flowing, narrow, meandering air currents in the atmospheres of the Earth
  - Jet Streams extend from 20 degrees latitude to the poles in both hemispheres.
  - **The** Upper air circulation dominated by a westerly flow. An Important component of this flow is the Jet stream.
  - These are formed due to the temperature contrast between the Meridional Cells near the tropo pause in the vertical column of air.
  - Jet streams form when warm air masses meet cold air masses in the atmosphere.
  - High velocity is due to great thermal contrast creating powerful pressure gradient force
  - These are 3 dimensional ie having length about 3000 km, width 10 to 12 km, Depth 2-3 km and altitude 8 to 14 km, located in upper troposhere
    are a narrow belt of high alti tude ie above 12000m, westerly winds in the troposhere
  - Maximum velocity if found at the centre and gradually velcoity decreases away from the centre.
  - They flow easterly course ie west to East direction
  - The winds blow from west to east in jet streams but the flow often shifts to the north and south.
  - The term was introduced in 1947 by Carl Gustaf Rossby.
  - Jet streams follow the boundaries between hot and cold air.
  - Since these hot and cold air boundaries are most pronounced in winter, jet streams are the strongest for both the northern and southern hemisphere winters.
  - Jet streams are stronger in winter in the northern and southern hemispheres, because that's when **air temperature differences between the warm and cool air masses can cause jet streams to move at much higher speeds**.
  -
  - Their speed varies from about 110 km/h in summer to about 184 km/h in winterGreater the difference in temperature, faster is the wind velocity inside the jet stream.

JETSTREAM : PRODUCT AND GENESIS

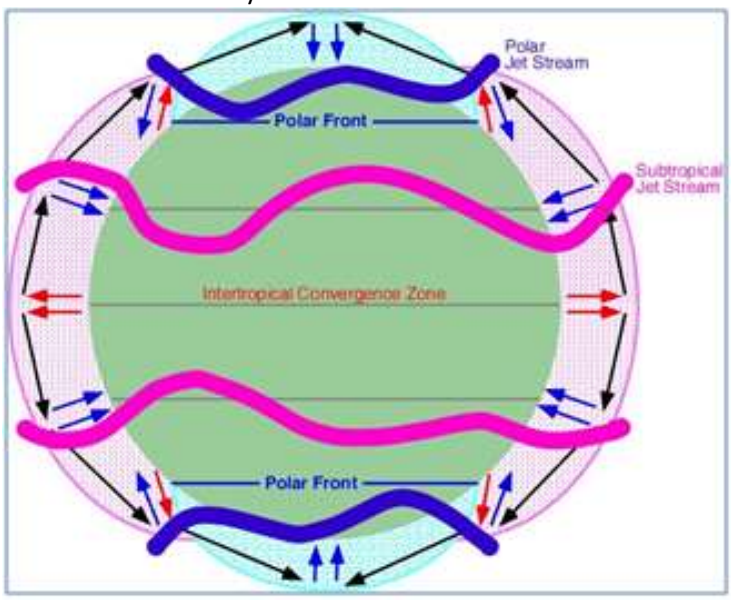
Jet streams are the product of two factors: the atmospheric heating by solar radiation that produces the large-scale polar, Ferrel, and Hadley circulation cells, and the action of the Coriolis force acting on those moving masses. The Coriolis force is caused by the planet's rotation on its axis

The genesis of the Jet-streams is provided by three kinds of gradients:

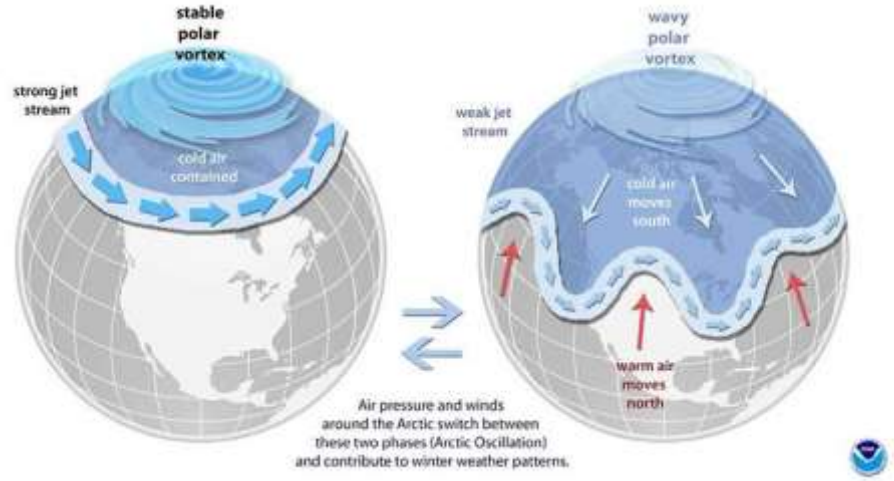
- Thermal gradient between pole and equator
- Pressure gradient between pole and equator
- Pressure gradient between surface and subsurface air over the poles.

TYPES OF JET STREAM :

- Two PolarJet Stream
- Two Subtropical Jetstream
- They are found in both the Northern and Southern Hemispheres.



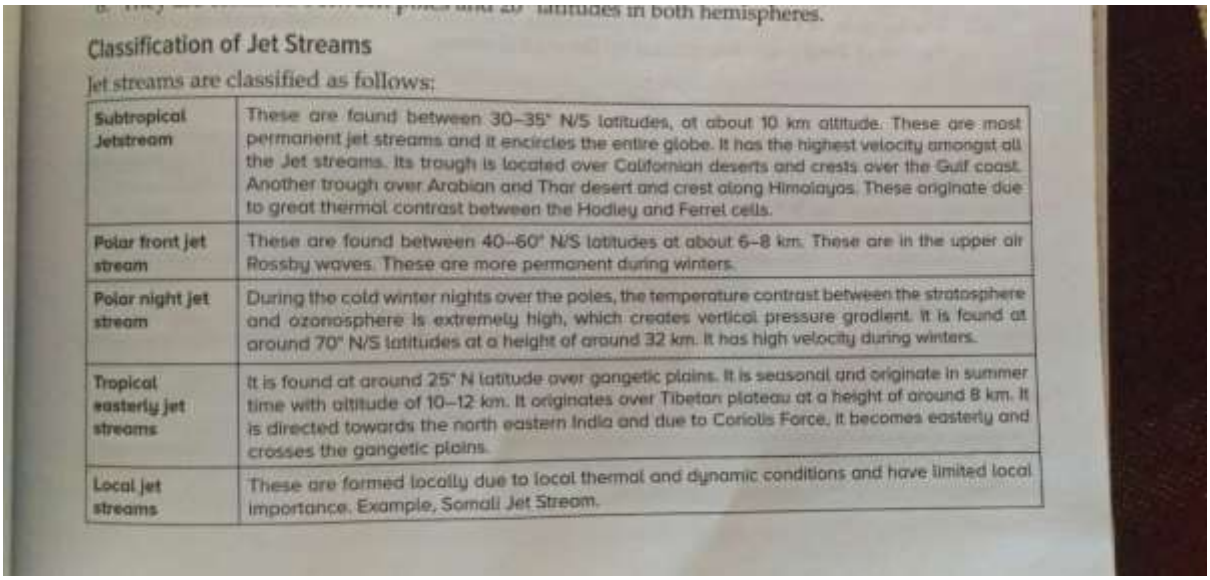
- strongest jet streams: Polar Jet : Fast and Strong around the polar vortex at 9 to 12 km
- Weak Jet stream: Sub tropical Jet stream at 10–16 km
- Polar- Jet Stream (Formed below tropopause but between Ferral + Polar cell)
- Sub-Tropical Jet Stream: formed below tropopause but between ferral and Hadley cell)



- When Temp contrast is maximum, Jetstream flow near Straight path.
  When Temp contrast/ Temp Gradient is minimum, or reduces, Jetstream flow a meandering path

Jet streams are stronger in winter in the northern and southern hemispheres, because that's when **air temperature differences between the warm and cool air masses can cause jet streams to move at much higher speeds**.

Meandering Jetstream called **Rossby Waves, Which are formed when polar air moves towards equator while tropical air is moving poleward.(N-S temp gradient) . the existence of these waves explain low pressure cells(cyclones) and HP cells.**



latitudes in both hemispheres.

