PRINCIPLES OF CLIMATOLOGY 18KP1G02

UNIT I: Climatology: Definition- Nature Scope and Significance - Composition and Structure of Atmosphere - Insolation- Heat Budget - Distribution of Temperature – Vertical and Horizontal.

NATURE, SCOPE AND SIGNIFICANCE OF CLIMATOLOGY

Definition , Meaning and Scope

Definiton : Klima – slope / angle of incidence , Logos- discourse / study Angle of incidence determines the earth temperature hence it is known as climatology

- It is the branch of physical geography – kenneth
- It is the science explain the nature of climate with time space and human interference – Critchfield
- Studies the weather over longer period – Riley & Spolton
- Branch of science deals the average condition of weather – Austin Miller
- It is the subject for parts of meteorology, statistics and geography - Arnold Court
- Study of atmosphere and earth - Thornthwaite

Aim and Objectives

To explain the casual relationship between climate and human with the following objectives

- to explain causing factors of different climates
- to explain the effects on natural vegetation
- to explain climate man relationship
- to synthesis the elements of climate based on empirical and statistical inferences

Nature

- Explain the casual relationship between climate and human
- It explains causing factors of different climates
- It explain the effects on natural vegetation
- It explain climate man relationship
- It synthesis the elements of climate based on empirical and statistical inferences

Major Divisions of Climatology

Physical Climatology: Mainly deals with process of heat energy and moisture transformation and air movement by the observation of insolation amount and duration, temperature, air pressure, precipitation, wind, cloudiness, fog and visibility etc., Energy transformation and momentum between earth and atmosphere and within the atmosphere leads different weather changes is core of the subject Physical climatology also deals other secondary factors causes this energy transformation such as Latitude, altitude, relief, prevailing winds , distance from the sea and land cover

Regional Climatology: Also known as descriptive climatology Mainly classifies the climatic type the region Identifies pattern, homogeneity and trend of the climate with the aid of scientific modeling Macro, meso and micro are hierarchy of the regional climatology

Applied climatology: Advanced climatology, Application of latest techniques - IT and related, Highly interdisciplinary , Problem and area specific such as

Plant and animal breeding

Aviation and navigation

Engineering – architectural applications

Fishing, non-conventional energy industries

Recent advancement -Disaster management

Meteorology and Climatology

Meteorology deals mainly

about the causing factors of individual weather element

Identifies the interdependence of this elements

Emphasis the instantaneous changes of atmosphere

Area and problem specific

Climatology mainly deals with

Synthesis the factors causing the climate

Reveals pattern , trend and type of cliamte

Explains the spatio-temporal variation of climatic elem

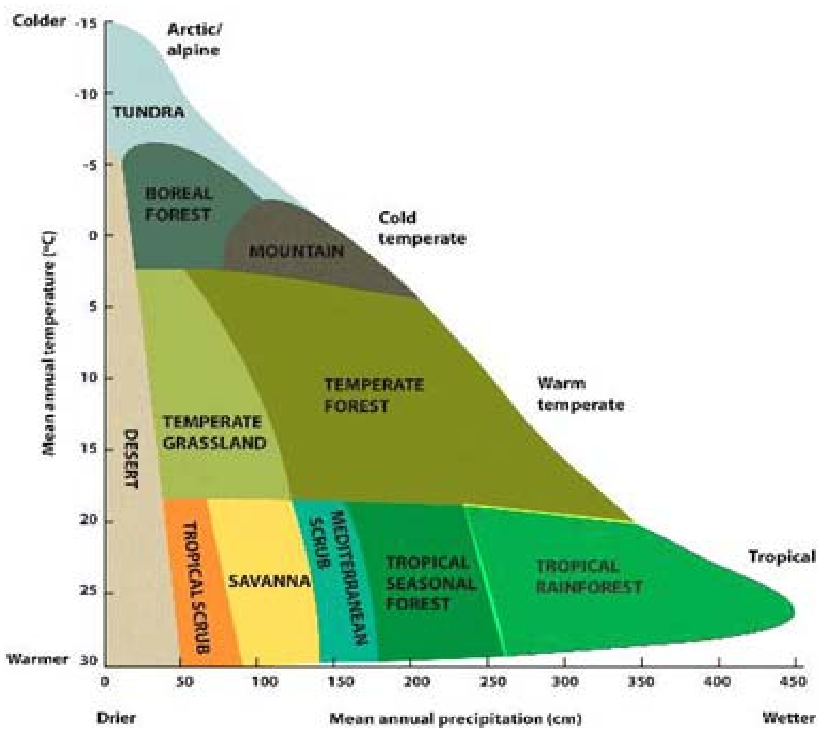
Relates with bioshpere

Weather and Climatic Elements

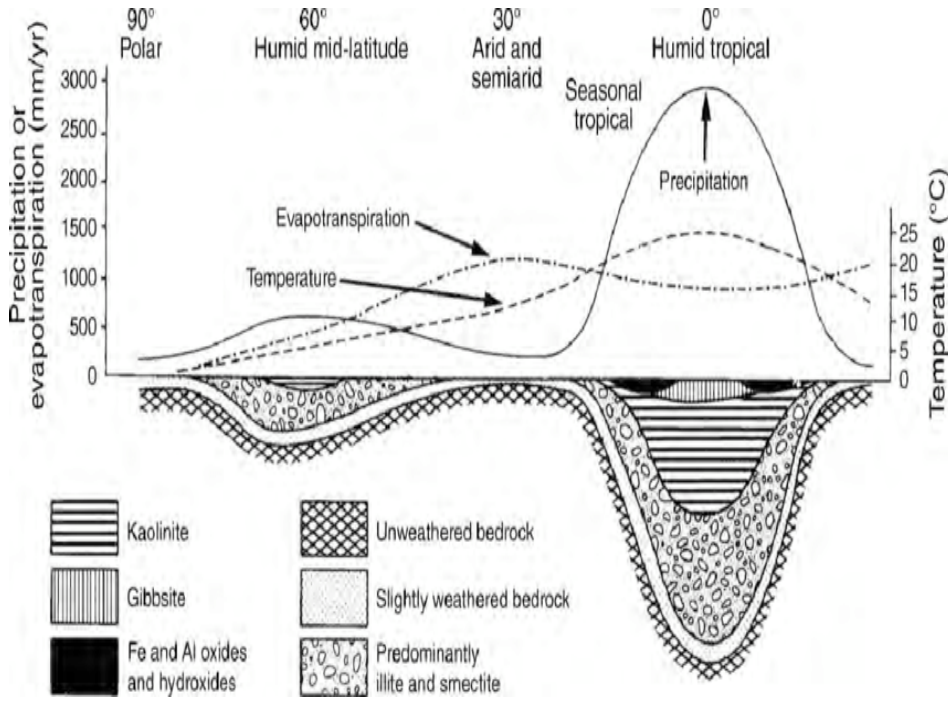
Climatic elements	Weather elements
Temperature	Air temperature
Pressure	Formation of troughs
Wind	Direction and intensity
Humidity	Cloud formation and moisture
Rainfall	Forms of precipitation

Significance of Climatology:

1. **Temperature and Annual precipitation on the vegetation type**



2. **Latitudinal gradient in soil structure and weathering depth in relation to climate and vegetation**



3. **Man and Climate**

Man's climatic environment affects him in many ways. His clothing, dwellings, food, occupations, and customs; his physical and mental characteristics; his systems of government; his migrations; his history—all are affected to a greater or less degree.

The colour of man's skin becomes paler with increasing distance from the equator the Pygmies are small because of the heavy seasonal rains which fall in hot equatorial. In Africa Climate was be- lieved to explain the overhanging eyebrows and partly-closed eyes of the negro; the small eyes and beardless faces of the Chinese; the (supposed) fact that more twins were born in Egypt than elsewhere.

Climate and House Types

COMPOSITION AND STRUCTURE OF THE ATMOSPHERE

Introduction

The atmosphere is a transparent envelope of gases and suspended particles that surround the Earth. The atmosphere is the source of every living thing in the world. The atmosphere protects earth from harmful solar radiations and regulates heating process of the Sun. It has two main functions, first it is made possible by ozone existing in the stratosphere, the second function is achieved by a mix of gases existing in the whole atmosphere called "**greenhouse gases**". The atmosphere provides the air we breathe, the food we eat, the water we drink and above all it supports life.

Evolution of Atmosphere

Primitive atmosphere composed of only two harm full gases, methane and ammonia, which was about 4 billion years ago. This is the period were the single – celled organism called prokaryotes, the only life forms that inhabited the earth. These organisms could synthesize the chemicals in the air for energy caused disintegration of methane and ammonia and some amount of water vapour which triggered formation of nitrogen, hydrogen and carbon dioxide to form. Subsequently, photosynthesis of green plant favours the development of ozone layer, which enriches the development of life over the surface of the early ocean and land. As of the development of various forms of life along with chemical, physical and geological process which gradually alters the composition of atmosphere and attains the present status.

Composition of Atmosphere

Earth’s atmosphere contains mainly several different gases and additionally aerosol particles. Atmospheric gases are generally classified as constant and variable by their amount and residence time. The amount of atmospheric gases generally expressed by the volume ratio (m^3 gas per m^3 air) and by mole fraction (mol mol^{-1}). For trace gases, ratio is commonly given in units of parts per million or simply ppm.

Atmospheric Gases

Nitrogen and **oxygen** are the main components of the atmosphere by volume. Together these two gases make up approximately 99% of the dry atmosphere. Both of these gases have very important associations with life. Nitrogen is removed from the atmosphere and deposited at the Earth's surface mainly by specialized nitrogen fixing bacteria, and by way of lightning through precipitation. The addition of this nitrogen to the Earth's surface soils and various water bodies supplies much needed nutrition for plant growth. Oxygen is exchanged between the atmosphere and life through the processes of photosynthesis and respiration. Photosynthesis produces oxygen, whereas by the respiration, oxygen is combined with glucose releases energy for metabolism causes the formation of water and carbon dioxide.

The fifth most abundant gas in the atmosphere is carbon dioxide. The volume of this gas has increased by over 35% in the last three hundred years. This increase is primarily due to human induced burning from fossil fuels, deforestation, and other forms of land-use change. **Carbon dioxide** is an important greenhouse gas. The human-caused increase in its concentration in the atmosphere has strengthened the greenhouse effect and has definitely contributed to global warming over the last 100 years. Carbon dioxide is also naturally exchanged between the atmosphere and life through the processes of photosynthesis and respiration.

Atmospheric Gases	Percentage	Atmospheric Gases	Percentage
Nitrogen	78.08	Krypton	0.000114
Oxygen	20.95	Ozone	0.000004
Water	0 - 4	Nitrous oxide	0.000031
Argon	0.93	Xenon	0.0000087
Carbon Dioxide	0.039	Carbon monoxide	Trace - 0.000025
Neon	0.0018	Sulfur dioxide	Trace - 0.00001
Helium	0.0005	Nitrogen dioxide	Trace - 0.000002
Methane	0.00017	Ammonia	Trace - 0.0000003
Hydrogen	0.00005		

Methane is a very strong greenhouse gas. The primary sources for the additional methane added to the atmosphere (in order of importance) are: rice cultivation; domestic grazing animals; termites; landfills; coal mining; and, oil and gas extraction.

The average concentration of the greenhouse gas **nitrous oxide** is now increasing at a rate of 0.2 to 0.3% per year. Sources for the increase of nitrous oxide in the atmosphere include: land-use conversion; fossil fuel combustion; biomass burning and soil fertilization.

Ozone is a form of oxygen that combines three oxygen atoms into one molecule (O_3). There is very little of this gas in the atmosphere, and it is concentrated in the stratosphere. Ozone absorbs ultraviolet (UV) radiation, and without it the Earth would be uninhabitable.

Water Vapour

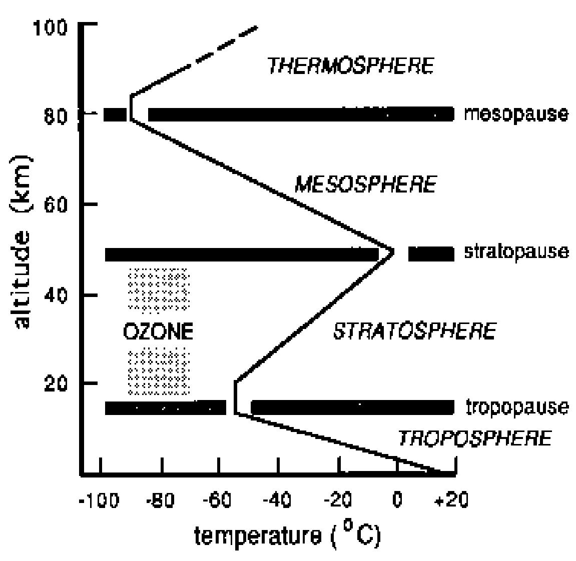
The amount of water is the atmosphere varies just between 1 and 4%, it has a significant role in the system of atmosphere. Water vapor is the source of all clouds and precipitation and it has the ability to absorb heat energy given off by the Earth. When water changes from one state to another it absorbs or releases heat. This heat is often called latent i.e. hidden heat. This is the energy source that helps drive a lot of storms.

Particulates and Aerosols

Atmospheric particulates and aerosols are very small particles of solid or liquid suspended in the air, where as the aerosols are colloidal suspensions combined with gases. Particulate matter includes dust, smoke, pollen, spores, and seeds. Dust particles are more commonly found in the troposphere, near the Earth's surface where their main source, the Earth itself. However, there is dust in the upper atmosphere as well because some dust is carried to great heights by rising currents of air. It includes microscopic particles including pollen, spores, and seeds. Other dust particles can be remains of meteors that disintegrate as the pass through the Earth's atmosphere. They act as surfaces where water can condense, forming clouds forms water droplets can grow large and fall to the ground as snow or rain. Dust can also absorb or reflect incoming solar radiation. Dust can also contribute to scattering light, giving rise to more orange and red sunrises or sunsets.

Structure of Atmosphere

Do you think the thicknesses of the atmospheric layers are constant throughout the globe? Not, exactly, layers has higher span over the equator caused by higher temperature and centrifugal force of earth. But the atmospheric layers become thin out at the poles, since lower temperature and centripetal force over here. This thickening at the equator and thinning at the poles has always been a natural phenomenon of the earth's atmosphere. This fact makes it difficult to define exact heights for the layers of the atmosphere. However in general earth's atmosphere is divided into five main layers: the exosphere, the thermosphere, the mesosphere, the stratosphere and the troposphere (**Fig 1**).



There is no distinct boundary between the atmosphere and space, but an imaginary line about 100 kilometers from the surface, called the Karman line, where atmosphere meets outer space.

Troposphere

Troposphere is the lower most layer to the Earth's surface, extends between 7 (near poles) and 20 km (over equator), and contains half of Earth's atmosphere. Air is warmer near the ground and gets colder higher up. Nearly all of the water vapor and dust in the atmosphere are in this layer and that is why clouds are found here. Air pressure and the density of the air also decrease with altitude. That's why the cabins of high-flying jet aircraft are pressurized. Temperature decreases with increasing height in the troposphere to away from the warming surface.

The changing rate of temperature with height is called "lapse rate", it is about 6,5 °C / 1000 m, but this rate is affected by water vapour content.

Stratosphere

The layer immediately above the troposphere is called the stratosphere. The boundary between the troposphere and the stratosphere is called the "tropopause" characterized by a sharp change in the lapse rate i.e temperature that stop decreasing with altitude and remain constant. Stratosphere is the second layer, starts from 10 km and ends above 50 km above ground. Temperature increase in the stratosphere is due to the relatively high concentration of ozone. Ozone strongly absorbs UV radiation from the sun.

Mesosphere

Mesosphere starts at 50 km and extends to 85 km high. Here the temperature again decreases with height, reaching a minimum of about - 90°C at the "mesopause", which is the coldest part of Earth's atmosphere.

Thermosphere

Thermosphere, consist of ionosphere and magnetosphere. Thickness of the thermosphere is about 90 km and extension varies between 500 and 1,000 km. The thermosphere lies above the mesopause, and is a region in which temperatures again increase with height.

This temperature increase is caused by the absorption of energetic ultraviolet and X-Ray radiation from the sun. Temperatures can get up to 1,500^o C at this altitude. Charged particles from space collide with atoms and molecules in the thermosphere, exciting them into higher states of energy. The atoms shed this excess energy by emitting photons of light, which we see as the colorful referred to as polar lights, aurora borealis (northern lights) or aurora australis (southern lights). The ionosphere reflects and absorbs radio waves.

Exosphere

Exosphere, the highest layer, is extremely thin and is where the atmosphere merges into outer space. It is composed of very widely dispersed particles of hydrogen and helium.