Classification of Jet Streams

Jet streams are classified as follows:

Subtropical Jetstream	These are found between 30–35° N/S latitudes, at about 10 km altitude. These are most permanent jet streams and it encircles the entire globe. It has the highest velocity amongst all the Jet streams. Its trough is located over Californian deserts and crests over the Gulf coast. Another trough over Arabian and Thar desert and crest along Himalayas. These originate due to great thermal contrast between the Hadley and Ferrel cells.
Polar front jet stream	These are found between 40–60° N/S latitudes at about 6–8 km. These are in the upper air Rossby waves. These are more permanent during winters.
Polar night jet stream	During the cold winter nights over the poles, the temperature contrast between the stratosphere and ozonosphere is extremely high, which creates vertical pressure gradient. It is found at around 70° N/S latitudes at a height of around 32 km. It has high velocity during winters.
Tropical easterly jet streams	It is found at around 25° N latitude over gangetic plains. It is seasonal and originate in summer time with altitude of 10–12 km. It originates over Tibetan plateau at a height of around 8 km. It is directed towards the north eastern India and due to Coriolis Force, it becomes easterly and crosses the gangetic plains.
Local jet streams	These are formed locally due to local thermal and dynamic conditions and have limited local importance. Example, Somali Jet Stream.

Temporary Jet Streams (Tropical)

- Tropical Easterly Jet Stream (TEJ): Dominant in the northern hemisphere in summer; found between 5° to 20°N; influences South Asian monsoon. •
- Somali Jet Stream: Occurs during the summer over northern Madagascar and off the coast of Somalia; intensifies from June to August; Impacts South Asian monsoon; major cross-equatorial flow from the southern Indian Ocean to the central Arabian Sea

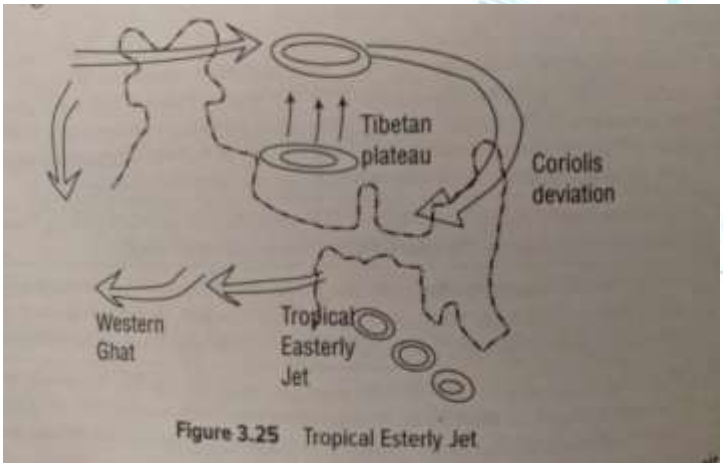


Figure 3.25 Tropical Esterly Jet

Summers:• In summer the **sub-tropical easterly jet** blows over Peninsular India approximately at 14N and bring some rain and storm

Formula

- **In India , Summer Season : Tropical Easterly jet Stream Upwards over India and ITCZ near Surface areas in India**
- **In Winter, ITCZ shifts Tropic of Capricorn, and in Upper areas Western Sub tropical Jet stream in India**

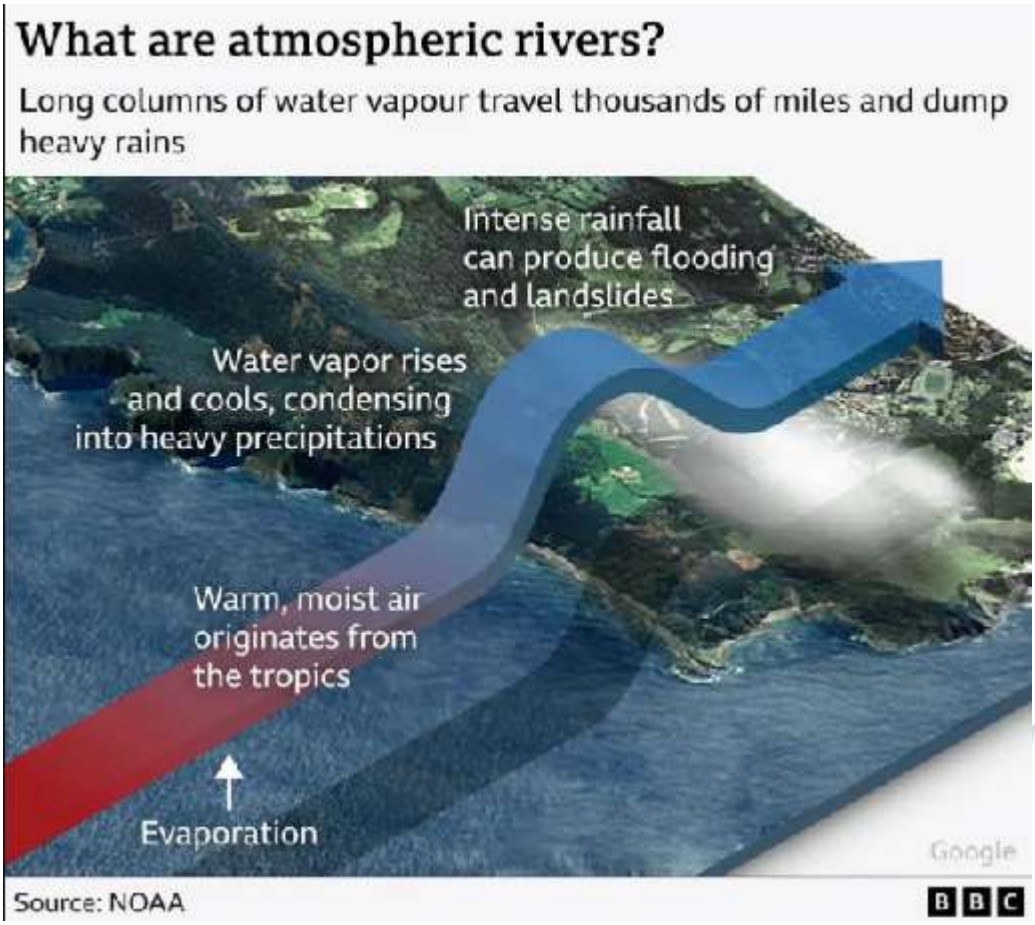
SIGNIFICANCE / AND ISSUE OF JET STREAMS

- Plays a significant role in the onset and withdrawal of monsoon winds. and influence the general circulation patterns in tropical, temperate, and polar regions.
- ❖ Intensifies alternative cyclonic and anticyclonic conditions with the crust and trough formation in its movement.
- ❖ in Air flight these are extremely important because eastbound flights takes less time than westbound ones .
- ❖ Brings Western disturbances in India in winter in North west India and useful for agriculture and building of ice caps

- ❖ Known to have brought some ozone depleting substances to stratosphere which result in ozone layer depletion
- ❖ They have an immense influence on local and regional weather conditions.

ATMOSPHERIC RIVER

- **Concept see recently in the News , As " Pineapple Express" Feb 2024**
- **California Region of USA experience wet winter (reason atmospheric river)**
- The 'flying rivers' causing devastating floods in India (BBC Aug 2024)
- In India, meteorologists say the warming of the Indian Ocean has created "flying rivers" that are influencing monsoon rains between June and September



- News : "In the last two decades, nearly 80% of the most severe atmospheric rivers caused floods in India,"
- Weather events like the 2013 Uttarakhand floods and the 2018 floods in Kerala that claimed several lives were all due to severe atmospheric rivers
- There are other weather systems like westerly disturbances, monsoon and cyclones that can cause floods as well
- But global studies have shown that atmospheric water vapour has increased by up to 20% since the 1960s.
- With temperature increase, intensity of rain events rises because of increase in atmosphere's moisture retention capacity

AR: ATMOSPHERIC RIVER / TROPICAL PLUME/ MOISTURE PLUME :

- **Narrow bands of moisture in the atmosphere that transport large amount of Water Vapour from Tropical Region to Higher Latitudes .**
- **They are the largest transport mechanisms of freshwater on Earth**
- **They are responsible for 90 percent of the movement of moisture from the tropics toward the poles**
- **The Atmospheric River is often associated with mT (Maritime Tropical) air mass.**
- **Play Key role in Global Water Cycle and Can Result in Heavy Precipitation**

-

WHERE THEY OCCUR ?