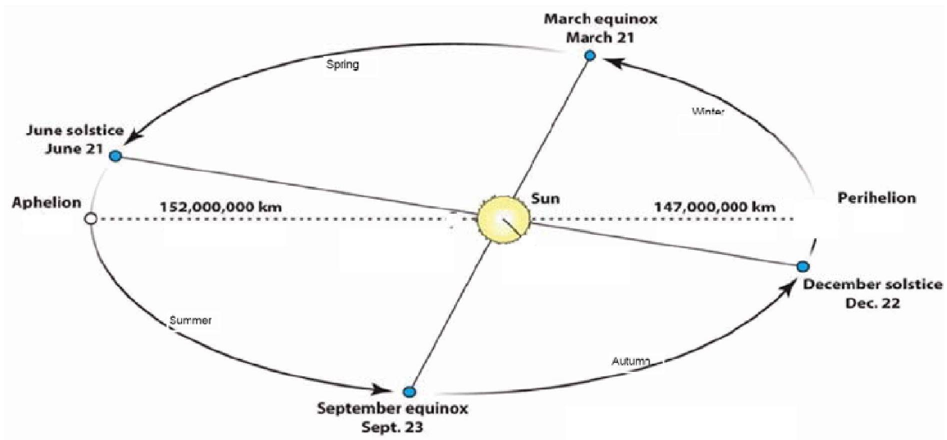
INSOLATION AND HEAT BUDGET

Almost all the energy received by the earth comes from the sun. Radiation of energy comes in wavelengths. The complete range of radiation wavelengths is called the electromagnetic spectrum. Earth receives, on average, 1368 w/m^2 of solar radiation at the outer edge of the atmosphere, called the 'solar constant'. The solar radiation that makes its way through the atmosphere travelling at the rate of 186000 miles a second is called solar radiation or Insolation, measured energy received per square centimeter per minute. The amount of insolation received at the surface depends on 1) apparent position of the sun and seasons 2) the sun angle and distance 3) the state of the atmosphere 4) sun spot and 5) altitude and ground slope

Apparent Position of the Sun and Seasons

Earth orbits the sun in an elliptical path, which means that there is one point of the path when the sun is at its closest to the Earth and another point when it is furthest away. Earth is about 147 million kilometres from the sun at perihelion (December), in contrast to about 152 million kilometres at aphelion (June), a difference of about 5.0 million kilometres. Because of the increased distance at aphelion, only 93.55% of the solar radiation from the sun falls on a given area of land as does at perihelion.

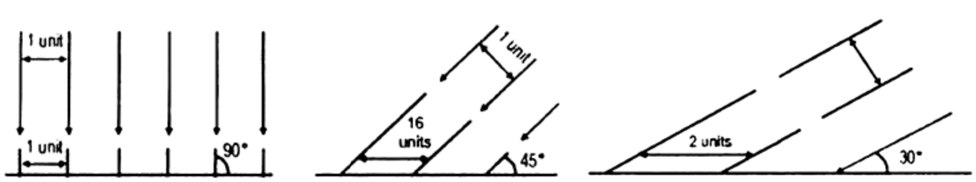
It is important to note that, in the northern hemisphere, summer occurs when the sun is farthest and winter occurs when the sun is closest to the earth, because the seasons result from the tilt of Earth's axis. Think the condition of summer and winter if the earth titles at the angle of 336.5^o and if it is not titled. Hence, it is understood that the distance of the sun do not cause directly the amount of insolation, but it cause the energy potential of the various seasons.



Two equinoxes occur, in March and September, when the sun is directly over the equator and day length and nigh-time durations are equal throughout the world. In June, the summer solstice in the northern hemisphere, the sun appears directly overhead the Tropic of Cancer, and the polar areas (north of 66 2/3^o N) have 24 hours of daylight. Similarly, in December winter solstice, the sun appears overhead the Tropic of Capricorn, and the south polar region receive 24 hours of daylight.

The sun angle and distance

Vertical rays are spread over minimum area of the earth's surface and they heat the minimum possible area and thus the energy received per unit area increases. Oblique rays are spread over larger area of the earth's surface and hence the amount of energy received per unit area decreases. Oblique rays have to pass through thicker portion of the atmosphere than the vertical rays thus the oblique rays have to travels larger distances than the vertical rays.



On an average, the amount of insolation received at the earth's surface decreases from equator towards the poles but there is temporal variation of insolation received at different latitudes at different times of the year. As the angle of sun's ray decrease poleward, the amount of insolation received also decreases in that direction

Latitudes (degree)	0	10	20	30	40	50	60	70	80	90
Insolation (in percent)	100	99	95	88	79	68	57	47	43	42

State of the atmosphere

The incoming short wave solar radiation have to pass through a mean sun-earth distance of 149.5 million kilometers and the earth's atmosphere and hence some portion of solar energy lost through the three process of scattering / diffusion, reflection and absorption. Clouds, particulates, and aerosols suspended in the air have a dramatic effect on the transmission of insolation.

The process of **scattering** occurs when small particles and gas molecules diffuse significant amount of energy back to space without any alteration to the wavelength of the electromagnetic energy which reduces the amount of incoming radiation reaching the Earth's surface. If intercepted, some gases and particles in the atmosphere have the ability to **absorb** incoming insolation Absorption is defined as a process in which solar radiation is retained by a substance and converted into heat energy. The final process in the atmosphere that modifies incoming solar radiation is **reflection**. Reflection is a process where sunlight is redirect by 180° after it strikes an atmospheric particle. This redirection causes an absolute loss of the insolation.

Sunspots

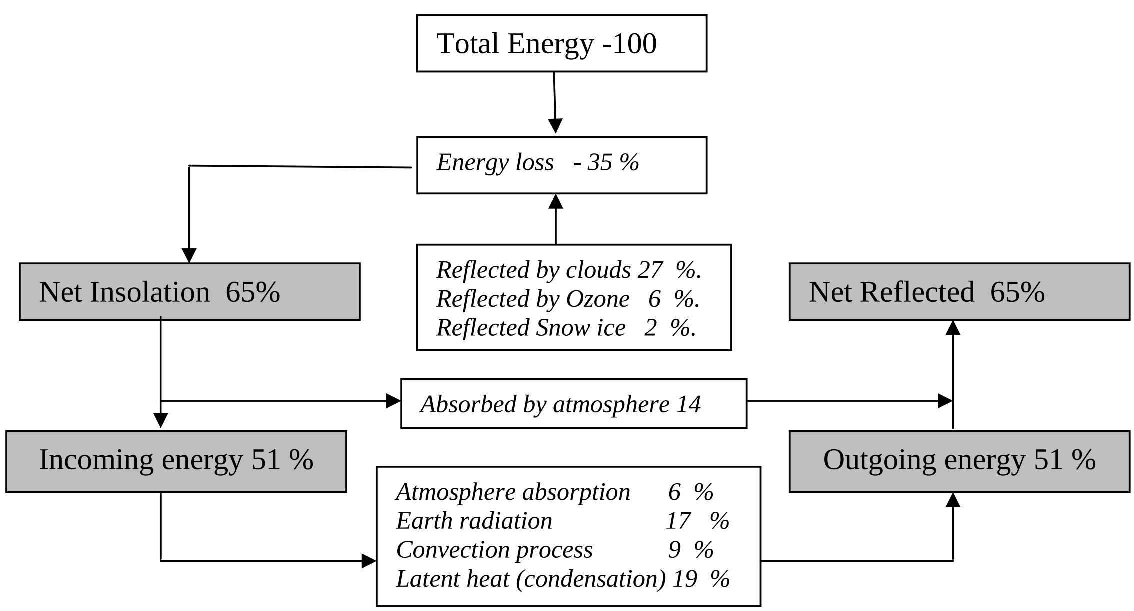
Sunspots defined as dark areas within photosphere of the sun and surrounded by chromospheres, are created in the solar surface. These dark areas are cool areas because they are characterized by 15000^{o} c less temperature then the chromospheres which surrounded them, but there is an increased magnetic activity causes emission of highly charged particles from the solar surface and which emits more UV and visible radiation. This means that more sunspots deliver more energy to the atmosphere, so that global temperatures should rise.

Altitude and ground slope

The slope of the surface that a beam of light strikes affects the intensity of energy it receives. Slope affects insolation intensity in two ways, 1) the degree of slope inclination, and 2) the orientation of the slope to incoming light. Orientation or direction the slope is facing also affects the amount of insolation received. Slopes facing into the Sun receive more while those that face away receive less. Some surfaces can be shaded during a portion of the day by obstructions reducing the amount of insolation received by them. However it is important to remember here, that the atmosphere is mainly heated by conduction from the earth, Thus temperature decreases with increasing height above sea level. But the potential difference in the amount of insolation received by different height and aspect of the slope has the significant impact on the distribution of rainfall and vegetation.

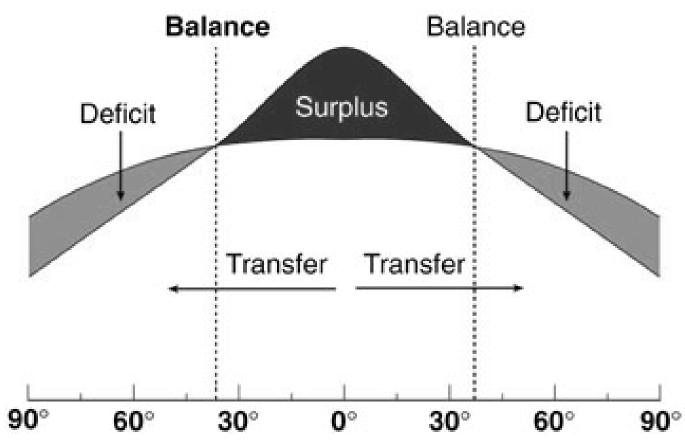
Energy Budget

For earth's temperature to be stable over long periods of time, incoming energy and outgoing energy have to be equal. In other words, the energy budget of the biosphere must balance. This state of balance is known as energy budget. About 35 % of the solar energy that arrives at the top of the atmosphere is reflected back to space by clouds, atmospheric particles, or bright ground surfaces like sea ice and snow. This energy plays no role in Earth's climate system. About 14 % of incoming solar energy is absorbed in the atmosphere by water vapor, dust, and ozone, and 51 % passes through the atmosphere and reached the surface, therefore net insolation will be 65 percent in the form of shortwave.



Out of which, 17 % directly radiated back to the space and only 34 % of energy is used for heats up the atmosphere through transfers of ***sensible heat***, ***latent heat*** and the release of long-wave ***radiation***. Therefore, 51 % of incoming energy radiated back to the space by means of long wave .Chart below shows the general heat budget of the globe by considering that the insolation received at the top of the atmosphere is 100 %. ***Conduction*** is when heat is conducted from the ground to the air that is in direct contact with the ground. The air, which is warmed by conduction, then rises by ***convection*** because it is less dense than the air around it. In this way heat is transferred into the upper parts of the atmosphere. On the other hand, ***latent heat*** transfer energy is required to evaporate water into a vapour.

Therefore, the energy that was required to evaporate the water is stored within the vapour as latent heat. The vapour then rises into the atmosphere through convection, or through forced rise (along fronts or up mountains) or by turbulence. On condensation the latent heat is released into the atmosphere as sensible heat, which warms the atmosphere. In the case of energy balance at latitudes, Insolation maxima are roughly between 35^o N to 35^o S latitude there is a surplus of energy as incoming radiation exceeds outgoing. Here, high sun angles and a lack of cloud cover allow much solar radiation to the surface. Insolation decreases to a minimum at the poles, there is more outgoing energy than incoming, yielding a net loss of energy from the Earth's surface where low sun angles and the fact that the Sun doesn't rise above the horizon nearly half the year reduces annual insolation and always under deficit.



The latitudinal imbalance in the energy gain and loss causes the energy circulation of the atmosphere and oceans. Heat gained in the tropics is transported poleward by the global circulation of air and warm ocean currents to heat higher latitude regions. Cooler air from the higher latitudes and cold ocean currents push equatorward to cool the lower latitudes. This process of redistributing energy in the Earth system helps to maintain a long-term energy balance.

Summary

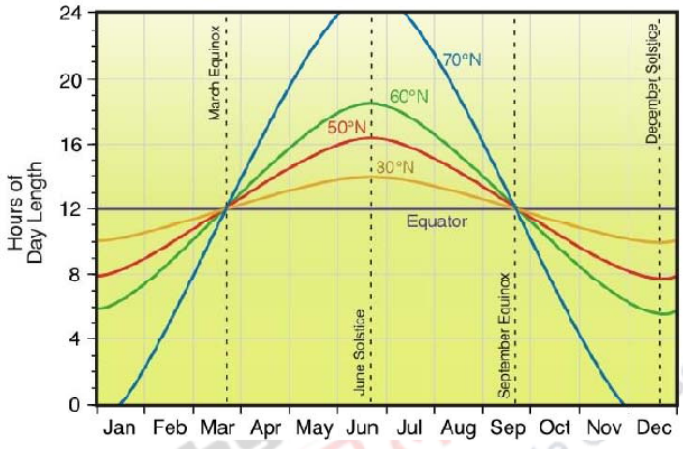
The layers of atmosphere divided based on the composition and temperature. The amount of insolation received by the atmosphere and earth caused by sun positional changes, atmospheric properties and by earth physical factors. In the system of biosphere, there is a equilibrium exists in between the incoming and outgoing energy called energy budget.

DISTRIBUTION OF TEMPERATURE

Global Temperature Distribution

The global temperature distribution is explained in two ways – horizontal and vertical. The temperature on the earth surface and in its atmosphere is not alike, but it varies significantly. The variation is controlled by various factors. Important among them are:

- Latitude
- Altitude
- Length of the day
- Continentality (maritime influence)
- Wind and ocean currents
- Aspect: Southern facing slope in the north hemisphere gets direct and almost vertical sun’s rays. In southern hemisphere, northern facing slope gets bright and effective sun’s energy and the temperature is high on the sun facing slopes.
- Topography and vegetation

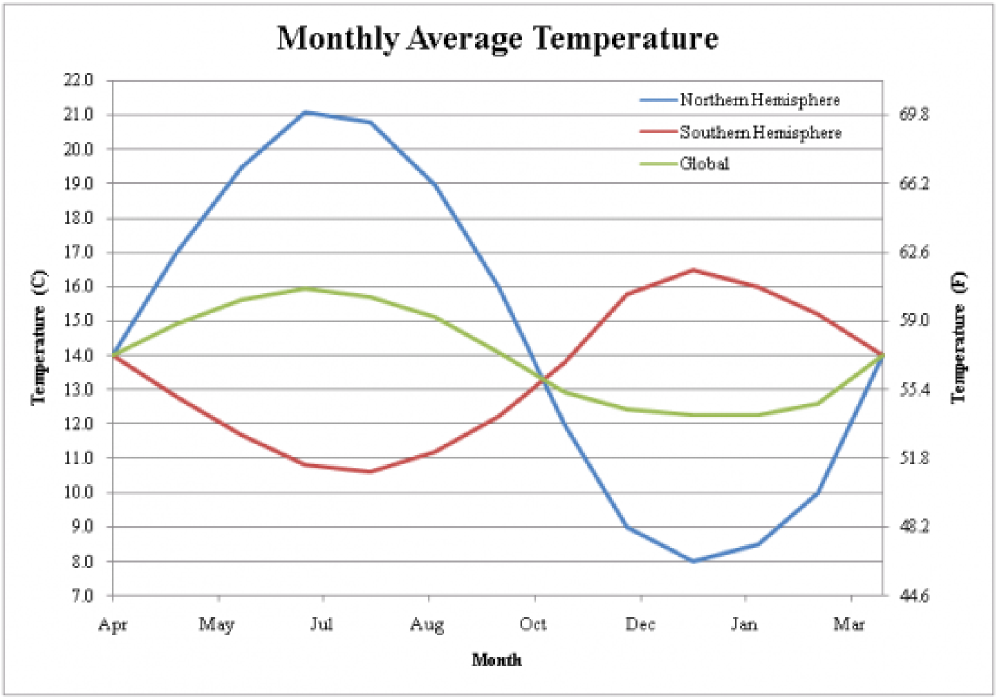


Horizontal Temperature Distribution

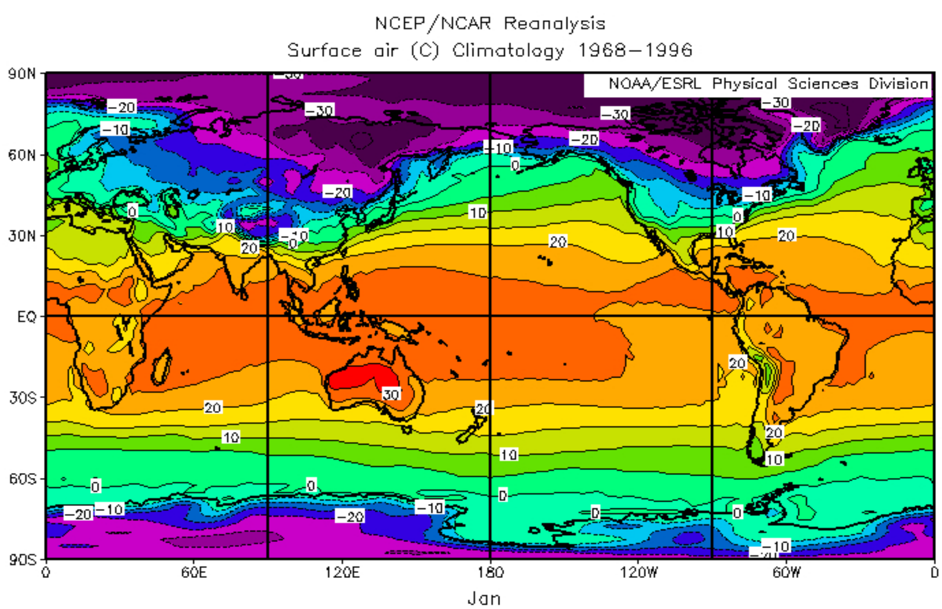
In general, equatorial region is hot and its temperature is high throughout the year. Generally, from equator to polewards, temperature keeps on declining. The lowest temperature is at and near the pole. Sun is almost vertical in the tropical zone, the annual average temperature varies between 22^0C to 26^0C. The 22^0C is at Tropic of Capricorn, laying in the southern hemisphere. Along Tropics of Cancer, the annual average temperature is 24^0C.

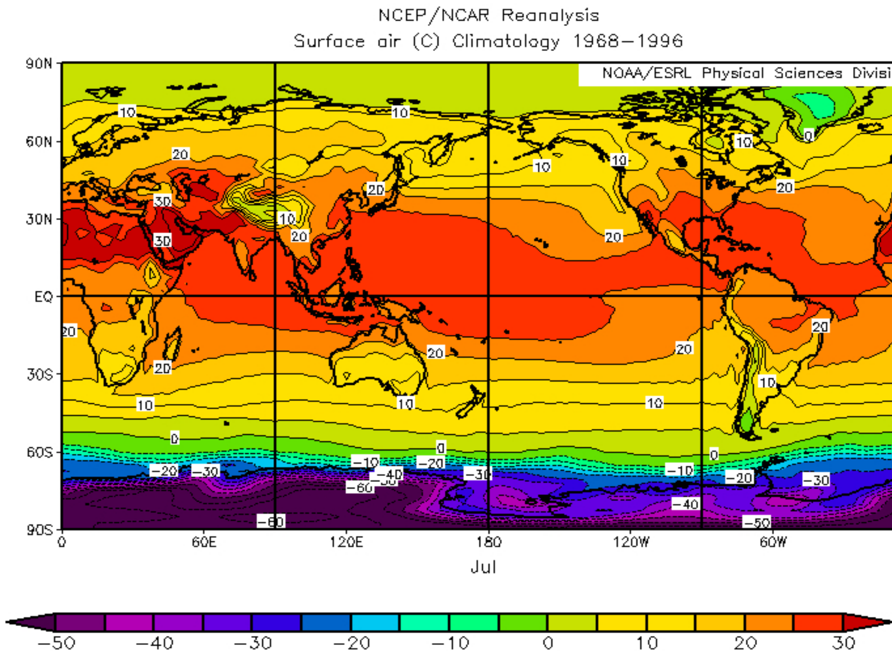
The reason behind the difference is that, southern hemisphere has more water bodies while northern hemisphere has relatively more continental areas.Isotherm is an imaginary line joining the places with same temperature are used to represent distribution of temperature

Sun Overhead on the Tropic of Cancer (July): The sun is overhead at the Tropic of Cancer by the end of third week of June (June 21^{st}) at 23.5^0N. Entire northern hemisphere witnesses bright sun, greater insolation leading to high temperature throughout. During northern hemisphere summer days, the isotherms turns towards northward over land as it is hotter than water. The condition is reversed on the oceans as the water bodies are not that hot as the land is. Isotherms are widely spaced over northern hemisphere, where as it is narrow spaced over southern hemisphere due to low temperature.



Sun Overhead on the Tropic of Capricorn (January): The sun is overhead at the Tropic of Capricorn by the end of third week of December (December 21st)at 23.50S. Entire southern hemisphere witnesses bright sun, greater insolation leading to high temperature throughout. There is no wide and large landmass in southern hemisphere as compared to the northern. The effects of ocean can be seen very clearly. Relatively, the temperature is recorded less.





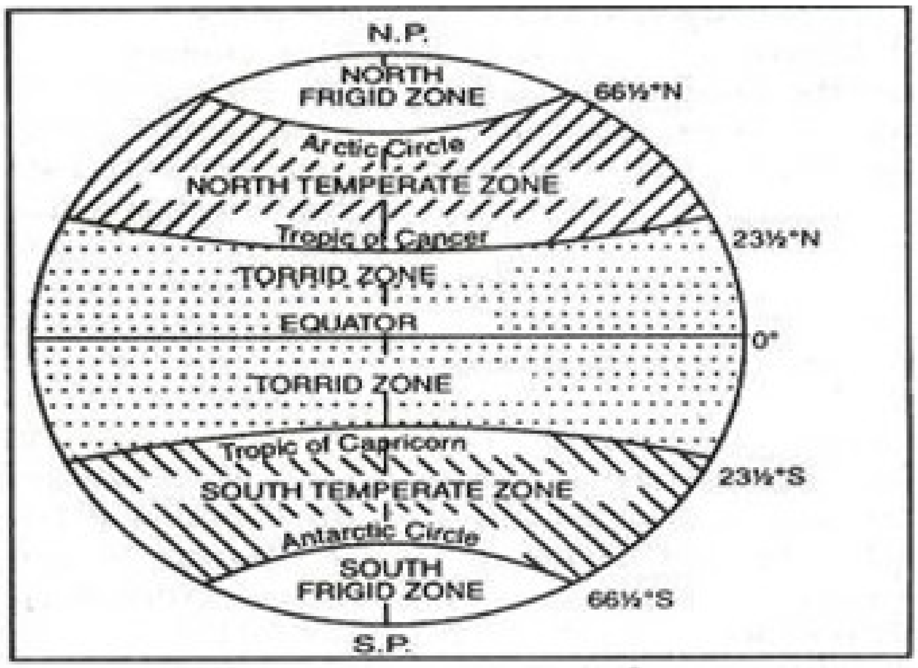
THERMAL ZONES OF THE EARTH

On the basis of the horizontal distribution of temperature earth is divided into the following heat zones,

- Torrid zone: It extends on both side of the equator and is bounded by the Tropic of Cancer and Capricorn. That is between 23 degrees half minute North and 23 degree half minute South latitudes.

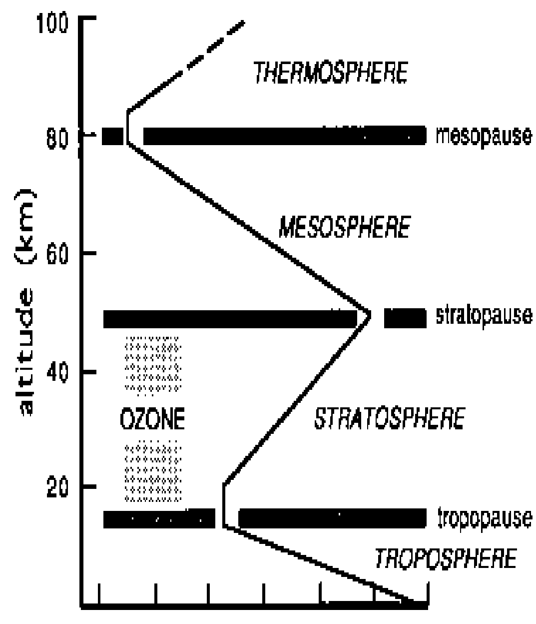
- Temperate zone: It extends in one each of the two hemispheres. They lie between the Tropic of Cancer and Arctic Circle in the northern and between Tropic of Capricorn and Arctic Circle in the southern hemisphere. That is between 23 degrees half minute North to 66 degrees half minute North and 23 degrees half minute South and 66 degrees half minute South latitudes.

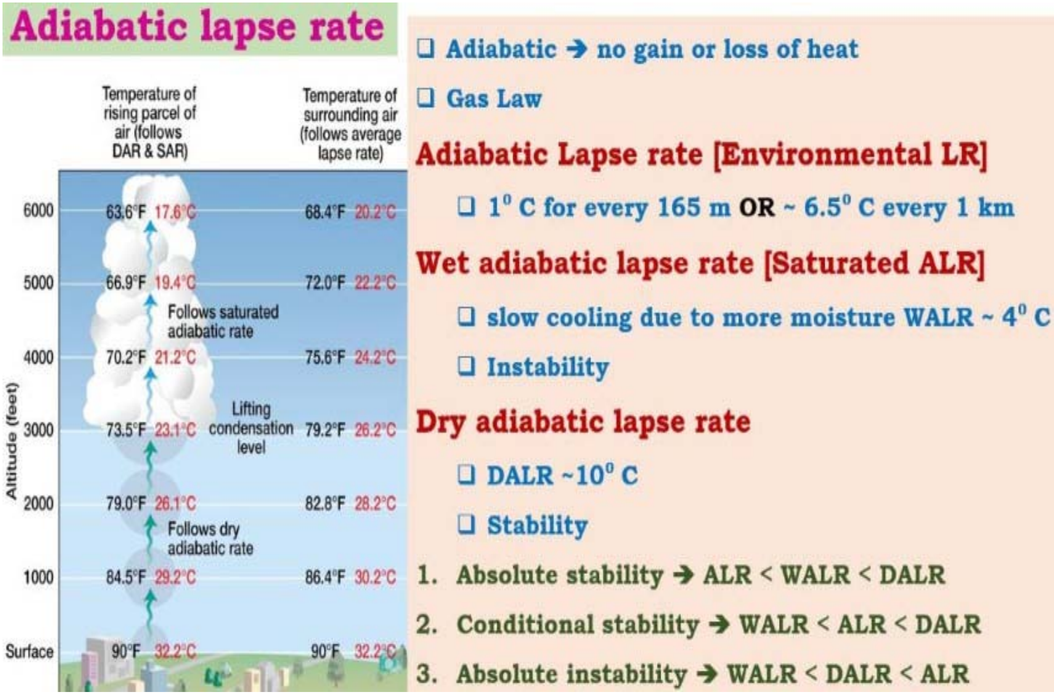
- Frigid zone: It extends in two hemispheres. The fried zone in Northern hemisphere lies between Arctic Circle and the North Pole and in the southern hemisphere between Antarctic circle and South pole.



Vertical Distribution Of Temperature

In general, temperature declines upward from surface of the earth in troposphere till its upper limit – tropopause. This decreasing temperature is termed as lapse rate. Generally, it is called normal lapse rate in which air keeps on laying at its place and someone or thermometer moves upward. In this way temperature is measured. This drop is 6.5^0C / km of ascent. It is also termed as vertical temperature gradient. The normal lapse rate is not always the same but it differs depending upon height, season, latitude or other numerous local factors.

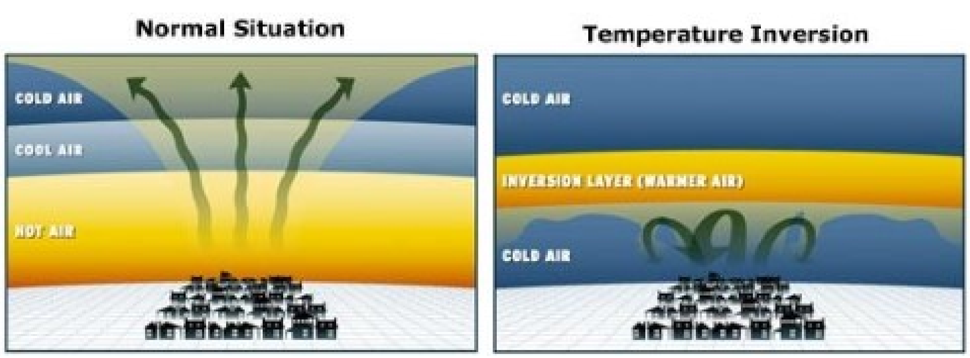


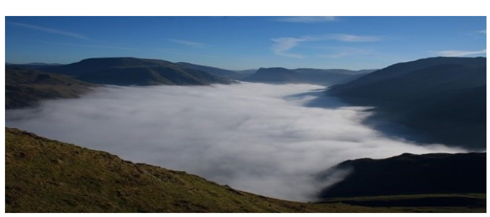


Types of Temperature Inversion

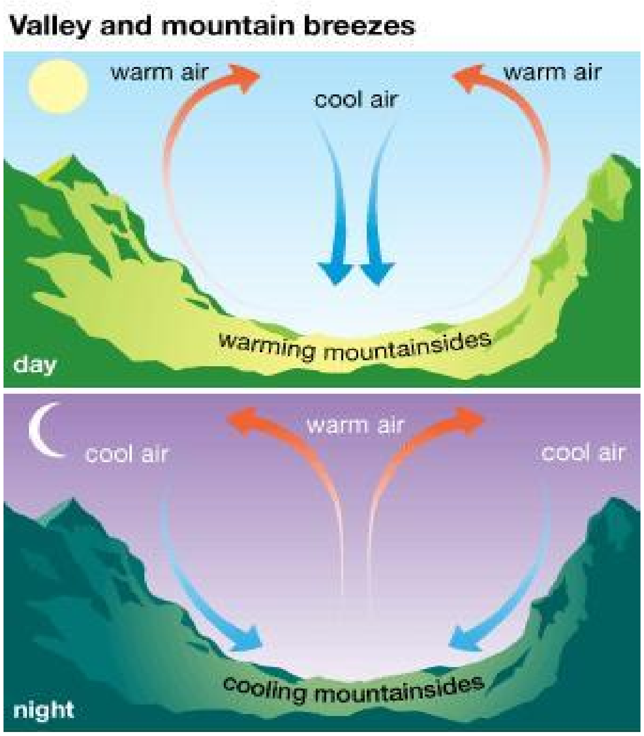
Primarily, there are several types of inversion of temperature. Important among them are:

1. **Ground inversion:** Ground inversion occurs when the surface is cooled rapidly by earth radiation under clear sky. In this way, temperature above the ground is still warmer than air near the ground. When temperature near surface reaches to dew level, the possibility of fog formation increases. Ground inversion is very common in the higher latitude areas or during winter in the plain



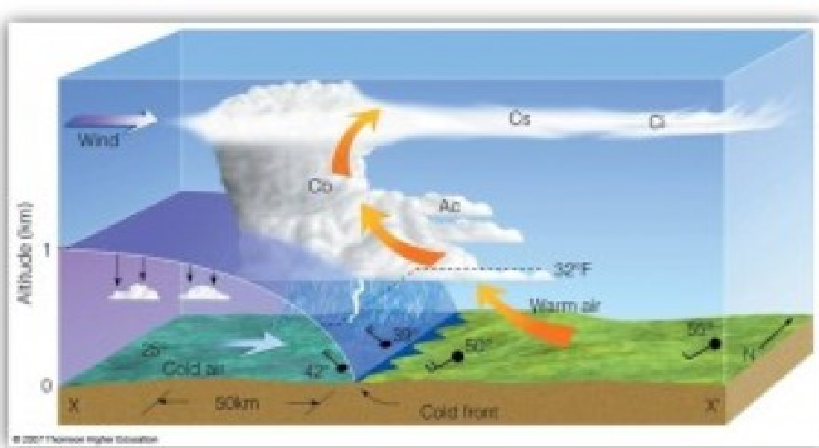


2. **Valley inversion:** Valley inversion takes place on the rolling topography, particularly in hilly areas. In such situation, mountain slope becomes cool in the night and the air with its contact gets cooler. Cool air creeps downward along the slope and occupies the valley. The warm air of the valley is pushed up and thus the inversion of temperature is evident.



Source: Encyclopedia Britannica

3. **Frontal inversion:** This type of inversion of temperature takes place under the frontal formation of two different air masses. When cold and heavier air mass undercuts warm sector occupied by warm air mass, the warm air is lifted up. The ground is occupied with cold air, and thus, inversion is observed



PRINCIPLES OFCLIMATOLOGY

UNIT II

Atmospheric Pressure: Pressure belts of the World - General circulation of wind: Planetary winds, Monsoon, Local winds - Jet Streams.

PREPARED BY

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PRINCIPLES OF CLIMATOLOGY

UNIT-II

ATMOSPHERIC PRESSURE

Atmospheric pressure is defined as the total weight of a mass of column of air above per unit area at sea level. The atmospheric pressure is maximum at sea level. At sea level, the column of mercury will rise (on average) to a height of 29.92 inches or 760 millimeters or 1013.2 millibars. This is the standard air pressure at sea level.

Measuring Atmospheric Pressure

Any instrument that measures air pressure is called a ***Barometer***. In a mercurial barometer (Fortin's barometer), a column of mercury in a glass tube rises or falls as the weight of the atmosphere changes. Altimeter, Aneroid Barometer is also used for the measurement of pressure. Scientists often use the kilopascal (kPa) as their preferred unit for measuring pressure.