- **Temperate Region of Both Hemisphere in Pacific and Atlantic Ocean, Indian Ocean Sometimes Greenland, Antartica region**
- **Warm Sea Surface Temperature over South Central Indian Ocean Play crucial role in AR development**
- They are **more frequent on the East Coast** than they are on the West Coast.
- They are also the major cause of extreme precipitation events that cause severe flooding in many mid-latitude, westerly coastal regions of the world, including the west coast of North America , Western Europe, the west coast of North Africa, the Iberian Peninsula, Iran and New Zealand
- Pineapple Express -A strong atmospheric river that is capable of bringing moisture from the tropics near Hawaii over to the U.S. West Coast.
- They **primarily occur during the winter of the respective hemisphere,** when extratropical cyclones are most prevalent. --

FORMATION?

- **Usually Begins in Tropical Region but part of Extra tropical Cyclone**
- **Reason : Warm Temperature cause Ocean Water to evaporate and rise into the Atmosphere. Then Winds carry water vapour to Atmosphere and Moves over land making rainfall .**
- **Often assoicated with Mudslides, Landslides, Flooding**
- **Some AR bring Beneficial rain or snow**
- Atmospheric rivers primarily occur during winter of the respective hemisphere (i.e., December, January, and February for the northern hemisphere and June, July, and August for the southern hemisphere) when extratropical cyclones are most prevalent
- Studies have found that atmospheric rivers generally last 20 hours over an area along the coastline and can move around in the ocean for up to five days.

Jet Streams and Geostrophic Winds Relationship with Atmospheric River :

- Geostrophic winds contribute to the broader atmospheric conditions that facilitate the formation a*nd movement of these rivers of moisture.
- Geostrophic winds help maintain the structure of both jet streams and atmospheric rivers by balancing forces in the atmosphere

  Jet streams provide the pathway for atmospheric rivers

EXAMPLES WORLD WIDE :

- **Pineapple Express Atmospheric river pick up warm moist air near Hawaii Island of Pacific Ocean and hits lands in Western USA and Canada, causing Heavy Rainfall and Snow .**
- **Events Happen in Iran , Australia, New Zealand Europe Regions**
- **Recent Study in India Around 70 % of Flood event in Summer months due to AR during 1985-2020 Period.**

Effect:

- Climate change **is expected to increase the frequency and intensity of ARs** in some regions of the world, particularly in the mid-latitudes

- When atmospheric rivers run up against mountains or run into local atmospheric dynamics and are forced to ascend, the moisture they carry cools and condenses, so they can produce intense rainfall or snowfall.
- While they are an incredibly important source of rainfall, they can also bring flashflooding, mudslides, and landslides, sometimes killing people and destroying property.
- When atmospheric rivers pass over land, they can cause conditions similar to those of hurricanes with intense and rapid rainfall, cyclone-force winds, and significantly increased wave heights.

CYCLONES

- A cyclone is a large-scale air mass rotating around a strong centre of low atmospheric pressure.
- Cyclones can be classified on the basis of their origin into tropical and extratropical cyclones.
- Wind circulation around a low pressure system is called cyclonic circulation and around a high pressure system is called anticyclonic circulation

Pressure system	Pressure Condition at the Centre	Pattern of wind direction	
		Northern Hemisphere	Southern Hemisphere
Cyclone	Low	Anticlockwise	Clockwise
Anticyclone	High	Clockwise	Anticlockwise

TEMPERATE CYCLONES

The low-pressure systems developing in the mid and high latitude, beyond the tropics are called the Temperate/ Extra-Tropical/ Mid-Latitude/ Frontal/ Wave Cyclones

- Most commonly formed at the polar fronts, where warm and moist air masses meet cold and dry air masses from poles.
- Occur mostly in winter, late autumn and spring.
- They stretch over large areas under the influence of westerlies.
- Approach of a temperate cyclone is marked by fall in temperature and pressure and a thin veil of cirrus clouds.
- These cyclones move from west to east under the influence of westerlies.
- The western disturbances arriving in North West India during winter are remnants of such cyclones

TROPICAL CYCLONES

- They are strong low pressure centres that originate over oceans in tropical areas and move over to the coastal areas bringing about large scale destruction due to violent winds, very heavy rainfall (torrential rainfall) and storm surge
- Violent storms; Originate over oceans in tropical areas
- A roughly circular calm area of comparatively light winds and fair weather at the centre is known as the Eye of the cyclone. It has lowest surface pressure and warmest temperatures and air descends at the centre
- The eye temperature may be 10°C warmer or more at an altitude of 12 km than the surrounding environment, but only 0-2°C warmer at the surface in the tropical cyclone
- Eye is surrounded by the eye wall with strong spiraling ascent of air where winds blow the fastest resulting in torrential rains.
- Latent heat of evaporation released by the condensation of moist rising air over oceans is the driving engine for tropical cyclones.
- They dissipate after they make landfall because the latent heat of evaporation is not available (moisture supply is cut off). They move in a parabolic path towards the west under the influence of trade winds.

Different names:

- Cyclones (Indian Ocean), Hurricanes (Atlantic), Typhoons (Western Pacific and South China Sea; Philippines islands, eastern China and Japan), and Willy-willies (North West Australia).
- In the South Atlantic and South-Eastern Pacific regions in tropical latitudes, cyclones do not originate because of low sea surface temperatures. [UPSC 2015]

Type	Wind speed in km/h
Low pressure area (L)	Less than 31
Depression (D)	31-49
Deep depression (DD)	50-61
Cyclonic storm (CS)	62-88
Severe cyclonic storm (SCS)	89-118
Very severe cyclonic storm (VSCS)	119-165
Extremely severe cyclonic storm (ESCS)	166-220
Super cyclonic storm (SupCS)	221 or more

Favourable Conditions for the formation

- Large sea surface with temperature> 27° C; •
- Presence of the Coriolis force; •
- Small variations in the vertical wind speed; •
- A pre-existing weak low-pressure area or lowlevel-cyclonic circulation; •
- Upper divergence above the sea level system

Characteristic	Tropical Cyclone	Temperate Cyclone
Origin	Thermal Origin	Dynamic Origin - Coriolis Force, Movement of Air Masses
Latitude	10-30° N and S of the equator	35-65° N and S of the equator. More pronounced in Northern hemisphere due to greater temperature contrast
Frontal System	Absent	Formation due to frontogenesis
Formation	Forms at sea (>26-27°C); dissipates on land	Can form on land and seas
Season	Seasonal: Late summers (Aug-Oct)	Irregular, fewer in summers, more in winters
Size	Limited to smaller area: 100-500 km diameter	Larger area: 300-2000 km diameter
Shape	Elliptical, Anvil Shaped	Inverted 'V' (middle latitude cyclones)
Rainfall	Heavy but short-lasting	Slow, continuous rainfall for days or weeks
Wind Velocity	Much greater (100-250 kmph)	Comparatively low (30-150 kmph)
Isobars	Complete circles, steep pressure gradient	'V' shaped, low pressure gradient
Lifetime	Lasts <1 week	Lasts 2-3 weeks
Path	East to West (Trade Winds)	West to East (Weterlies)
Calm Region	Eye at the center, calm region with no rainfall	No single region with inactive winds or rains
Driving Force	Energy from latent heat of condensation	Energy depends on air mass densities
Influence of Jet Streams	Relationship with upper-level airflow less clear	Distinct relationship with upper-level airflow (Jet streams, Rossby waves)
Clouds	Few varieties (cumulonimbus, nimbostr-atus)	Variety of cloud development at various elevations; occluded front clouds
Influence on India	Affects both coasts; East coast more impacted	Brings rains to North-West India; associated with 'Western Disturbances'

SPECIAL CYCLONES

Fujiwhara Effect = Definition: Interaction between simultaneous tropical storms within 1,400 km.