1 kilopascal is equal to 10 millibars.

Another unit of force sometimes used by scientists to measure atmospheric pressure is the **newton**.

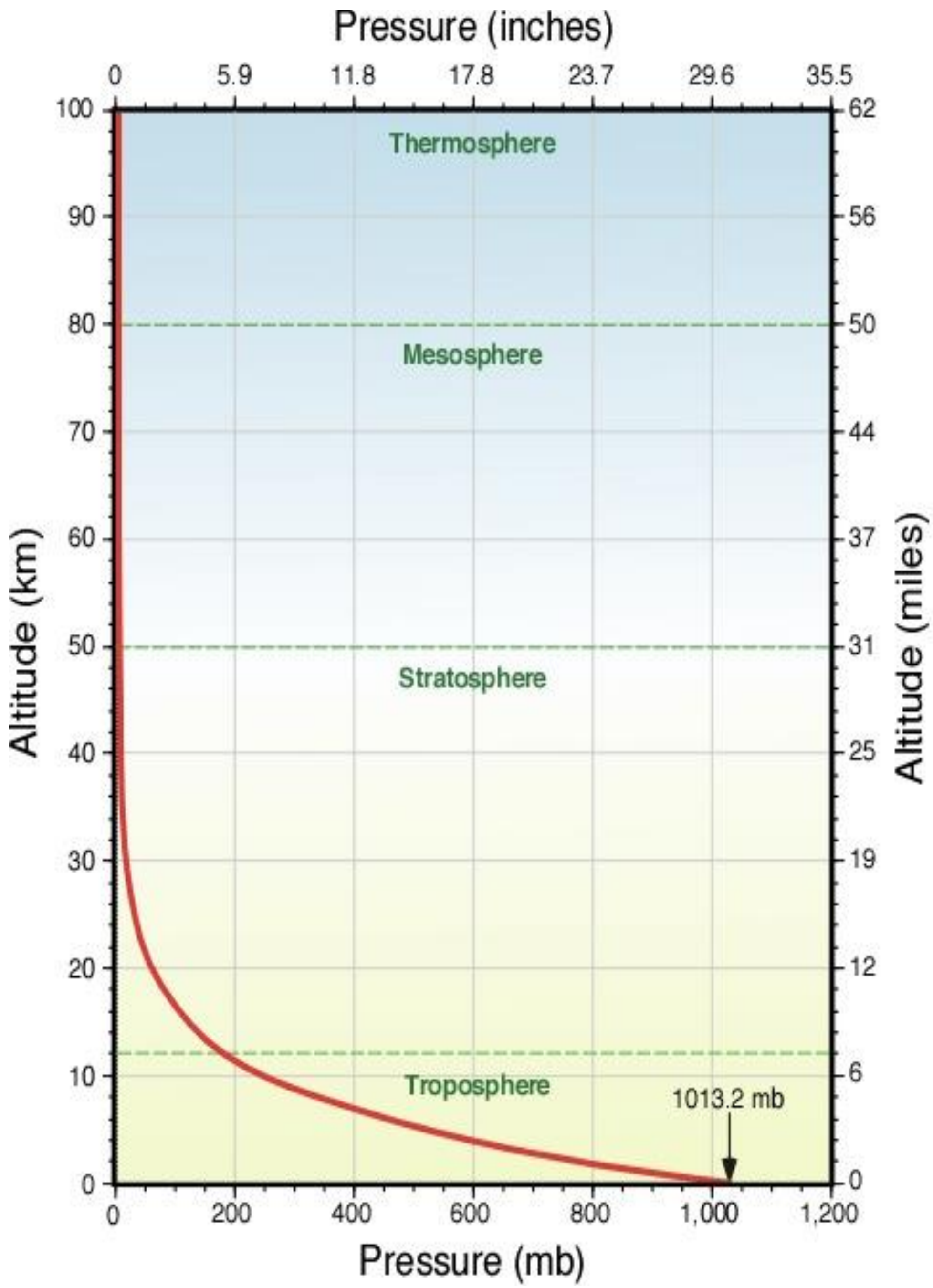
One millibar equals 100 newtons per square meter (N/m^2).

Pressure on Earth varies with the altitude of the surface; so air pressure on mountains is usually lower than air pressure at sea level. As elevation increases, there is less overlying atmospheric mass, so that atmospheric pressure decreases with increasing elevation. Pressure decreases with increasing altitudes at a rate of 0.1 inch or 3.4 mb per 600 feet.

Air pressure varies seasonally, diurnally and spatially. There is an inverse relationship between temperature and pressure. When the temperature of a place increases, the atmospheric pressure decreases.

> **"*When the mercury of thermometer rises, mercury of barometer falls*"**.

As the gravity of the Earth pulls the molecules and gases towards the ground, the lowest layer of the air becomes densest. This dense layer of air exerts the greatest pressure. Air inside the human body exerts equal amount of outward pressure which balances the inward atmospheric pressure; so we do not feel the enormous weight of air pressure.



Change in average atmospheric pressure with altitude.

The following factors affect the atmospheric pressure distribution.

1. Temperature:

- As the temperature increases, air expands (its density decreases) which results in low pressure.
- On the other hand air shrinks due to low temperature (its density increases) which creates high pressure.

- Equatorial regions have low pressure because of high temperatures.
- On the other hand Polar Regions have high pressure due to low temperature.

2. Height from Sea Level:

- Air pressure is created due to weight of air; therefore sea level has highest air pressure.

- As we move upward from sea level, air pressure decreases because the upper air is light and its density is low.

- Air pressure is reduced to half at the height of 5 Kms from seal level and at the height of 11 kms it is reduced to one fourth.

- It is because of low pressure in mountainous regions that breathing gets hard.

3. Moisture in Air (Humidity):

- Conversion of water from liquid state to gaseous state because of evaporation is known as atmospheric humidity.

- Water vapors are light in weight therefore they rise up and pressure of humid air decreases as compared to dry air.

- Amount of water vapors changes with time and place and because of this the pressure of air also varies.

4. Gravitation of the Earth:

- Atmospheric pressure is directly proportional to the force of gravity.
- The air near the ground is pulled by the gravity and compressed by the air higher in the sky.
- This causes the air near the ground to be denser.

5. Rotation of Earth:

- Rotation of Earth produces centrifugal force which has more effect in Equatorial region while lesser effect on Polar Regions.

- Centrifugal force pushes things away from its core.

- Same is the effect on air pressure which results into lesser pressure in Equatorial regions as compared to that in Polar Regions.

The rate of change of pressure per unit horizontal distance is called ***'Pressure Gradient'***

PRESSURE BELTS OF THE WORLD

Distribution of Air Pressure

As air is present all around the Earth, it may be distributed in two ways namely- horizontally and vertically.

1. Horizontal Distribution:

Air pressure of a particular place changes with day and night, with summer and winter but average air pressure conditions remain same. On maps these variations are shown with help of isobars.

Generally air pressure is divided into two types:

a. High pressure.

b. Low pressure.

Pressure Belts of the World

On the basis of combined effect of various factors affecting the air pressure on different latitudes, **seven air pressure belts** are found on the Earth. There are high and low alternate pressure in Northern and Southern hemisphere and one common equatorial pressure.

1. *Equatorial low pressure belt:*

- **I**t is located on either side of the geographical equator.
- Extending between 5°N latitude of Equator to 5°S latitude is known as Equatorial low pressure belt.
- This is ***'thermal in origin'***.

- It is the zone of convergence of North-east and South-east Trade Winds.

- This belt is called ***'Doldrums'*** because of the frequent calm conditions. It is a continuous belt of windless weather or belts of calm.

- It is otherwise termed Inter Tropical Convergence Zone (ITCZ).

- Ships travelling in these latitudes get stuck on windless waters.

Following are the reasons which are responsible for its origin:

(i) Rays of sun fall vertically in this region whole the year long and because of this temperature is high which creates low pressure (Ht=Lp) resulting in little or no surface wind.

(ii) Owing to high temperature, evaporation process is also very fast while large number of water vapors' decreases the weight and density of air resulting in reduction of air pressure.

(iii) Rotation of Earth has its maximum effect on Equator and so is effect of centrifugal force which results into reduction in air pressure.

2. **Subtropical High Pressure Belts:**

- At about 25° to 35° N & S latitudes, high pressure regions are found in both hemispheres.

- This zone has subsidence of air from higher altitudes.

- The belt is dynamic in origin.
- Descending of winds causes high pressure over the surface due to their contraction of their volume.
- So this belt is characterized by anti-cyclonic conditions, resulting in atmospheric stability and aridity resulting in hot deserts of the world in western margins of continents.
- The zone of high pressure is called ***'Horse Latitudes'*** because of the prevalence of frequent calms. Sailors unable to travel in these latitudes by ships would throw the horses they were transporting overboard to make the ships lighter. So the phrase 'horse latitudes' was born.
- This zone of high pressure is not a continuous belt but broken into a number of high pressure cells.

3. **Sub-Polar Low Pressure Belts:**

   - Between the latitudes of 60°and 65°in both the hemispheres low pressure regions are found.
   - This zone is more developed and regular in the Southern Hemisphere because of the dominance of water.
   - It is broken in the Northern Hemisphere. But there are well developed belts over the oceans in the Northern Hemisphere .e.g.- near Aleutian Islands in the Pacific Ocean and between Greenland and Iceland in the Atlantic Ocean.
   - It is dynamic in origin.

4. Polar High Pressure Belts:

- At poles (North & South Poles) high pressure regions are formed because of very low temperature (below freezing point).
- Both the factors thermal and dynamic operate at the poles.
- High pressure prevails throughout the year.

Shifting of Pressure Belts:

It is important to mention that these belts are not stable. There are diurnal, seasonal and annual changes. They shift according to the position of overhead sun e.g. in Northern Hemisphere, pressure belts shifted to North in summer and shifted to south in winter.

Diurnal change of thermal condition alters the pressure condition and so the wind shifts its direction regionally. Sea breezes and land breezes are the examples of local shifting of pressure.

The pressure belts occupy their normal position at the time of Vernal Equinox (21 March) and Autumnal Equinox (23 September) when the sun is vertical at the equator.

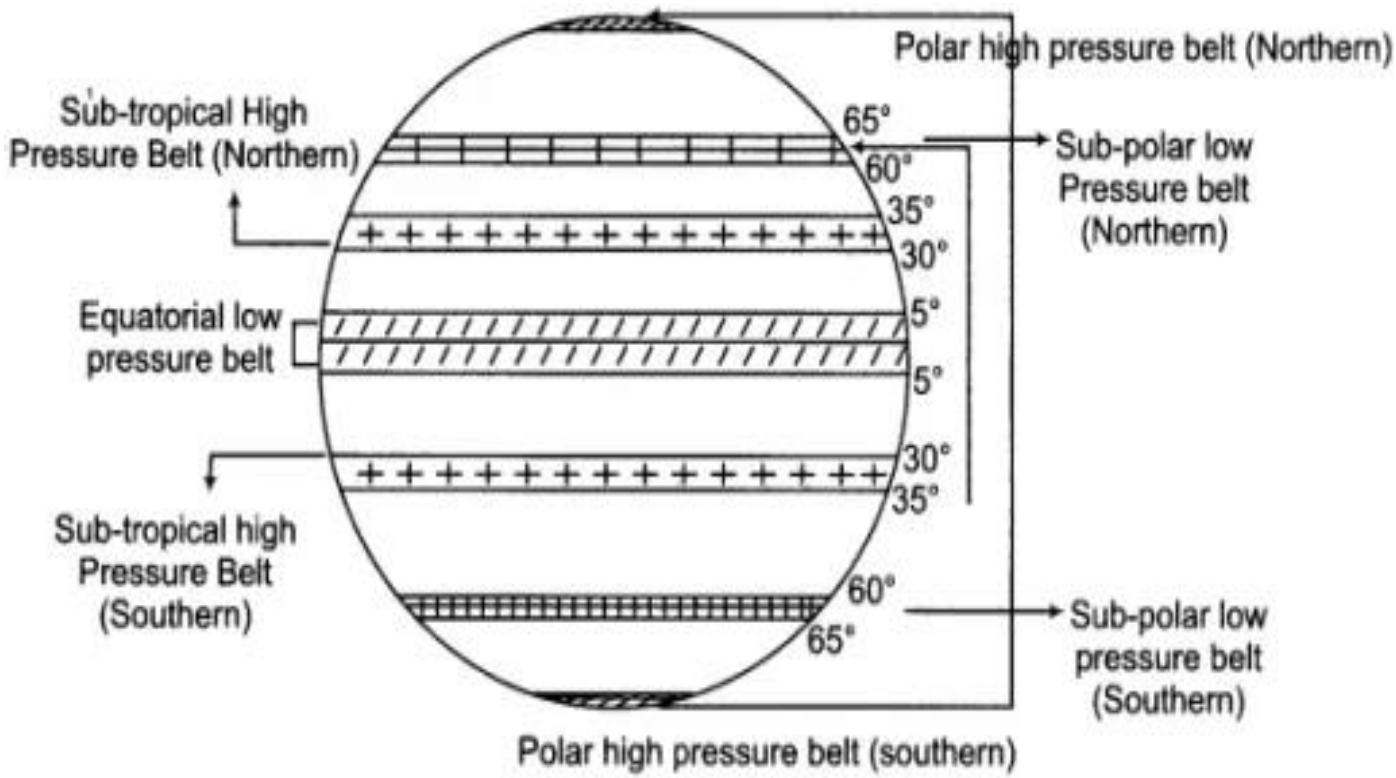


Fig. Distribution of Air Pressure belts on Globe

2. Vertical Distribution of Pressure:

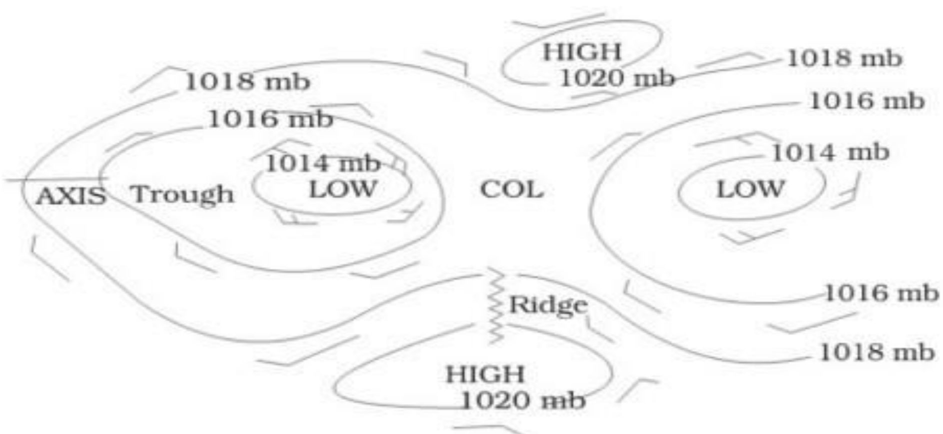
Air pressure on Earth exists due to pressure of upper layers. Atmosphere extends up to the height of hundred kilometers from the Earth surface. Air pressure is highest at sea level because the density of gases is highest in lower layers. At the height of Mt. Everest, the air pressure is about two-thirds less than what it is at the sea level.

Air pressure and height are reversely proportional to each other, which mean air pressure decreases due to increase in height. But the rate of fall in air pressure decreases with increase in height. In general, the atmospheric pressure decreases on an average at the rate of about 34 millibars every 300 metres of height

ISOBARS

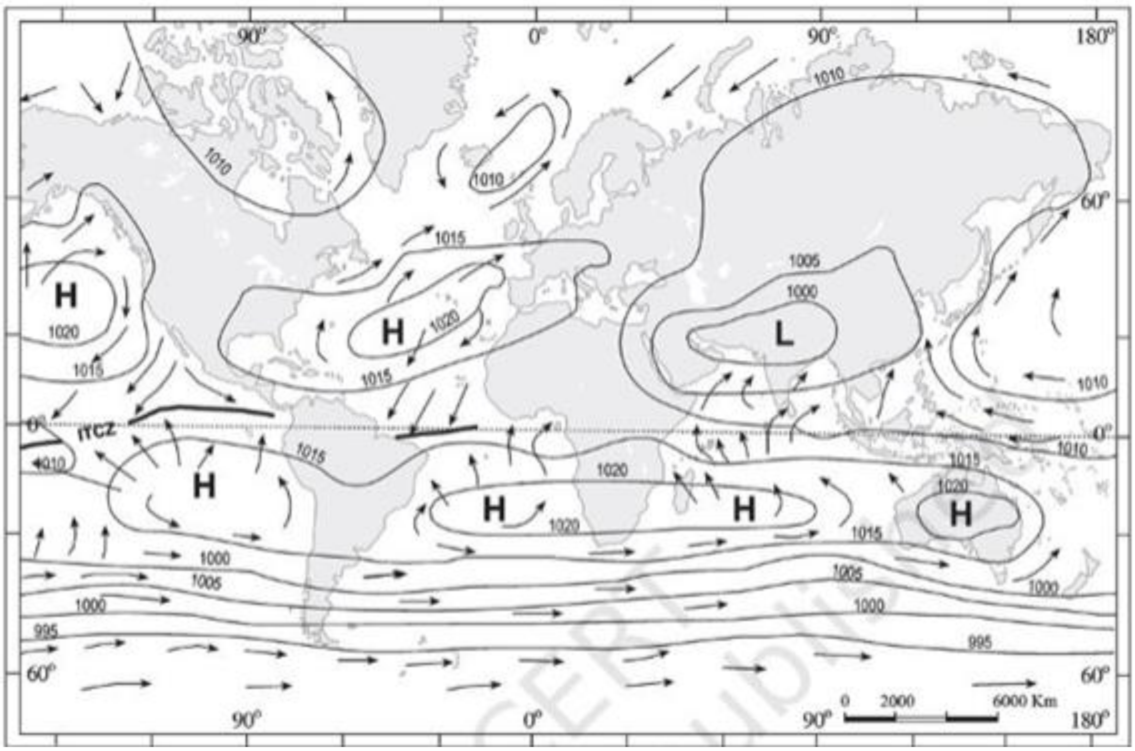
Isobars : Isobars are those lines drawn on a map which enjoins places with same air pressure. This air pressure is measured, taking average air pressure at sea level as base so that difference created by increase in height may vanish. For this purpose air pressure for isobars is deducted 34 milbars for each 300 meters height.