Bomb Cyclone =

- Characteristics: Midlatitude storm, rapid intensification (≥24 mb in 24 hours). •
- Genesis: Clash of warm and cold air masses. •
- Areas: Common on the US coast, colder months

Thunderstorms and Tornadoes

Thunderstorms and tornadoes are brief but highly destructive, typically limited to a small area

Thunderstorms:

- A well grown cumulonimbus cloud producing thunder and lightning. •
- Caused by intense convection during hot, humid conditions.
- Short duration occurring over a small area; Violent in nature.
- • When these clouds reach altitudes with subzero temperatures, hailstones form and fall as hailstorms. In cases of limited moisture, dust storms are created.

Tornadoes:

- Sometimes severe thunderstorms generate a spiralling wind with very low pressure at the center that descends like the trunk of an elephant, causing massive destruction on its way; generally occur in middle latitudes; tornadoes over the sea are called waterspouts.

Polar Vortex

- Polar vortex is a large area of low pressure and cold air surrounding both of the Earth's poles.
- It always exists near the poles, but weakens in summer and strengthens in winter.
- It is counter-clockwise flow of air that helps keep the colder air near the Poles.
- It is usually contained above the poles by the polar front jet streams.
- In winters, the vortex becomes stronger and bigger in extent and the polar front jets also shift towards the Equator. As a result, a part of the polar vortex may split and intrude into the mid latitudes, called Polar Outbreak, bringing extremely cold weather there. E.g., large outbreaks of Arctic air in the United States.

HUMIDITY

- Water vapour present in the air is known as humidity
- Measure in Hygrometer or psychrometer
- Also Humidity measured by remote sensing satellites.
- Three Types
- Absolute Humidity: The actual amount of water vapour present in the atmosphere; represents the mass of water vapour per unit volume of air; measured in grams per cubic meter. It depends entirely on the temperature of the air (Greater over the ocean and less over the continent).
- Relative Humidity: Percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature.

Absolute Humidity	Relative Humidity
Actual water vapour content in a unit volume of air, measured in weight	percentage of the atmosphere's moisture content that is present relative to its maximum amount.
Expressed in grams per cubic meter of air	Expressed in percentages.
Independent of temperature	Decreases with an increase in temperature and vice versa.
It remains relatively constant,	Subjected to changes in water vapour.
Determines the amount of precipitation.	Tells us about the possibility of rainfall

Specific Humidity -

- is measured by the weight of water vapour per unit weight of air. Specific Humidity is a constant,

- it is stated in grammes per kilogramme of air
- The specific humidity is unaffected by changes in pressure or temperature because it is measured in weight units (typically grammes per kilogramme).
- whereas Absolute and Relative Humidity are variable they differ place to place.

Saturated Air (100% RH): Holds maximum moisture at that temperature; any moisture in excess causes condensation. Saturation is achieved by raising absolute humidity (adding moisture) or lowering temperature.

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Note

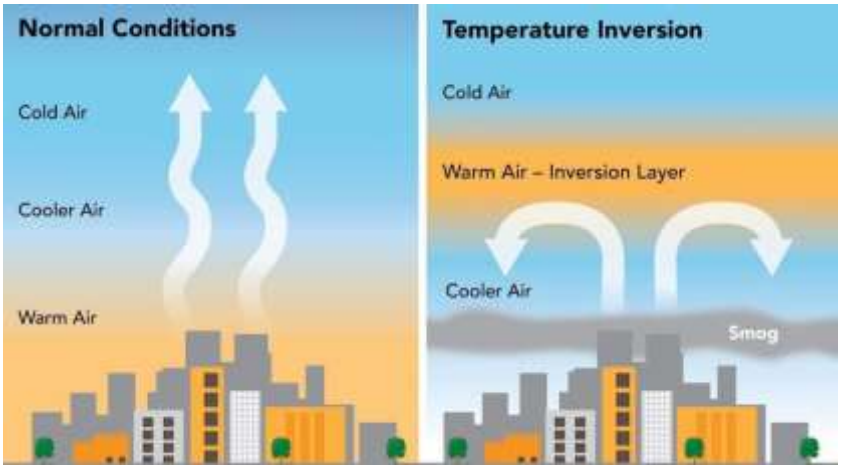
- **Define Lapse** : Rate of Change with altitude/ Height.
- **Lapse Rate:** Fall in Temp with Height/ elevation/ Altitude
- **Adiabatic** : related with Pressure and Height
- **Adiabatic Change:** refers to change in Temperature with Pressure.
- Height Increases Temp decrease : called Normal Lapse Rate .
- Height Increase Temp Increase called Inversion NLR/ Inversion of Temperature.

****

INVERSION OF TEMPERATURE
Temperature Inversion or Thermal inversion

NORMAL LAPSE RATE : temperature decreases with increase in elevation in the troposphere at a rate of 1 degree for every 165 meters.

But sometimes due to local conditions, the temperature, instead of decreasing, increases with height. This phenomenon is called **temperature inversion (thermal inversion**). This is also known as a **negative lapse rate**.



Ideal Conditions For Temperature Inversion

- Long winter nights, so that the outgoing radiation is greater than the incoming radiation.
- Clear skies, which allow unobstructed escape of radiation, facilitate Heat Loss
- Calm and stable air, so that there is no vertical mixing at lower levels
- dry air and ice cover: promote TI

- ❖ So inversion of temp causes atmospheric stability.

Note:

- moist air absorb more heat radiation and obstruct the temp Inversion
- Dry air does not absorb much radiation and promotes temp Inversion

Concept of Types of Temperature Inversion depends on Topopgrahy, Latitude and Altitudes :

- In mountains and Hills region: Air Drainage Inversion
- In Polar Regions and Plains areas in Winters Morning : Surface Temp Inversion
- Stratosphere Region : Upper Air Inversion
- Temperate Region/ Temperate Cyclones : Advection type of Inversion/ Frontal Inversion

Effects

- Inversions play an important role in determining cloud forms, precipitation, and visibility , formation of Fog and cause atmospheric Stability .(due to cap on the upward movement of the air)
- affects transportation and navigation
- Trains and flights are often delayed.
- Damage to crops
- the smog is considered a health hazard. Breathing problems, asthma, and bronchitis, etc. are common problems in Delhi and big cities of northern India during the winter season

Evaporation

- The process by which water is transformed from liquid to gaseous state.
- Moisture is added to the air through evaporation
- Higher temperatures lead to increased water absorption and retention capacity in a given volume of air
- Air with a lower moisture content has the ability to absorb and retain moisture.
- The movement of air replaces saturated air with unsaturated air, which promotes evaporation. Consequently, greater air movement results in higher rates of evaporation.
- Globally, oceans have higher evaporation due to extensive coverage.
- Evaporation decreases from equator to poles.
- The western North Atlantic shows the highest rates.

Condensation

- Process of transformation of water vapour into water; caused by the loss of heat.
- Sublimation: Process of condensation of water vapour directly into the solid form
- Condensation Nuclei: Small particles in the atmosphere that provide surfaces for water vapour to condense. E.g., Dust, smoke, pollen, and salt;
- Factors Influencing Condensation: Air movement; Temperature: Lower temperature favours condensation; Humidity: Higher humidity promotes condensation; Altitude and pressure changes

Types of Condensation

- **Dew -** involves condensation on surfaces at temperatures above freezing
- **Mist : Less dense fog and visibility more than one kilometer but less than two km**
- **Fog-** consists of suspended water droplets in humid air near ground level and visibilty less than 1 km
- **Rime - Supercold Fog**
- **Frost-** white crystalline ice formations layer on surfaces like grass, leaves, and cars
- **Smog: mixture of fog + Smoke**
- **Haze: Smoke + Dust particles**

Que :Which type of **deposit of ice crystals** formed by the freezing of **supercooled fog** or cloud droplets on objects whose surface temperature is **below freezing**.

a. Mist
b. Fog
c. Snow
d. Rime

Rime is a deposit of ice crystals formed by the freezing of supercooled fog or cloud droplets on objects whose surface temperature is below freezing.