- When Isobars are above normal value, they form clustering around in a circular manner and are known as **'high pressure region'**.
- When there is clustering of Isobars belonging to less than normal value, they are known as **'low pressure region'**
- An outward extension of high pressure into a region of low pressure is known as a **'ridge'.**
- An extension of low pressure into a region of high pressure is known as '**Trough'**.
- An area of almost uniform pressure between two highs and two lows is known as **'Col'**.

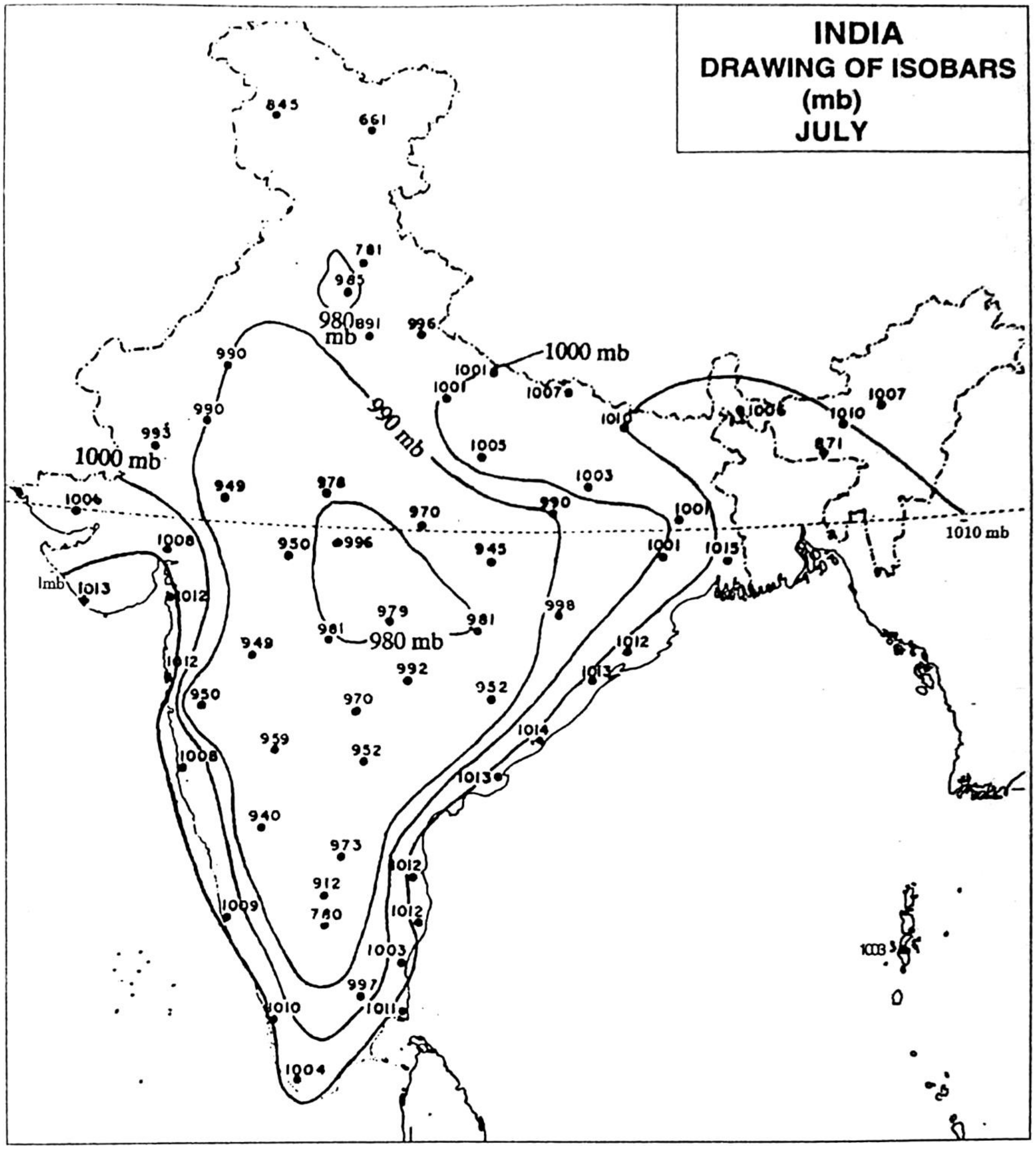


DISTRIBUTION OF PRESSURE

ISOBARS (JULY)



Source: https://www.pmfias.com



Source: https://www.zigya.com

GENERAL CIRCULATION OF WINDS

Atmospheric circulation is the large-scale movement of air and together with ocean circulation is the means by which thermal energy is redistributed on the surface of the Earth. The circulation of wind in the atmosphere is driven by the rotation of the earth and the incoming energy from the sun. Also, there is close relationship between pressure gradient and circulation of air. So, the air moves from high pressure to low pressure. Pressure gradient, rotation of the earth, and coriolis force, frictional force, centrifugal action of wind etc. affect and control air motion.

Wind circulates in each hemisphere in three distinct cells which help transport energy and heat from the equator to the poles.

1. Hadley cell

- ❖ The circulation cell closest to the equator is called the *Hadley cell*.

- ❖ The atmospheric circulation pattern that George Hadley described was an attempt to explain the trade winds.

- ❖ Hadley cells exist on either side of the equator.

- ❖ The Hadley Cell involves air rising near the equator, flowing toward the North and South Poles, returning to the surface of the Earth in the subtropics, and flowing back toward the equator at the surface of the Earth.

- This flow of air occurs because the Sun heats air at the Earth's surface near the equator.

- Hadley Cells are the low-latitude overturning circulations that have air rising at the equator and air sinking at roughly 30° latitude.

2. Ferrel Cell

- From 30° latitude to 60° latitude, a new cell takes over known as the Ferrel Cell.

- With the converging air masses at the surface, the low surface pressure at 60° latitude causes air to rise and form clouds.

- Some of the rising warm air returns to 30° latitude to complete the Ferrel Cell.

- This movement is the reverse of the airflow in the Hadley Cell.

3. Polar cell

- The smallest and weakest cells are the Polar cells, which extend from between 60 and 70 degrees north and south, to the poles.

- Near the ground level, air currents flow from the poles toward the equator.

- These are called polar easterlies, because they are distracted from eastside by the rotation of the earth.

- Near the 60^{th} latitude, the winds are heated and rise up on the way to the South. This second circulation is called Polar cell.

WIND DIRECTION AND RELATED LAWS

The direction of surface winds is usually controlled by the pressure gradient, rotation of the earth and friction of the earth. Because of the rotation of the earth along its axis, the winds are deflected and do not blow in a straight direction. The force which deflects the direction of winds is called 'Coriolis Force'. This force is also called deflection force. Because of Coriolis force, all winds are deflected to the right in the northern hemisphere and left in the southern hemisphere (Ferrel's Law).

Frictional force not only reduces the speed of the wind but also deflects wind. Frictional forces are effective only up to an elevation of 1-3 km and over the ocean surface, frictional force is minimal.

The earth rotates from west to east. The whole earth completes one rotation in 24 hours. The rotational speed of the earth is highest at the equator and decreases pole ward. When the wind moves either northward or southward in straight path in equatorial region, it does not move to its destination, because the wind lags behind due to high rotational speed of the earth.

PLANETARY WINDS

CLASSIFICATION OF WINDS

The wind is caused by differences in atmospheric pressure**.** Atmospheric motion or wind movement is divided into three categories.

1. **Primary circulation** including planetary wind systems which are related to pressure belts (e.g. trade winds, westerlies and polar easterlies)
2. **Secondary circulation** consisting of cyclones, anticyclones, monsoons and air masses and
3. **Tertiary circulation** includes local winds.

The winds blowing in the same direction throughout the year are called prevailing winds. They are invariable or planetary winds because they involve larger areas of the globe.

Winds with seasonal changes in their directions are called seasonal winds (e.g. monsoon winds).

Winds blowing in a particular locality are called local winds (e.g. Chinook, sirocco, harmattan, mistral, bora, blizzards, loo etc.).

Winds blowing from hill tops to the valleys and from valley floor to the hill tops are called mountain and valley breezes.

Winds blowing from land to sea and from sea to land are called land and sea breezes.

So, winds can be broadly be grouped into two categories:

1. Prevailing or permanent or invariable winds –Trade winds, Westerlies and Polar Easterlies.

2. Variable winds are grouped into seasonal winds, local winds, mountain and valley breezes and land and sea breezes.

PLANETARY WINDS AND ITS TYPES

Any wind system of the earth's atmosphere which owes its existence and direction to solar radiation and to the rotation of the earth are called ***Planetary Wind***. Planetary winds effect climate because they cause the land to cool down. They also cause the moisture in the air to condense and from clouds, thus precipitation.

The characteristics of planetary winds are as follows:

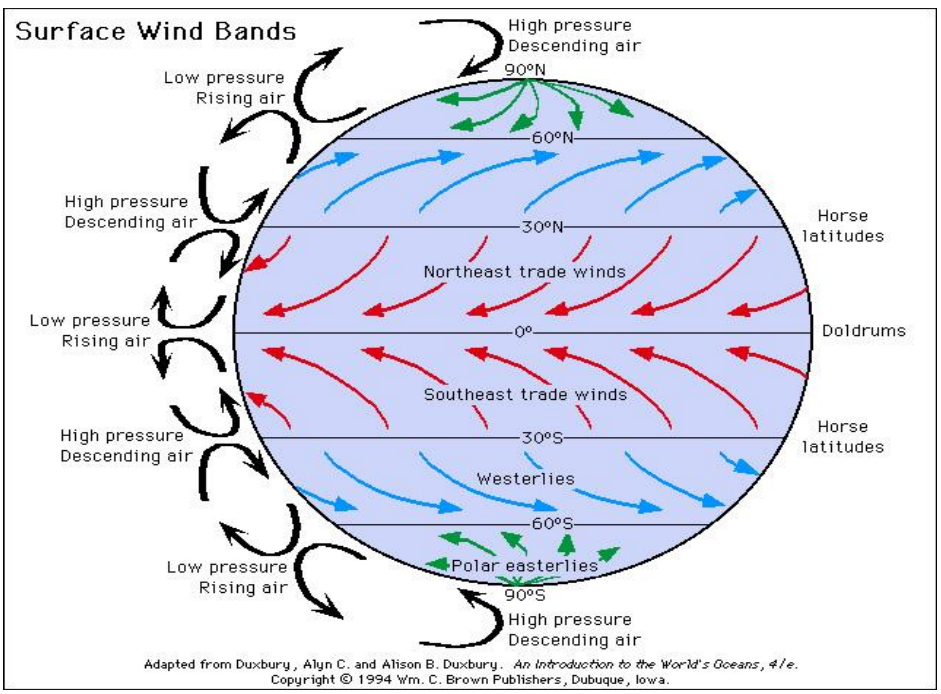
- These winds being controlled by the pressure belts to blow towards the same direction throughout the whole year.
- Blow from high to low pressure, over the earth surface and oceans throughout the year and in a particular direction.
- These winds are named according to the direction from which they blow.
- These winds are divided into 3 categories viz.
    1. Trade Winds (Tropical Easterlies)
    2. Westerlies
    3. Polar winds (Polar Easterlies)

1. Trade Winds (Tropical Easterlies)

- The sun's rays fall vertically over the equatorial region, so the air becomes hot and goes upwards.
- As a result, the air moves towards north and south directions through the upper atmosphere.
- Moving up to 30° latitudes some part of this air finds its way to come downward and blows towards the equatorial low pressure belt. This part of the air is known as the Trade Wind.
- According to Ferrel's Law, the trade wind blows from north-east in the northern hemisphere and south-east in the southern hemisphere. The trade wind of northern hemisphere is known as North-East Trade Wind and that of southern hemisphere as South-East Trade Wind.
- The sky remains clear and the weather is hot and dry as this trade wind originates in the high pressure zones.
- The big deserts of the world are situated nearer to this area. For example, the Sahara desert, the Lybian desert, the Arabian Desert in the northern hemisphere and the Kalahari Desert in the southern hemisphere can be mentioned.

Winds are blowing from subtropical high pressure area to equatorial low pressure area (Extremely steady winds). So, the main characteristics can be summed up as follows:

- Since they travel from high latitude to low latitude area, they become gradually hot and dry and hence have a great capacity to hold moisture
- These winds cause good rainfall on eastern margins of the continents (onshore winds) as they get moisture after blowing over oceans. They make the western margins of continents as deserts and dry throughout the year because they become moisture less.
- These winds converge near equator and form ITCZ (Inter Tropical Convergence Zone). Here these winds are forced to rise and causes heavy rainfall.
- Very little surface wind exists here.



Source: https://history.aip.org

2. The Westerlies

- This is known as West Wind. In the northern hemisphere, it blows from south-west and in the southern hemisphere from north-west direction.
- As the area of the landmass is greater in the northern hemisphere, some changes occur in the air motion.
- In the southern hemisphere, the maximum area is covered by the water bodies and hence the west wind blow strongly and this air movement is known as ***'Brave West Winds'*** in the southern hemisphere.
- These brave winds are associated with storms and gales.
- Westerlies can be termed as '***Roaring Forties'***, '***Furious Fifties***' and '***Shrieking Sixties*** 'in the latitudes of 40,50 and 60 degrees in southern hemisphere.

Major characteristics of the Westerlies can be summed up as follows:

- Winds blowing from subtropical high pressure belts towards subtropical low pressure belts
- Blow from lower latitudes to higher latitudes
- Cause considerable rainfall particularly on western margins of the continents
- Not all the western coast of the temperate zone (30^0- 60^0) receive Westerlies throughout the year due to shifting of wind belts.

3. Polar winds (Polar Easterlies)

- The polar easterlies are the dry, cold prevailing winds that blow from the high-pressure areas of the polar highs at the north and south poles towards low-pressure areas.
- Cold air subsides at the pole creating the high pressure, forcing a southerly outflow of air towards the equator.
- Since the winds originate in the east, they are then known as easterlies.
- In the middle latitudes, the polar easterlies are often weak and irregular.

So, major characteristics can be pointed out as follows:

- Winds blowing from polar high to sub polar low pressure belt
- They are very cold in nature as originate in polar areas and do not cause much rainfall
- These winds give birth to cyclones when they come in contact with Westerlies.
- Influence the climate wherever they flow.

Measurement of Winds

The instrument widely used for measuring wind direction is called weather cock or wind vane. The speed of the wind is measured by an anemometer and is estimated by Beaufort wind scale, which has measures from 0-12. Zero indicates calm wind when smoke raises vertically, 12 shows the speed of hurricane type devastative cyclonic conditions.

MONSOON WINDS

Seasonal Winds

Seasonal winds are movements of air repetitively and predictably driven by changes in large-scale weather patterns. Seasonal winds occur in many locations throughout the world. Commonly recognized seasonal winds are the monsoon winds. The winds that change their direction with onsets of different seasons are hence called as ***Seasonal Winds***. Example - A ***monsoon*** is a type of seasonal wind in low-latitude climates that seasonally changes direction between winter and summer.

What are Monsoons?

. The word monsoon originates from Arabic ***mauzim,*** meaning season. It was first used to depict the winds in the Arabian Sea, by the Arab navigators but later it was extended for seasonally changing wind systems all over the world. The driving force shaping monsoons is the difference in the heating of land and water surfaces, which results in land-ocean pressure differences.

- Monsoons were traditionally explained as "*land* ***and sea breezes on a large scale".*** Thus, they were considered a ***convectional circulation on a giant scale.***
- The monsoons are characterized by ***seasonal reversal*** of wind direction.
- During summer, the trade winds of southern hemisphere are pulled northwards by an apparent northward movement of the sun and by an intense low pressure core in the north-west of the Indian sub-continent.
- While crossing the equator, these winds get deflected to their right under the effect of Coriolis force.

- These winds now approach the Asian landmass as south-west monsoons. Since they travel a long distance over a vast expanse of water, by the time they reach the south-western coast of India, they are over-saturated with moisture and cause heavy rainfall in India and neighboring countries.
- During winter, these conditions are reversed and a high pressure core is created to the north of the Indian subcontinent. Divergent winds are produced by this anticyclonic movement which travels southwards towards the equator. This movement is enhanced by the apparent southward movement of the sun. These are north-east or winter monsoons which are responsible for some precipitation along the east coast of India.
- The winter monsoon is stronger than the summer monsoon.
- The Asian monsoon is one of the most vigorous climatic phenomena on Earth and also one of the most societally important.
- The monsoon drives vital seasonal rainstorms that water crops and forests as well as damaging typhoons and floods.

Monsoonal Distribution

The most pronounced monsoon system is in eastern and southern Asia. Monsoons can also be observed in West Africa, Australia, or the Pacific Ocean. Even in the southwestern United States, a smaller scale monsoonal circulation system exists (called North American monsoon, Mexican monsoon, or Arizona monsoon.

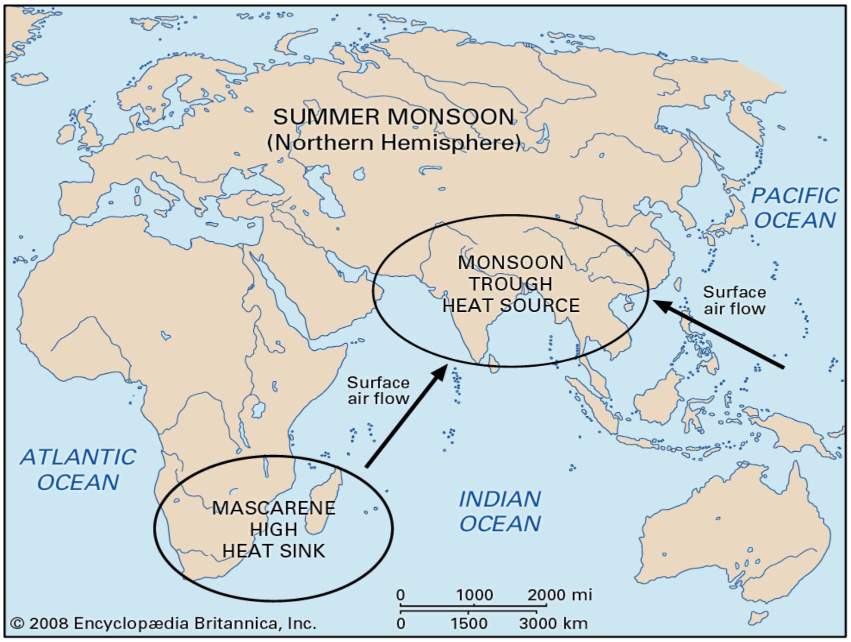
Monsoons are more developed in India, Bangladesh, Sri Lanka and Myanmar which experiences monsoonal climate. The East Asian monsoon affects large parts of Indochina, the Philippines, China, Taiwan, Korea and Japan. It is characterized by a warm, rainy summer monsoon and a cold, dry winter monsoon.

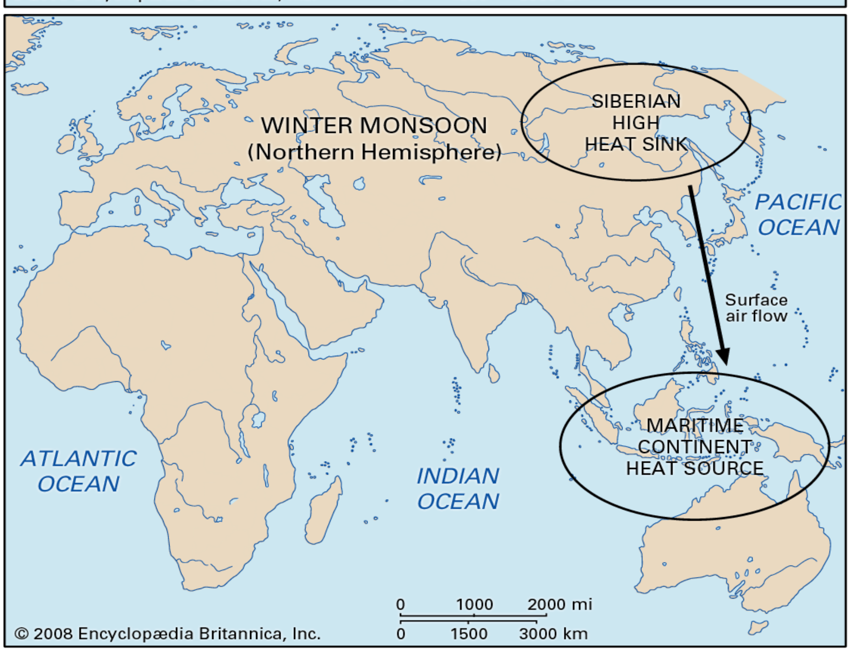
The most prominent monsoons occur in South Asia, Africa, Australia, and the Pacific coast of Central America. With the world's strongest monsoons, this region stretches from the South China Sea into the Indian Ocean and includes Asia and the northern end of Australia. From June until September, summer monsoon rains occur in South Asian countries such as Vietnam, Thailand, Cambodia, Bangladesh, Laos, India, and Pakistan

Impact of monsoons

- The agricultural economies of impacted areas (e.g., Asia or India) frequently depend on the moisture provided by monsoons.
- The variations in the wind and precipitation patterns are so great, that more severe winds and storms can result in flooding that can damage thousands of lives.
- They are not steady winds; vary from year to year.
- They have active and break spells in rainfall distribution.
- They are unreliable in nature.
- The onset on monsoons may be early or delayed.

SUMMER & WINTER MONSOONS





LOCAL WINDS

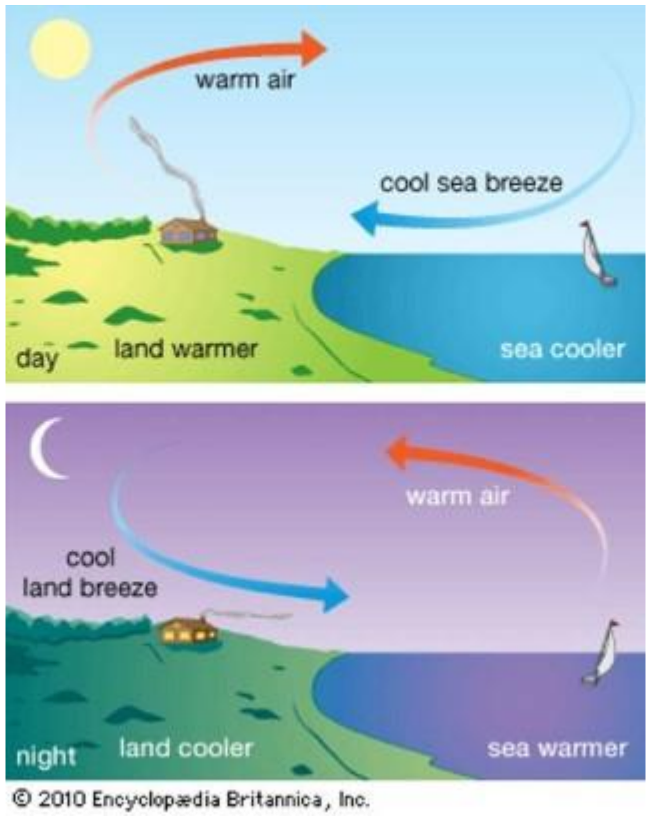
- Local winds are winds that blow over a limited area.
- Local winds blow between small low and high pressure systems.
- They are influenced by local geography.
- Nearness to an ocean, lake, or mountain range can affect local winds.
- Local winds can affect the weather and climate of a region.
- Local winds occur on a small spatial scale, their horizontal dimensions typically several tens to a few hundreds of kilometers.
- They also tend to be short-lived - lasting several hours to a day.
- There are many such winds around the world, some of them cold, some warm, some wet, some dry.
- There are many hazards associated with the winds.

Land and Sea Breezes

Ocean water is slower to warm up and cool down than land. So the sea surface is cooler than the land in the daytime. It is also cooler than the land in the summer. The opposite is also true. The water stays warmer than the land during the night and the winter. This difference in heating cause local winds known as land and sea breezes.

- A **sea breeze** blows from sea to land during the day or in summer. That's when air over the land is warmer than air over the water. The warm air rises. Cool air from over the water flows in to take its place.
- A **land breeze** blows from land to sea during the night or in winter. That's when air over the water is warmer than air over the land. The warm air rises. Cool air from the land flows out to take its place.

LAND & SEA BREEZES



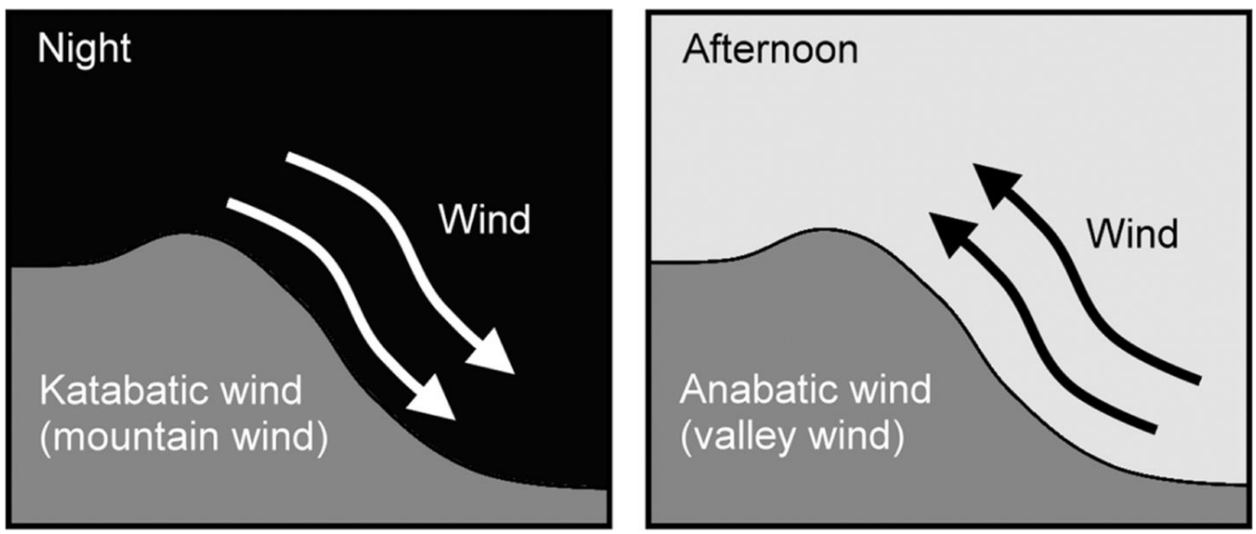
Mountain and Valley Breezes

The air on a mountain slope warms more than the air over the nearby valley. The warm air rises and brings cool air up from below. This is a valley breeze. At night the mountain slope cools more than the air over the valley. The air flows downhill creating a mountain breeze.

Katabatic and Anabatic Winds

Katabatic wind, also called down slope wind, or gravity wind, wind that blows down a slope because of gravity. It occurs at night, when the highlands radiate heat and are cooled. The air in contact with these highlands is thus also cooled, and it becomes denser than the air at the same elevation but away from the slope; it therefore begins to flow downhill.

Anabatic wind, also called upslope wind, local air current that blows up a hill or mountain slope facing the Sun. During the day, the Sun heats such a slope (and the air over it) faster than it does the adjacent atmosphere over a valley or a plain at the same altitude. This warming decreases the density of the air, causing it to rise. More air rises from below to replace it, producing a wind.



The mountain cools down, the air becomes heavier so it descends

The sun warms the mountain, the air is lighter and ascends

Chinook

Chinook winds occur when air is forced over a mountain range. It is a warm, westerly wind found in western North America – Canada and the USA, when air from the Pacific blows over the Rocky Mountains and other upland areas. This is a hot and dry wind blowing along the eastern slope of the Rockies and covers an area from the Southern part of Colorado in the south to British Columbia in the north. Due to its effect, the snow melts and green grass sprouts even in the winter. The word Chinook means ***'snow eater'***.

Föhn

This is a warm, dry, gusty wind which occurs over the lower slopes on the lee side (the side which is not directly exposed to wind and weather) of a mountain barrier. It is a result of forcing stable air over a mountain barrier. The onset of a Föhn is generally sudden. Föhn winds occur quite often in the Alps (where the name föhn originated) and in the Rockies (where the name chinook is used).It makes the snow to melt and makes the weather pleasant. It helps in early ripening of grapes.

Harmattan

These dry, dusty trade wind blows off the Sahara Desert across the Gulf of Guinea and the Cape Verde Islands. Dust and sand are carried many hundreds of kilometers out to sea. Sometimes called as ***'DOCTOR***, because of its supposed healthful properties.

Scirocco/ Sirocco

This is a hot, dry southerly wind which blows from the Sahara in northern Africa into the southern Mediterranean. It picks up moisture as it crosses the Mediterranean and can reach Spain, France, Italy and Greece bringing Saharan dust and hot, windy, damp weather, often with fog or low stratus cloud. In spring, the Sirocco can bring gale force winds. There are many local names for the Sirocco, including **-** ***chom, arifi, Simoom, Ghibli, Chili, Khamsin, Solano, Leveche, Marin and Jugo.***

Mistral

The mistral is also a strong and often violent wind. It blows from the north or north-west down the Rhône Valley of southern France and across the Rhône Delta. It may blow continuously for a day or two. It attains speeds of 100km/h, causing considerable damage to crops.

Bora

Bora is a strong, cold and gusty north-easterly wind which descends to the Adriatic Sea from the Dinaric Alps, the mountains behind the Dalmatian coast (the coast of Croatia).

Blizzard

These winds affect Polar Regions of Canada and USA. On the arrival, the temperature falls below freezing point. In the Tundra and Siberian regions of Russia, it is known as Purga and Buren.

Santa Ana winds

They are responsible for many large fires in Southern California The Santa Ana winds arrive at the end of California's long summer drought season.

Bise

This is a cold dry wind which blows from the north-east, north or north-west in the mountainous regions of southeastern France and western Switzerland in winter months. The Bise is accompanied by heavy cloud.

Khamsin

They are hot, dry, dust-laden, southerly wind over Egypt, the Red Sea and eastern parts of the Mediterranean Sea ahead of eastward-moving depressions.

Pampero

The name is given to severe line squalls in Argentina and Uruguay and is usually accompanied by rain, thunder and lightning, a sharp drop in temperature and a sudden change of wind direction.

Loo

A Harmful Wind that blows in the plains of northern India and Pakistan. It is a very hot and dry wind blows from the west in the months of May and June, usually in the afternoons. Its temperature invariably ranges between 45°C and 50°C. It may cause sunstroke to people.

Thus, local winds blow due to local variation in the temperature and pressure. They blow in the lower layers of the Troposphere.

$$$$$$$$$

JET STREAMS

Jet streams are fast flowing, narrow, meandering air currents in the atmospheres of some planets, including Earth. They form where large temperature differences exist in the atmosphere. A number of separate jet streams have been identified. Jet streams are narrow bands of strong wind that generally blow from west to east all across the globe.

- **Jet Streams** are a narrow belt of high altitude (above 12,000 m) westerly winds in the troposphere.
- Their speeds usually range from 129 to 225 kilometers per hour (80 to 140 miles per hour), but they can reach more than 443 kilometers per hour (275 miles per hour).
- They are faster in winter when the temperature differences between tropical, temperate, and polar air currents are greater.
- They move eastward at altitudes of about 8 to 15 kilometers (5 to 9 miles).

Types of Jet Streams

Earth has four primary jet streams:

- Two polar jet streams, near the north and south poles
- Two subtropical jet streams closer to the equator.

The polar-front jet stream forms at about 60 degrees latitude in both hemispheres, while the subtropical jet stream forms at about 30 degrees.

Impact of Jet Streams

Shifting jet stream patterns can have a big impact on the weather.