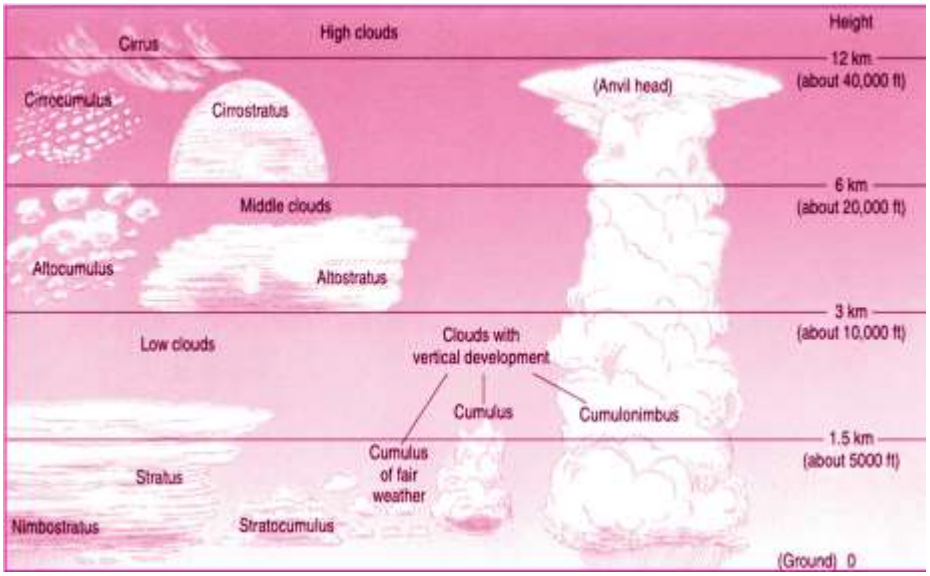
Forms of Condensation

- **Dew:** When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects
- **Dew Point**: The temperature at which saturation occurs in a given sample of air.
- **Dew point** is above the freezing point.
- **When Dew Point > Freezing Point: Outcomes are Dew, fog, and clouds**
- **when Dew Point < Freezing Point: Outcomes are White frost, snow, hailstones and cirrus clouds**
- **Fog**: Essentially a cloud that forms either at or extremely close to the Earth's surface
- **Haze**: Reduced visibility; Linked to low humidity
- **SMOG**: Combination of smoke and fog; caused due to Urban/industrial air pollution; Greyish, brownish, hazy appearance; 3 Types: Classical (London), Photochemical (Summer/Los Angeles) and VOG (Volcanic Smog)
- **Classical Smog**: Caused by coal combustion, high concentration of sulphur dioxide and particulate matter; Weather conditions: Cold and humid climate.
- Photochemical Smog: A mixture of pollutants that are formed when nitrogen oxides and volatile organic compounds (VOCs) react to sunlight, creating a brown haze; Creates secondary pollutants: Ozone, PAN (Peroxyacetyl nitrate) and, aldehydes. •
- **VOG (Volcanic Smog):** From volcanic eruptions; hazy mixture of SO2 gas and aerosols.

CLOUDS

- A cloud is a collection of small water droplets or tiny ice crystals (0.02 mm) that result from the condensation of water vapour in the open atmosphere at a significant altitud
- They have a dual impact: cooling (reflecting sunlight) and warming (trapping heat).

Thick, low clouds mainly cool down the Earth's surface by reflecting solar radiation. High, thin clouds in addition to transmitting incoming solar radiation also retain part of the outgoing infrared heat that the Earth emits and reflect it back downward, warming the Earth's surface. [UPSC 2022]



Types of Clouds

- Cirrus: They are thin, separate clouds with a delicate, feather-like appearance Develop at elevated heights (8,000 to 12,000 m). • Always white and composed of ice crystals
- Nimbus: Formed at intermediate altitudes or extremely close to the Earth's surface with no specific shape. Have a dark, black, or deep grey colouration.
- Cumulonimbus, with its strong vertical updraft, extends well into the high level of clouds.
- Stratus: Extensive, layered clouds that envelop significant sections of the sky. Generally formed either due to loss of heat or the mixing of air masses with different temperatures.
- Cumulus: Cumulus clouds look like cotton wool and have a flat base. Generally formed at a height of 4,000 - 7,000 m and exist in patches
- Alto - Middle Clouds

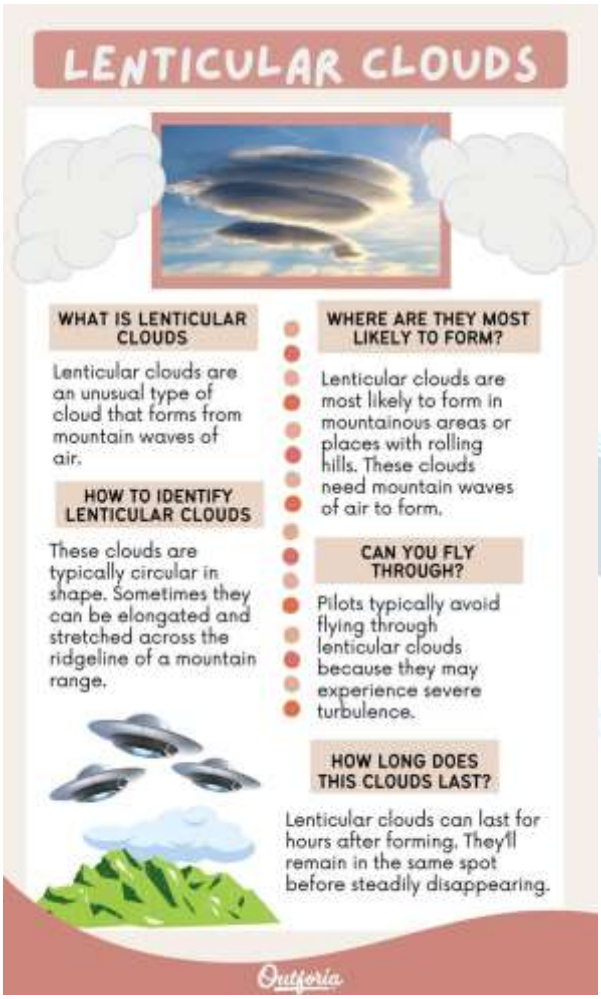
A combination of these four basic types can give rise to the following types of clouds:

- High clouds: Cirrus, cirrostratus, cirrocumulus;
- Middle clouds: Altostratus and altocumulus;
- Low clouds: Stratocumulus and nimbostratus;
- Clouds with extensive vertical development: Cumulus and cumulonimbus

Other Clouds

Polar Stratospheric Clouds (Pscs) Or Nacreous Clouds	Polar Mesospheric Clouds Or Noctilucent Clouds	Lenticular Clouds
Location : found in the stratosphere	Mesophere	Troposphere
Altitude : 15 to 25 kilometers above earth surface	80 and 85 kilometers	do not have a specific altitude range ; 2 to 10 km
Duration: winter in polar region	Duration : Summer in Polar Region and are visible during twilight	Any Season but from near mountains And can indicate turbulent weather conditions
composed primarily of ice crystals and nitric acid	formed from ice crystals	Water droplets or ice crystals

	Form in the coldest part of Earth's atmosphere	characterized by their lens-like shape .
play a significant role in ozone depletion	do not play a direct role in ozone depletion and they are an indicator of climate change	but do not directly contribute to phenomena like ozone depletion and do play a role in atmospheric processes
mother-of-pearl appearance	nightshining clouds	crucial indicators of turbulence for pilots



PRECIPITATION

- Precipitation refers to the release of moisture that occurs after the condensation of water vapour.
- Rainfall: Precipitation in the form of liquid water.
- Snowfall: When the temperature is below freezing point, precipitation takes the form of fine snowflakes.
- Sleet: Consists of frozen raindrops or refrozen melted snow-water; Occurs when there's a layer of air with a temperature above freezing point overlying a subfreezing layer near the ground.
- Hailstones: Formed when rainwater droplets solidify into small, rounded pieces of ice while passing through colder layers; Typically have multiple concentric layers of ice.
- Freezing Rain: Drizzles or light rains occurring below 0° C temperature and being frozen before reaching the ground.
- Virage: Raindrops evaporate before reaching Earth in dry air.

Types of Rainfall

On the basis of origin

1 Convectional Rainfall:

- Warm air rises due to convection currents, expands, cools down, and subsequently undergoes condensation, resulting in the formation of cumulus clouds & precipitation
- Prevalent during the summer or in the warmer hours of the day.
- Particularly common in equatorial regions and the inner regions of continents, especially in the northern hemisphere.
- Heavy rainfall accompanied by thunder and lightning occurs, but it tends to be of shorter duration

2 Orographic Rainfall (Relief Rainfall) or Inversion of rainfall :

- Occurs when a moisture-saturated air mass encounters a mountain and is compelled to rise. With ascendance, adiabatic expansion and cooling takes place resulting in condensation and precipitation. •
- More rainfall towards windward slopes, while on the leeward side (rainshadow area), adiabatic heating (temperatures increase) takes place, allowing for greater moisture absorption and resulting in dry conditions without rain. •
- Area situated on the leeward side is known as the rain-shadow area.

3 Cyclonic Rainfall:

- Widespread precipitation associated with weather fronts and cyclones; includes tropical and extra-tropical cyclonic rain.

World Distribution of Rainfall

- Rainfall diminishes steadily from the equator towards the poles.
- Equatorial regions receive consistent year-round rainfall.
- Coastal areas receive more rainfall than inland regions.
- Between latitudes 35° and 40° N and S, eastern coasts get heavier rainfall due to easterly winds, decreasing westward.
- Between 45° and 65° N and S, westerly winds bring rainfall first to western continental margins, decreasing eastward.

Rainfall Regions

- Heavy Rainfall (greater than 200 cm annually): equatorial region; coastal monsoon region; Windward side of coastal mountains.
- Moderate Rainfall (between 100 to 200 cm annually): Adjacent regions of very heavy rainfall areas; Coastal regions in the warm temperate region.
- Inadequate Rainfall (between 50 to 100 cm annually): Eastern part of the continents in temperate regions; Interior of continents in tropical regions.
- Low Rainfall (less than 50 cm annually): Rain shadow regions; Western part of continents in tropical regions

WORLD CLIMATE

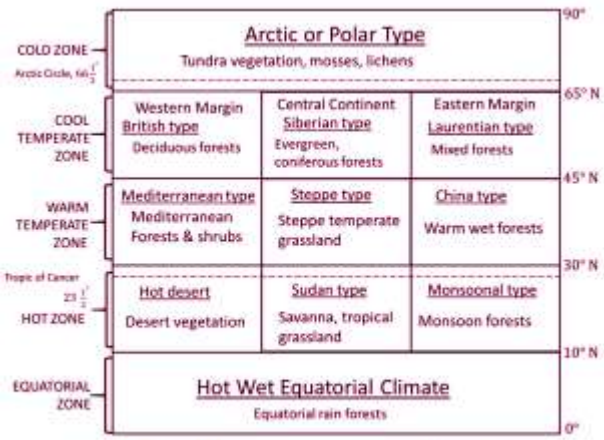


Fig.: Climatic Regions of the World

HOT, WET EQUATORIAL CLIMATE

- Located up to 5° and 10° N and S of the equator (in the lowlands of the Amazon, the Congo, Malaysia and the East Indies). Away from the equator, the influence of the onshore trade winds gives rise to a modified type of equatorial climate with monsoonal influence.

Climate

- Temperature - uniformily high throughout the year with average monthly temperatures above 180C, mean annual temperature around 20 c
- Cloudiness and heavy precipitation help to moderate the daily temperature
- Precipitation: Heavy and well distributed throughout the year, with average above 200-250cm; mostly convectional rain and orographic rainfall in mountains.
- No distinct dry season; very high Realtive Humidity (>80%);
- Double rainfall peaks coincide with the equinoxes in April & October.

Vegetation

- Tropical Evergreen Rainforest ("Lungs of the Planet") with dense canopy cover (Selvas in Amazon). E.g., mahogany, ebony; Creepers - epiphytes & woody climbers like 'Lianas'; Lalang (tall grass).
- Distinct layer arrangement in forests.
- High Diversity: Trees are not found in pure stands of a single species

Economic Activity

- Sparsely populated area with primitive people practising hunting and gathering;
- Shifting cultivation is practised here: Ladang (Malaysia), Taungya (Burma), Tamari (Thailand), Caingin (Philippines); Humah (Java); Chena (Sri Lanka); Milpa (Africa and Central America); Jhum (North-east India). A less luxuriant secondary forest called Belukar is also found
- Tropical hardwoods make lumbering difficult.

- Cocoa industry (Ghana, Nigeria) and Natural Rubber and Oil Palm (Malaysia and Indonesia) thriving here.
- Crops like coconuts, sugar, coffee, tea, tobacco, spices, and sago are cultivated.
- Congo (Cobalt reserves); Gold mining in the Amazonian forests of Brazil and Peru.
- Livestock Farming in Africa is handicapped by Tsetse Flies that cause Ngana, a deadly disease.
- Tribes: Pygmies (Congo Basin), Orang Asli (Malaysia)

Tropical Monsoon

- The region witnesses complete seasonal reversal of winds. Best developed in the Indian subcontinent, Burma, Thailand, Laos, Cambodia, parts of Vietnam and south China and northern Australia (5 to 30 N and S of the Equator)
- Trade winds after crossing the equator are drawn towards the continental low-pressure area reaching the Indian sub-continent as the South-West Monsoon.

Climate

- Temperature: Average monthly temperature > 18 C, Maximum temperature can reach 45 C ; Average temperature in summer is around 300C and during winters is around 25 C
- Seasons: Cool, dry season (October to February); the hot dry season (March to mid June); the rainy season (mid June to September).
- Concentrated heavy rainfall in summers; Mean annual rainfall is about 150 cm but there are temporal and spatial variations

Vegetation

- Dry-deciduous forestswith broad-leaved hardwood trees.E.g., Teak.
- Less luxuriant than tropical forests with fewer species

Economic Activity

- Supports high-population density.
- Subsistence farming with intensive cultivation in regions with irrigation facilities.
- Shifting cultivation is followed in North-East India and South-East countries.
- Agriculture: wet paddy cultivation, lowland cash crops (sugarcane, jute, Indigo, cotton), Highland plantation crops (Tea, coffee, spices).
- Cattle and sheep rearing prevalent.

Tropical Marine Climate

- Climate is under the influence of the on-shore Trade Winds all the year-round. Experienced along the eastern coasts of tropical lands: Central America, West Indies, north-eastern Australia, Philippines, parts of East Africa, Madagascar, Guinea Coast and eastern Brazil.

Climate

- Rainfall: Rainfall (both orographic and convectional) is maximum in summer, but without any distinct dry period; Influence of onshore trade winds.
- Prone to severe tropical cyclones, hurricanes or typhoons.

Vegetation

- Rainforests, mangroves, and coastal vegetation; Constant moisture and warmth contribute to the growth of diverse plant species.

SAVANNA OR SUDAN CLIMATE

- Transitional type found between the equatorial forests and the trade wind hot desert. Best developed in Sudan, includes west African Sudan, east Africa and southern Africa north of the Tropic of Capricorn. In South America: llanos of Orinoco Basin, Campos of Brazilian Highlands

Climate

- Temperature: Mean annual temperature is greater than 18°C; extreme diurnal range of temperature
- Rainfall: Alternate hot, rainy season and cool, dry season; rainfall is concentrated in summer; Floods and droughts are common. Mean annual rainfall - 80-160 cm
- Winds: Prevailing winds are the trade winds. Trade winds bring rains to the eastern coasts but become dry by the time they reach the interiors of the continents

Vegetation

- Tall grass (elephant grass) and short trees; deciduous trees usually having broad trunks, with water-storing devices to survive (like acacia tree)
- Grasslands are called bush-veld or parkland.
- Trees decrease in height and density polewards. z As the rainfall diminishes towards the desert the savanna merges into thorny scrub. In Australia, this scrubland is represented species: Mallee, Mulga, Spinifex grass etc;
- Many trees are umbrella shaped, exposing only a narrow edge to the strong winds.
- Tall Savanna grasses (elephant grass) have deep roots. It lays dormant during the cool, dry season

Wildlife

- The savanna is known as the big game country as thousands of animals are trapped or killed each year ;
- Two main groups of animals-grass-eating herbivorous animals and the fleshing-eating carnivorous animalsfound.
- Tribes: Masai (Kenya and Tanzania), Hausa (Nigeria)