- Jet streams are always changing: moving to higher or lower altitudes, breaking up, and shifting in flow, depending on the season and other variables, such as energy coming from the sun.
- During winter, jet streams tend to follow the sun's elevation and move toward the equator, while they move back toward the poles in spring.
- Jet streams are like rivers of wind high above in the atmosphere. These slim strips of strong winds have a huge influence on climate, as they can push air masses around and affect weather patterns.
- At times, Jet Streams bring about some moisture to the stratosphere, leading to the formation of ***noctilucent clouds*** (tenuous cloudlike phenomena in the upper atmosphere which are made of ice crystals visible in a deep twilight.)
- Plays a significant role in the onset and withdrawal of monsoon winds.
- Known to have brought some ozone depleting substances to stratosphere which result in ozone layer depletion**.**
- Intensifies alternative cyclonic and anti-cyclonic winds.

Characteristics of Jet Streams

- Its genesis is associated with the thermal contrast of air cells, for example Hadley cell, Ferrel cell.
- The meandering or the whirl movement of the Jet Stream is called **'*Rossby Wave*'.**
- Equatorial extension of the Jet Stream is more in winter because of the southern shift of the pressure belts.

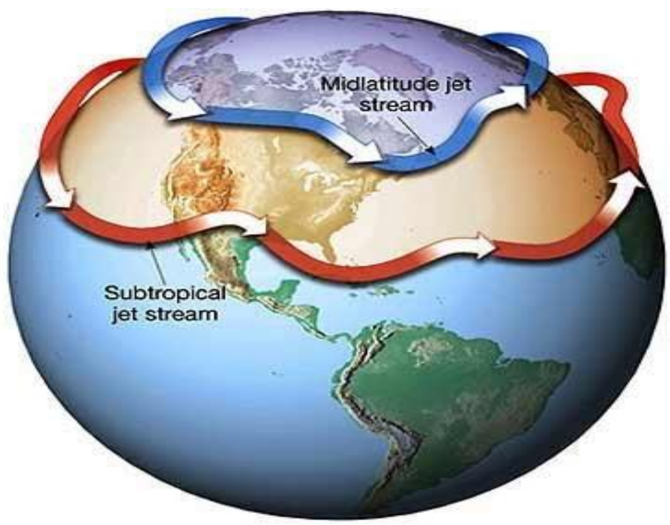
Indian Monsoon Mechanism and the Role of Sub Tropical Jet Streams

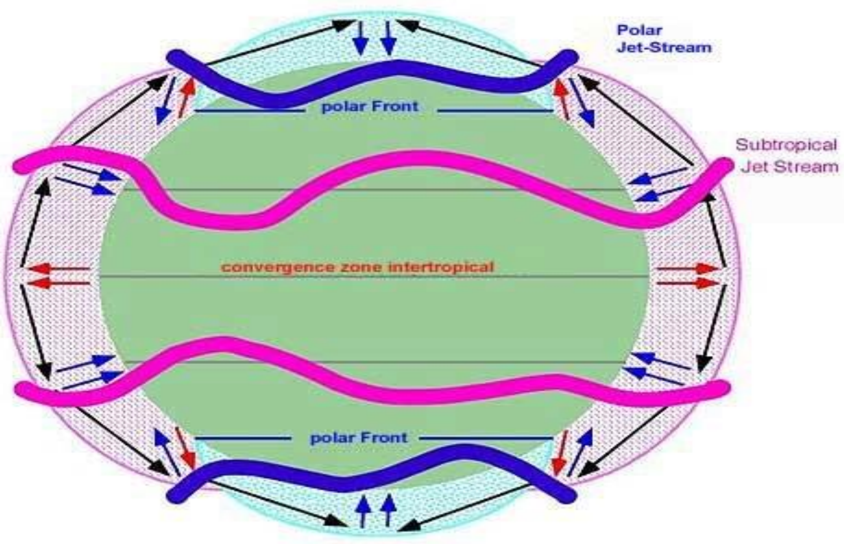
- The burst of monsoons depends upon the upper air circulation which is dominated by Sub Tropical Jet Streams (STJ).
- The westerly flows are responsible for the ***western disturbances*** experienced in the north and north-western parts of the country.
- These are of two types, westerly jet streams move to the north of Himalayas in summer and easterly jet streams move to the peninsular India.
- The south west monsoon coming in India is related to tropical easterly stream. It blows between 8 degree - 35 degree North latitudes.
- The north east monsoon (winter monsoon) is related to the subtropical westerly Jet Stream which blows between 20 degree and 35 degree latitudes in both hemispheres.

Airplanes fly in the mid to upper troposphere. So, if an airplane flies in a powerful jet stream and they are traveling in the same direction, the airplane can get a boost. That's why an airplane flying a route from west to east can generally make the trip faster than an airplane traveling the same route east to west.

Weather satellites, such as the Geostationary Operational Environmental Satellites-R Series (GOES-R), use infrared radiation to detect water vapor in the atmosphere. With this technology, meteorologists can detect the location of the jet streams. Monitoring jet streams can help meteorologists determine where weather systems will move next. But jet streams are also a bit unpredictable. Their paths can change, taking storms in unexpected directions. So satellites like GOES-16 can give up-to-the-minute reports on where those jet streams are in the atmosphere — and where weather systems might be moving next.

JET STREAMS





Source:https://www.drishtiias.com/

UNIT III

Atmospheric Disturbances: Cyclones and Anticyclones – Tornadoes – El Nino and La Nina impacts.

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UNIT-III
ATMOSPHERIC DISTURBANCES

TROPICAL AND TEMPERATE CYCLONES

Atmospheric disturbances are any disturbance in the atmosphere. They are short lived, and transient. This means they generally only last a few days, and do not stay in one place for a prolonged period of time. During their short lives, the atmospheric disturbances have a dramatic effect on the atmosphere and surrounding areas. They are important because they tend to lead to harsh weather conditions and storms. Some of the most common disturbances are mid-latitude cyclones, hurricanes, and tornadoes.

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

They are:

A. Tropical cyclone B. Temperate cyclone

A. Tropical Cyclones

Tropical Cyclones are organized low pressure systems of clouds and thunderstorms that form over tropical or subtropical waters and has a closed low-level circulation, rotate counterclockwise in the Northern Hemisphere and clock wise in southern hemisphere, which is one of the notable characteristic feature of global energy circulation. Tropical Cyclones are classified as follows:

1. Tropical Depression: A tropical cyclone with maximum sustained winds of 38 mph (33 knots) or less.
2. Tropical Storm: A tropical cyclone with maximum sustained winds of 39 to 73 mph (34 to 63 knots).
3. Hurricane: A tropical cyclone with maximum sustained

winds of 74 mph (64 knots) or higher. In the western North Pacific, ***hurricanes are called typhoons***; similar storms in the Indian Ocean and South Pacific Ocean are called ***cyclones***. A tropical cyclone with maximum sustained winds of 111 mph (96 knots) or higher, corresponding to a Category 3, 4 or 5 on the Saffir-Simpson Hurricane Wind Scale are called as major hurricane.

Tropical cyclones are known by various names in different parts of the world.

- In the North Atlantic Ocean and the eastern North Pacific they are called ***hurricanes***
- In the western North Pacific around the Philippines, Japan, and China the storms are referred to as ***typhoons***.
- ***Willy Whillies*** in Australia.
- The Bay of Bengal region is prone to depression and tropical cyclones due to upward movement of ITCZ in summer, warming of sea water which creates a low pressure area in the region.

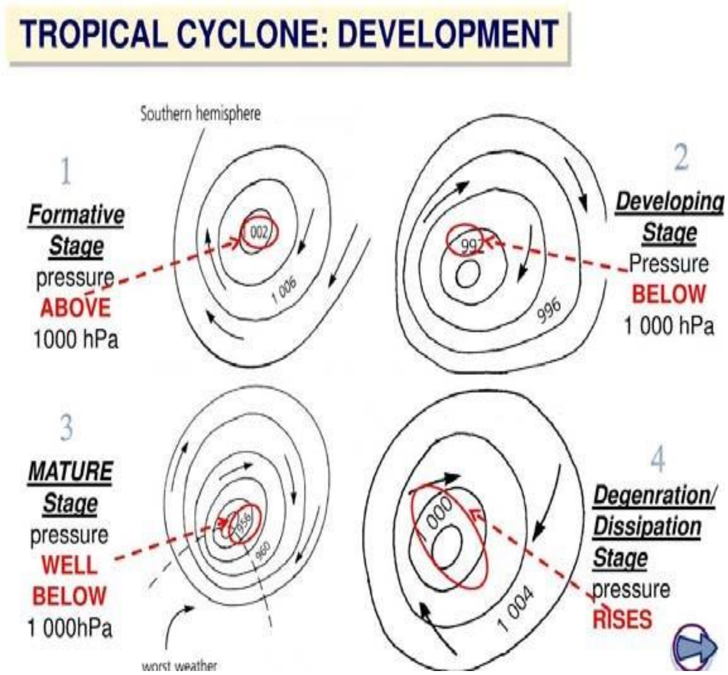
Characteristics of Tropical Cyclones

1. Tropical cyclones forming between 5 and 30 degrees North latitude typically move toward the west. Sometimes the winds in the middle and upper levels of the atmosphere change and steer the cyclone toward the north and northwest. When tropical cyclones reach latitudes near 30 degrees north, they often move northeast.

2. The gale force winds can extend hundreds of kilometres from the cyclone centre. If the sustained winds around the centre reach 118 km, then the system is called a ***severe tropical cyclone***. These are referred to as hurricanes or typhoons in other countries.

3. The circular ***eye*** or centre of a tropical cyclone is an area characterized by light winds and often by clear skies. Eye diameters are typically 40 km but can range from under 10 km to over 100 km. The eye is surrounded by a dense ring of cloud about 16 km high known as the ***eye wall*** which marks the belt of strongest winds and heaviest rainfall. They have lots of rain and lots of cloud. There are also ***outer bands***, which surround the cyclone, which forms the greatest part of the storm. These have winds so strong they can even form other tornadoes.

4. Tropical cyclones derive their energy from the warm tropical oceans and do not form unless the sea-surface temperature is above 26.5°C. Tropical cyclones can persist for many days and may follow quite erratic paths. They usually dissipate over land or colder oceans.



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

Naming of Tropical Cyclones

The practice of naming storms (tropical cyclones) began, in order to help in the quick identification of storms in warning messages. Names are presumed to be far easier to remember than numbers and technical terms.The naming of tropical cyclones is a recent phenomenon. The process of naming cyclones involves several countries in the region and is done under the aegis of the World Meteorological Organization.

- In the Atlantic and in the Southern hemisphere (Indian Ocean and South Pacific), tropical cyclones receive names in alphabetical order, and women and men's names are alternated.
- Nations in the Northern Indian Ocean began using a new system for naming tropical cyclones in 2000; the names are listed alphabetically

country wise, and are neutral gender wise.

- For the Indian Ocean region, deliberations for naming cyclones began in 2000 and a formula was agreed upon in 2004. Eight countries in the region - Bangladesh, India, Maldives, Myanmar, Oman, Pakistan, Sri Lanka and Thailand - all contributed a set of names which are assigned sequentially.

The use of short, distinctive given names in written as well as spoken communications is quicker and less subject to error than the older more difficult latitude-longitude identification methods. These advantages are especially important in exchanging detailed storm information between hundreds of widely scattered stations, coastal bases, and ships at sea.

Distribution of Tropical Cyclones

The majority of storms occur in the months between June and November in the northern hemisphere whereas; in southern hemisphere it has been occurring during November and April as this is when sea temperatures are at their highest. In general, tropical oceans generate around 80 storms per year. The highest number is in the Pacific Ocean, followed by the Indian Ocean and the Atlantic Ocean is third.

The most powerful storms occur in the Western Pacific, mainly the Gulf of Mexico and Caribbean hosts three countries that get hit often, including some of the most intense cyclones on Earth. As for as frequency concerned, Asian countries get hit more often than countries on other continents.

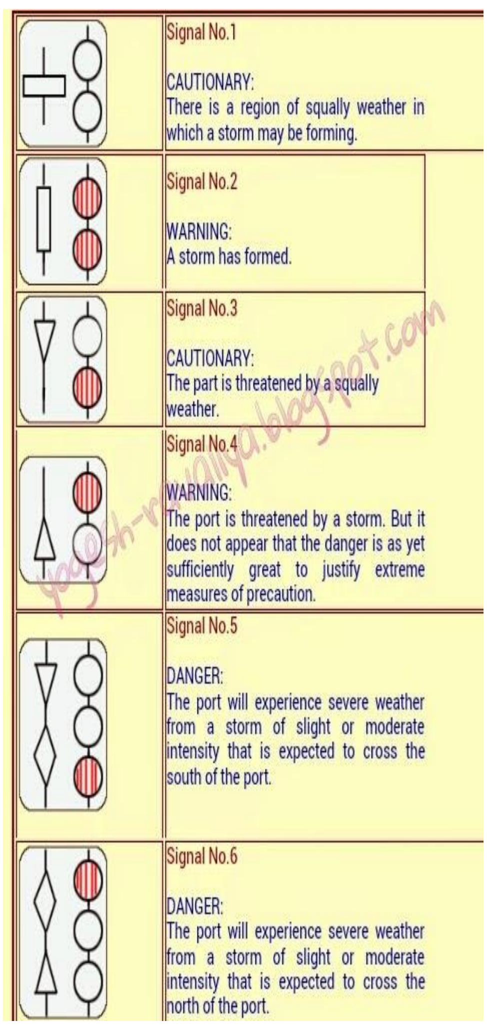
The following top 10 countries are the most affecting in descending order, which includes five Asian countries: Cuba, Madagascar, Vietnam, Taiwan, Australia, United States (including Hawaii), Mexico, Japan, Philippines and China.

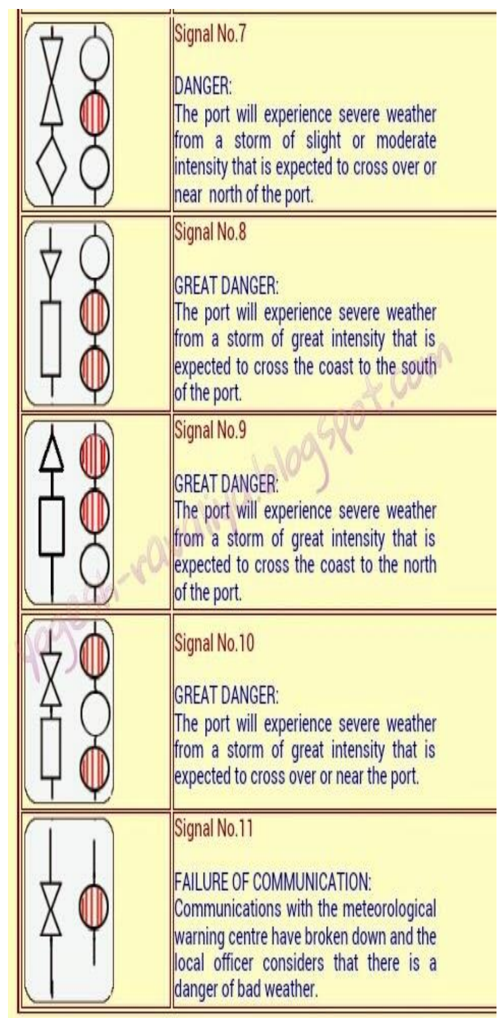
Destructions of Tropical Cyclones

Main effects of tropical cyclones include -

- Heavy rain
- Strong wind
- Large storm surges near landfall
- Produce destructive winds,
- Flooding.

CYCLONE WARNING SIGNALS IN PORTS





https://www.yogeshravaliya.in/2014/10/

B.TEMPERATE CYCLONES

A temperate cyclone is referred as ***mid-latitude depressions, extra-tropical cyclones, frontal depressions and wave cyclones***. Temperate cyclones are active above mid-latitudinal region between 35° to 65° latitudes in both hemispheres. The direction of movement is blow from west to east and more pronounced in the winter seasons. It is in these latitude zones the polar and tropical air masses meet and form fronts.

- These cyclones are mainly observed in Atlantic Ocean and northwest Europe.
- These cyclones have characteristics to develop over both oceanic and land surface.
- Much of the highly variable and cloudy weather come across in the temperate zone.
- Since mid-latitude is an area of convergence of different air masses, it leads to the formation of fronts as well as the cyclonic conditions are bound to happen.