DESERT CLIMATE

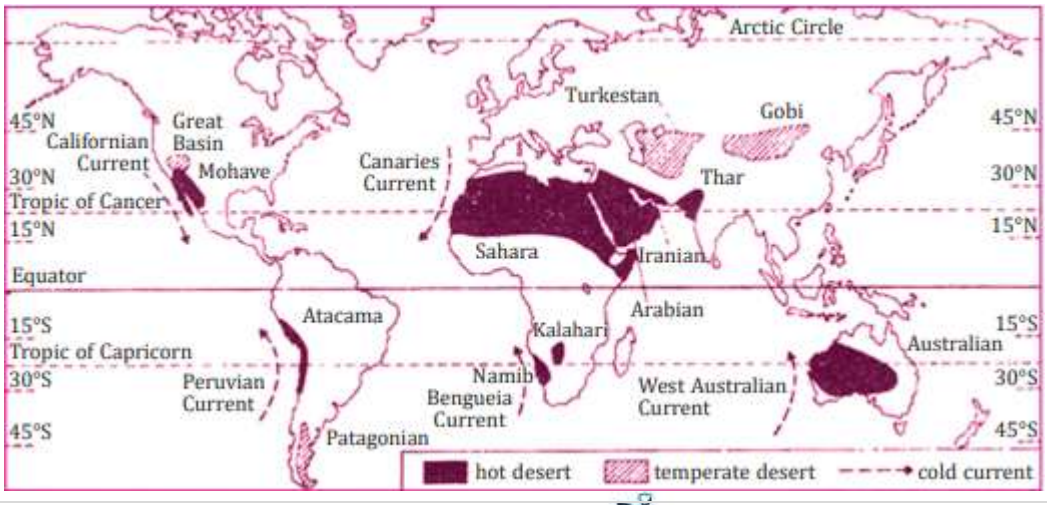
- Deserts are regions of scanty rainfall that may be Hot like the hot deserts of the Saharan type or Temperate as are the mid-latitude deserts like the Gobi

Hot Desert Climate

- Major hot deserts of the world are located on the western coasts of the continent between 15° and 30° N and S
- Aridity of the hot deserts is mainly due to the effects of off-shore Trade Winds; also called Trade Wind Deserts
- Sahara Desert, Great Australian Desert, Arabian, Iranian, Thar, Kalahari, Namib, Mohave, Sonoran, Atacama desert

Mid-Latitude Desert Climates

Among the mid-latitude deserts (usually between 30° and 50° N and S of the equator), many are found on plateaus



Climate Conditions in Hot Deserts (Trade Wind Deserts)

- Average summer temperature is around 30°C.
- Rainfall: scarce (less than 25 cm)and most unreliable.
- Aridity is high due to subtropical high-pressure belt (descending air), offshore trade winds, desiccating effect of cold current.
- Temperature: high throughout the year, coastal deserts due to maritime influence have much lower temperatures; desert interiors however experience much higher summer temperatures and winter months are rather cold.
- Diurnal temperature range is very great, frost may occur at night in winters.

Climate Conditions in the Mid-Latitude Deserts

- They are cutoff from the rain-bearing winds; Rainfall less than 25 cm.
- Occasionally depressions may penetrate the Asiatic continental mass or unexpected convectional storms may bring rain in summer and falls in winter.
- Rainless because of either continentality (Gobi Desert) or rain-shadow effect (Patagonian Desert).
- • Patagonian Desert is drier due to its rain-shadow position on the leeward side of the lofty Andes than to continentality.

Vegetation

- Xerophytic/drought-resistant scrubs, grasses and plants;
- Most desert shrubs have long roots to gather moisture
- Few or no leaves; foliage is waxy, leathery, hairy, or needle-shaped to prevent moisture loss.

Economy

- Gold mining in Great Australian Desert (e.g., Kalgoorlie, Coolgardie); Diamonds and copper in Kalahari; Sodium nitrate extraction in Atacama.
- North American deserts (silver in Mexico, uranium in Utah, copper in Nevada)
- Oil exploration in Sahara and Arabian Deserts (Saudi Arabia, Iran, Iraq, Kuwait, Algeria, Libya, Lebanon, Nigeria)
- Tribes: Bedouin (Arabs), Bushman (Kalahari), Bindibu (Australia), Tuaregs (Sahara), Gobi Mongols (Gobi)

WARM TEMPERATE WESTERN MARGIN (MEDITERRANEAN) CLIMATE

Confined to the western portion of continental masses, between 30 and 45 degrees north and south of the equator. Basic cause of this type of climate is the shifting of the wind belts. Found in areas around Mediterranean sea, central Chile, California, south- western tip of Africa, Southern Australia and south west Australia

Climate

- Temperature: Monthly average in summer is around 25° C and in winter below 10°C.
- Dry, warm summer with offshore trade winds, a concentration of rainfall in winter with on shore westerlies; annual precipitation ranges between 35-90 cm

Local winds around the Mediterranean Sea:

- Sirocco- hot, dry, dusty wind which originates in the Sahara Desert (Most frequent in spring). • Other names of Sirocco: Chili (Tunisia), Ghibli (Libya), Leveche (Spain), Khamsin (Egypt), Gharbi (Adriatic and Aegean sea). •
- Mistral: cold wind from the north, rushing down the Rhone valley, intensified by the funnelling effect in the valley between the Alps and the Central Massif (Plateau in France). •
- Bora: cold north easterly wind in Adriatic sea.
- • Tramontana and Gregale: cold winds of Mediterranean sea;

Vegetation

Shrubs- Maquis (South France), Macchia (Italy), Chaparral (California), Mallee (Australia) Eucalyptus forests in Australia, and Giant Sequoias or Redwoods in California; Species found include Pines, Firs, Cedars. Bushes and Shrubs are the most predominant type.

Economic Activity

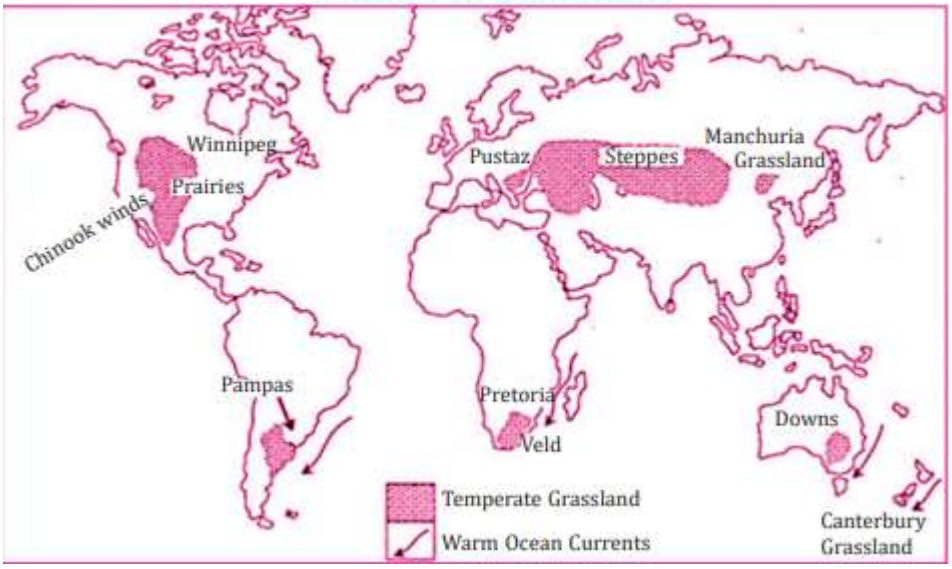
- World's orchard lands: famous for citrus fruitsSunkist oranges (California), Seville oranges (Spain), Jaffa oranges (Israel) etc;
- Wine production: Viticulture is by tradition a Mediterranean occupation, sherry (Wine from southern Spain), Port wine (Portugal), Chianti, asti and marsala (Italy), Champagne, Bordeaux and Burgundy (France).
- Nut-bearing trees like chestnuts, walnuts, hazelnuts, and almonds;
- Cattle Rearing: Mountain pastures, with their cooler climate, support sheep, goats and sometimes cattle. Transhumance is widely practised (moving up and down the hills in search of pastures according to seasons)

TEMPERATE CONTINENTAL (STEPPE) CLIMATE

- Lies in the westerly wind belt but they are so remote from maritime influence that the grasslands are practically treeless (between 40° and 55° N and S of the equator).
- They are known as Steppe (Eurasia), Pustaz (Hungary), Prairies (North America), Pampas (Argentina and Uruguay), Bush-Veld (North South Africa), High-Veld(Southern South Africa), Downs (Australia), Canterbury (New Zealand).

Climate

- Temperature: Seasonal variations with warm to hot summers (often exceeding 30°C) and cold winters.
- Extremes of temperature in northern hemisphere, steppe type of climate in the southern hemisphere is never severe (maritime influence) and winters are mild
- Precipitation: Low annual rainfall (25-75 cm); the dry season is particularly pronounced in temperate grasslands adjoining desert
- Summer rainfall (Maximum) from convectional sources when continental interiors are heated
- Winter rainfall (lesser) by occasional depressions of the Westerlies.
- Maritime influence in the southern hemisphere, greater rainfall because of warm ocean currents.
- In Prairies a local hot wind called the Chinook (also called 'snow eater') comes melting the snow covered pastures



Vegetation

- Grasslands are practically treeless, grass is nutritious thus promoting livestock rearing in the region
- Grasses are not only shorter but also wiry and sparse. In arid areas like Asia's continental interiors, wiry grasses favour ranching over arable farming.
- Moving polewards, increased precipitation results in wooded steppes, where conifers gradually appear

Economic Activity

- Extensive mechanized wheat cultivation, nomadic herding, pastoral farming etc; Due to extensive, mechanised wheat cultivation they are known as the 'granaries of the world'.

WARM TEMPERATE EASTERN MARGIN (CHINA TYPE)

- It is a modified form of monsoonal climate, found on the eastern margins of continents in warm temperate latitudes. In summer, the regions are under the influence of moist, maritime airflow from the subtropical anticyclonic cells
- Climate: Warm moist summer and cool, dry winter; strong maritime influence; small annual temperature range
- In summer, the regions are under the influence of moist, maritime airflow from the subtropical anticyclonic cells
- Rainfall throughout the year (60 to 150 cm); Rainfall from Convectional sources or as orographic rain in summer, or from depressions in winter.
- Local storms: Typhoons (tropical cyclones), and Hurricanes, also occur

Subdivided Into Three Main Types

- China Type (Central and North China, South Japan): temperate monsoonal; great annual temperature range; rain in summer and winter; occurrence of typhoons in late summer;
- Gulf Type (South Eastern USA): slight monsoonal; no distinct dry period; occurrence of hurricanes and tornadoes
- Natal type: Natal, Eastern Australia, Southern Brazil, Paraguay, Uruguay and Northern Argentina and all warm eastern temperate margins of southern hemisphere; Dominance of maritime influence

Vegetation

- Lush vegetation with evergreen broad-leaved forests and deciduous hardwood trees in lowlands due to welldistributed rainfall all year round.
- Conifer species like pines and cypresses in highlands; z No dry or cold seasons, allowing uninterrupted perennial plant growth.

Economic Activity

- Warm temperate eastern margins are the most productive parts of the middle latitudes.
- World's greatest rice-growing areas, warm wet and lowland favour rice cultivation. Sugarcane, cotton, tobacco, maize, dairy products etc.
- Timber: Economic value in China and southern Japan (oak, camphor); Eucalyptus forests in Eastern Australia; Lowland deciduous forests in Gulf states of the U.S.A.

Local Winds Southerly Burster (Cold Wind in Australia) impacts New South Wales and Victoria ; Pampero (Cold Dry Wind in Argentina & Uruguay; Berg (Hot & Dry Wind in South Africa) bring

Cool Temperate Western Margin (British Type)

Found in Britain, North West Europe, British Columbia(USA), Southern Chile, Tasmania and most parts of New Zealand (between 40° and 65° latitude in the Northern Hemisphere)

Climate

- They are under the permanent influence of westerlies throughout the year;
- Regions of frontal cyclonic activity, typical of Britain, and are thus said to experience the British type of climate.
- High maritime influence on temperature and precipitation
- Temperature: Mild winters and cool summers (Mean annual temperature - 5 to 150C) z
- Rainfall: Throughout the year, with a tendency towards a slight winter or autumn maximum from cyclonic sources.
- Seasons are very distinct. Winter - short duration and mild (due to warming effect of North Atlantic Drift); Spring are driest; summer and autumn

Vegetation

Deciduous trees occur in pure stands. z Higher up the mountains deciduous trees (Shed leaves in winters to protect against snow and frost) are generally replaced by conifers. z Valuable temperate hardwood: oak, elm, birch, beech, poplar, Willows, Alder, Aspen, etc.

Economic Activity

- Market gardening, mixed farming, sheep rearing etc. z Fishing is important in Britain, Norway, and British Columbia.
- British-type climate suitable for crops and dairy farming. Mixed farming in north-western Europe with wheat, barley, and advanced dairy practices.

COOL TEMPERATE EASTERN MARGIN (LAURENTIAN):

Intermediate type of climate between the British and the Siberian type that is found in only two regions: north eastern North America (eastern Canada, north east USA and Newfoundland) and eastern coastlands of Asia, including eastern Siberia, North China, Manchuria, Korea and northern Japan.

In the southern hemisphere, this type of climate is absent.

Climate

- Temperature: Features of both continental and maritime climate; cold, dry winters and warm, moist summers.
- Arctic off-shore cold currents are instrumental in cooling the summer, otherwise, it would have been even hotter
- Rainfall: 75 - 150 cm of rainfall distributed throughout the year with a maximum during summer,
- Northern Hemisphere: Rainfall distribution is uniform due to Atlantic influence and the Great Lakes, high temperatures in summer and snowfall in winters;
- Asiatic regions: Rainfall is far less uniform, the rainfall regime is similar to that of the tropical monsoon type in India. Japan receives adequate rainfall from both the south east monsoon in summer and North West Monsoon in winter

Vegetation

- Coniferous (north of 50 Degree N latitude) and deciduous (south of 50 Degree N latitude); Oak, beech, maple, and birch are principal trees.

Economic Activity

- Lumbering important activity, agriculture is less important due to severity and length of winter.
- Fishing, particularly in the Grand Banks of Newfoundland.

THE COOL TEMPERATE CONTINENTAL CLIMATE (SIBERIAN)

Experienced only in the Northern hemisphere: North America (from Alaska across Canada into Labrador), Europe and Asia (between 50° and 70° N and S of the equator).

Climate

- Temperature Brief, warm summers (20-25°C) and long, extremely cold winters (-30 to -40°C); Occasional violent cold polar winds, like Canadian blizzards and Eurasian buran.
- Rainfall: Relatively dry year-round, low annual precipitation mainly in the form of snow ;
- Vegetation Mosses, lichens and sledgesIn more sheltered spots, stunted birches, dwarf willows, hardy grasses and reindeer moss are found.
- Tundra, taiga (boreal forest), and grasslands adapted to harsh conditions ;
- Conifers with adaptations like conical shape, thick needle-shaped leaves, and podzolized soils

Economic Life

- Lumbering is the primary economic activity, utilizing vast coniferous forests; Softwood logs transported downstream on rivers.
- Paper and pulp industry (Canada and the U.S.A.)

- Agriculture is challenging with limited crops due to extreme cold and short growing season

Arctic or Polar or Tundra Climate

- Found north of the Arctic Circle in the northern hemisphere and in the southern hemisphere in the continent of Antarctica; Extremely cold with long winters, devoid of tall trees or forests.
- Climate
- Temperature: Winters harsh, often below -37°C; summers brief with temperatures rarely exceeding 10°C.
- Precipitation: Generally low, with limited moisture in the form of snow and occasional freezing rain; Summer maximum precipitation in the form of rain or sleet

Vegetation

- Tundra vegetation limited to hardy, low-growing plants, mosses, and lichens
- Permafrost restricts the growth of deep-rooted plants
- Coastal lowlands support hardy grasses and reindeer moss;
- Brief summer bloom with the melting of snow, known as “Arctic Prairies
- Inhabitants like Eskimos, Lapps, and Samoyeds lead a semi-nomadic lifestyle, residing in compact igloos during winter