Origin of Temperate Cyclone

It is explained by Polar Front Theory, accordingly temperate cyclone originate,

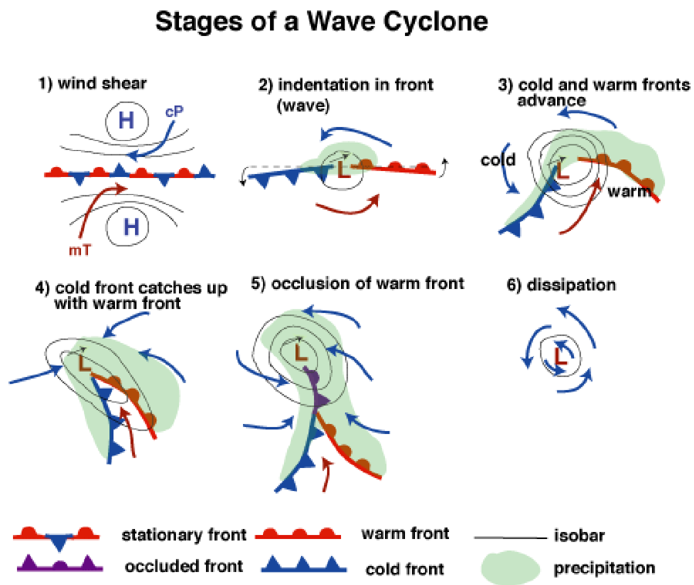
- In the northern hemisphere, warm air blows from the south and cold air from the north of the front.
- When the pressure drops along the front, the warm air moves northwards and the cold air move towards south setting in motion an **anticlockwise cyclonic circulation (northern hemi sphere). This is due to Coriolis Force.**

The cyclonic circulation leads to a well-developed extra tropical cyclone, with a warm front and a cold front.

- There are pockets of warm air or warm sector wedged between the forward and the rear cold air or cold sector. The warm air glides over the cold air and a sequence of clouds appear over the sky ahead of the warm front and cause precipitation.
- The cold front approaches the warm air from behind and pushes the warm air up. As a result, cumulus clouds develop along the cold front. The **cold front moves faster** than the warm front ultimately overtaking the warm front. The warm air is completely lifted up and the front is **occluded (occluded front)** and the cyclone dissipates.
- The processes of wind circulation both at the surface and aloft are closely interlinked.

- So temperate cyclone is intense frontogenesis involving mainly occlusion type front. (The process of formation of a front is known as **Frontogenesis** ***-war between two air masses*** and dissipation of a front is known as **Frontolysis** ***-one of the air masses win against the other***.

- Normally, individual frontal cyclones exist for about 3 to 10 days moving in a generally **west to east direction**.
- Precise movement of this weather system is controlled by the orientation of the polar jet stream in the upper troposphere.



Characteristics

- **Size and Shape:** The temperate cyclones are asymmetrical and shaped like an inverted 'V'.
- They stretch over 500 to 600 km. They may spread over 2500 km over North America (Polar Vortex). They have a height of 8 to 11 km.

Wind Velocity and Strength:

- The wind strength is more in eastern and southern portions, more over North America compared to Europe.
- The wind velocity increases with the approach but decreases after the cyclone has passed.

Structure:

- The north-western sector is the cold sector and the north-eastern sector is the warm sector (Because cold air masses in north and warm air masses in south push against each other and rotate anti-clockwise in northern hemisphere).

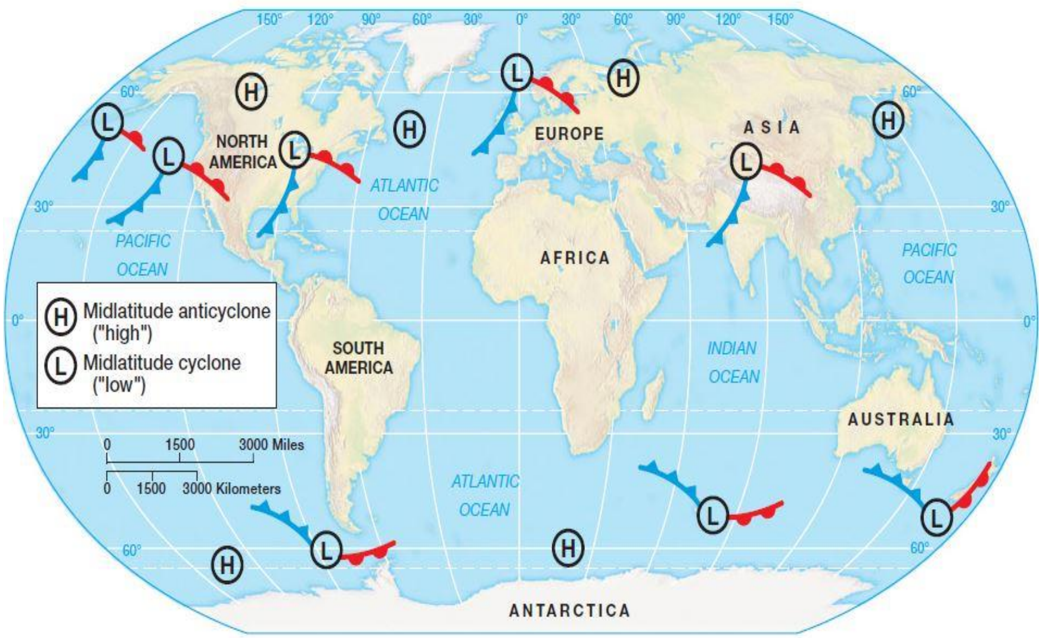
Associated Weather:

- The approach of a temperate cyclone is marked by fall in temperature, fall in the mercury level, wind shifts and a halo around the sun and the moon, and a thin veil of cirrus clouds.
- A light drizzle follows which turns into a heavy downpour.
- Rainfall stops and clear weather prevails until the cold front of an anticyclonic character arrives which causes a fall in temperature, brings cloudiness and rainfall with thunder.
- After this, once again clear weather is established.
- The temperate cyclones experience more rainfall when there is slower movement and a marked difference in rainfall and temperature between the front and rear of the cyclone.
- These cyclones are generally accompanied by anticyclones.

Distribution of Temperate Cyclones

- USA and Canada – extend over Sierra Nevada, Colorado, Eastern Canadian Rockies and the Great Lakes region,
- The belt extending from Iceland to Barents Sea and continuing over Russia and Siberia, winter storms over Baltic Sea
- Mediterranean basin extending up to Russia and even up to India in winters (called western disturbances) and the Antarctic frontal zone.

TEMPERATE CYCLONES



Major Differences between Temperate Cyclone and Tropical Cyclone

Tropical Cyclone	Temperate Cyclone
Tropical cyclones, move from east to west.	These cyclones move from west to east
A tropical cyclone has an effect on a comparatively smaller area than a Temperate cyclone.	Temperate cyclone affect a much larger area
The velocity of wind in a tropical cyclone is much higher and it is more damaging.	The velocity of air is comparatively lower
Tropical Cyclone forms only on seas with temperature more than 26-27degree C and dissipate on reaching the land.	Temperate cyclones can be formed on both land and sea
A tropical cyclone doesn’t last for more than 7 days	Temperate cyclone can last for a duration of 15 to 20 days

ANTICYCLONES

An anticyclone is a weather phenomenon defined as a large-scale circulation of winds around a central region of high atmospheric pressure, clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

- A high pressure system, also known as an anticyclone occurs when the weather is dominated by stable conditions that may extend horizontally many hundreds of kilometers.
- Under an anticyclone air is descending, forming an area of higher pressure at the surface.
- As air descends, air pressure increases. When air hits the ground, it has to go somewhere.
- The earth's rotation makes the air change direction. In the Northern Hemisphere the air is pushed clockwise. In the Southern Hemisphere the air is pushed anticlockwise.
- Anticyclones are much larger than depressions and produce periods of settled and calm weather lasting many days or weeks.
- Anticyclones often block the path of depressions, either slowing down the bad weather, or forcing it round the outside of the high pressure system. They are then called 'Blocking Highs'.
- They frequently persist for a week or more, and the occurrence of a few such blocking anticyclones may dominate the character of a season.

Sir Francis Galton first discovered anticyclones in the 1860s. Anticyclones can be identified on weather charts as an often large area of widely spaced isobars, where pressure is higher than surrounding areas.

Areas of Distribution

- Blocking anticyclones are particularly common over Europe, the eastern Atlantic, and the Alaskan area.
- The strongest anticyclones occur over snow-covered portions of Asia and North America in the winter.
- The Siberian anticyclone is an example of a polar anticyclone. Polar anticyclones are created by the cooling of surface layers of air.
- The weather within the central regions of these anticyclones is typically clear and quite cold.

Types of Anticyclones

There are three types of anticyclones:

- Surface-based systems,
- Mid-tropospheric systems, and
- Upper Tropospheric systems.

Anticyclones of summer season

- In summer, anticyclones bring dry, hot and warm, sunny weather.
- Summer anticyclones can result in "Heat wave" conditions with temperatures significantly above average.
- One such event occurred in the summer of 2003 affecting continental Europe and the UK, it proved to be particularly hazardous to humans.

Anticyclones of winter season

- In winter, clear skies may bring very cold, crisp bright days and cold nights with fog, mist and frost.
- This is because the cold forces moisture in the air to condense at low altitudes.
- In winter, the clear, settled conditions and light winds are associated with anticyclones.

Difference between summer and winter Anticyclones

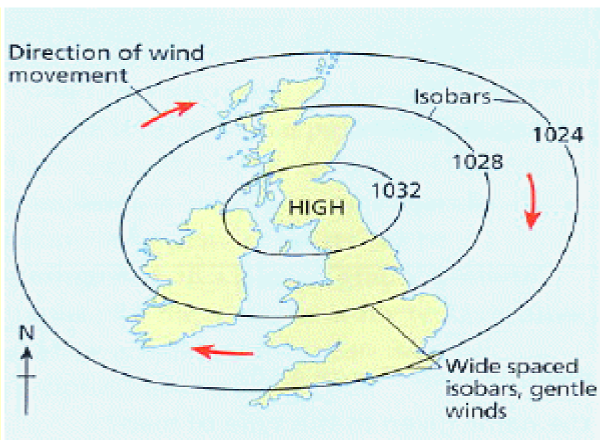
Characteristics of summer anticyclones	Characteristics of winter anticyclones
Few or no clouds. Strong sunshine will make it hot	Cloudless skies
Light winds	Temperature drop, making the days cold and the nights even colder due to lack of cloud cover
Cooling of ground leading to morning mist	Fog and frost forming at night
Warm moist air rising from the ground forming thunderstorms	Cold air from Asia bringing snow to the east of the UK
Cloud cover over Eastern England caused by light winds blowing over the cooler North Sea	Winter anticyclones produce cloudy and foggy weather

Characteristics of Anticyclones

- Anticyclones are areas of intense high pressure (typically above 1020mb) where air molecules descend to the earth's surface from the upper Troposphere.
- Anticyclones can occur in both winter and summer but both are typified by low wind speeds and stable conditions with no clouds.
- Anticyclones only involve one type of air mass and do not have any fronts.
- They are high pressure systems in which the air moves downwards towards the earth's surface.
- As the air descends, the molecules become compressed, the pressure increases and it warms.

- When air is warming, any moisture in the atmosphere is evaporated so no clouds can form.
- The sky is clear.
- Anticyclones can be very large, typically at least 3,000 km wide which is much larger than depressions.
- Once they become established, they can give several days of settled weather.
- Winds are very gentle or even calm in an anticyclone, move clockwise, and this is shown on a synoptic chart by widely spaced isobars.

ISOBARS IN AN ANTICYCLONE



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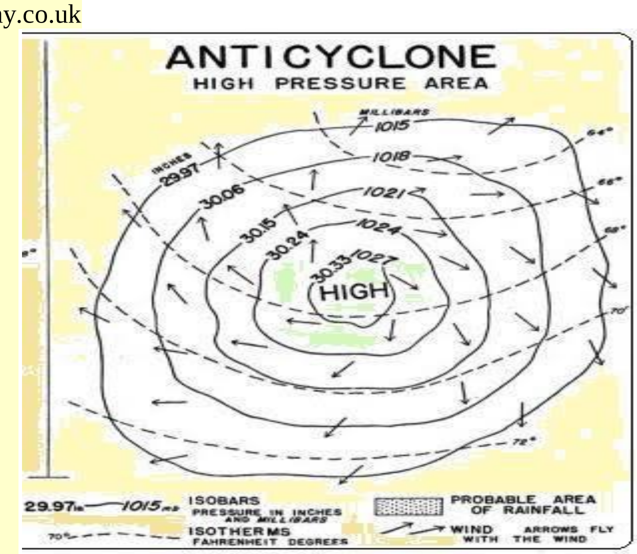
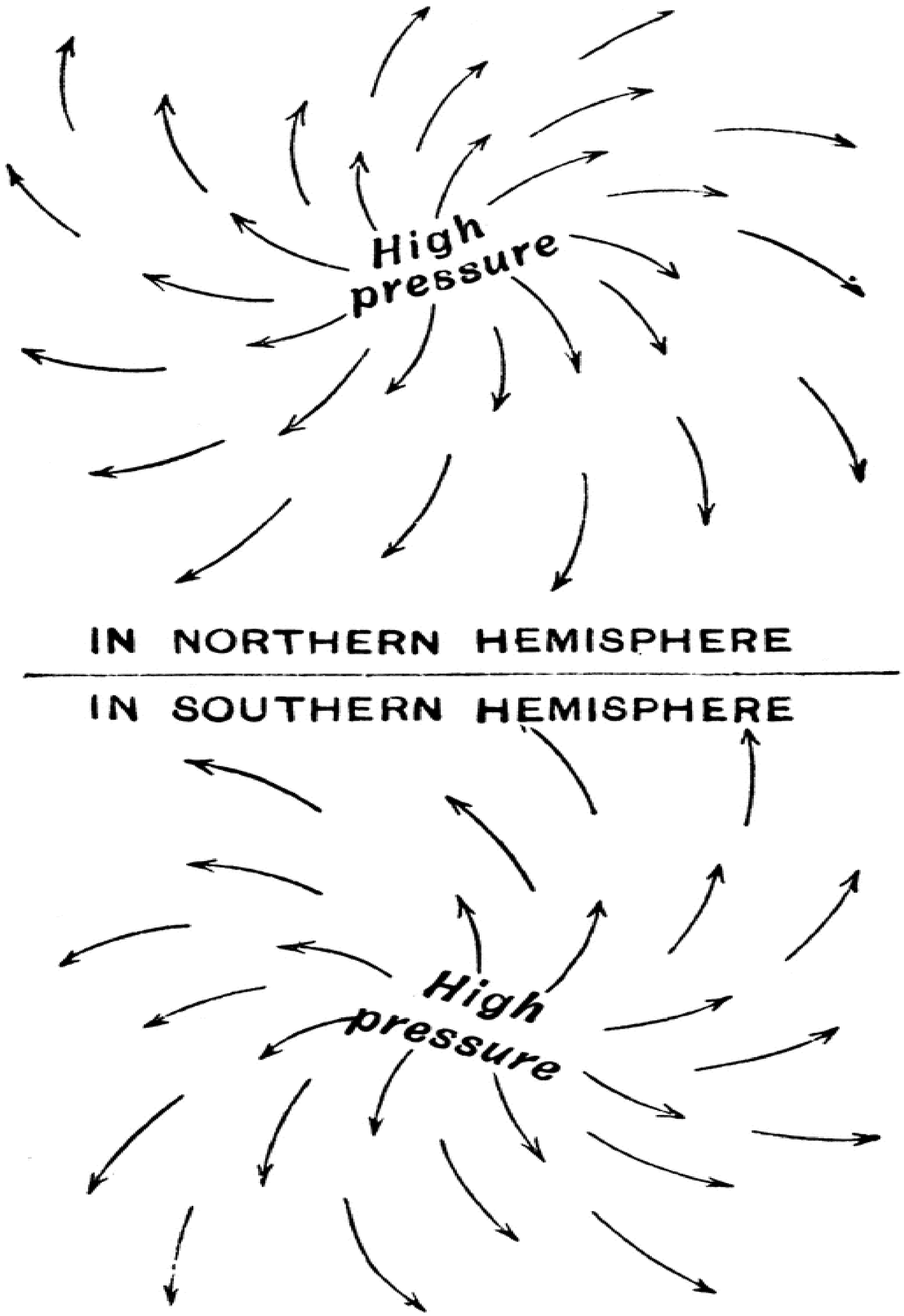


Source: Encyclopedia Figures- https://www.coolgeography.co.uk



DIRECTION OF ANTICYCLONIC WINDS

Source:https://etc.usf.edu/clipart/46200/46247/46247_anticyclones.htm

Strength and Direction

- The winds of an anticyclone typically blow from regions of high pressure towards regions of low pressure.
- The difference in pressure between the two areas usually determines the strength of the winds.
- Therefore, winds will travel at higher speeds, and vice versa.
- The outward movement of an anticyclone from its central region is caused by friction with land.

To conclude-

Anticyclones -

- are larger than low pressure systems
- last longer than low pressure systems
- have lighter winds blowing around them
- have clockwise winds blowing around them in the Northern Hemisphere
- usually give us clear skies
- can give us 'Anticyclonic gloom' in spring
- are responsible for periods of little or no rain, and such periods may be prolonged in association with blocking highs.
- Near the centre of the anticyclone, the winds are light and the air can become stagnant.
- Air pollution can build up as a result. The city of Los Angeles, for example, often has poor air quality because it is frequently under a stationary anticyclone.

TORNADOES

A tornado is a violently rotating column of air that is in contact with both the surface of the Earth and a cumulonimbus cloud. The word ***tornado*** comes from the **Spanish word** tornado (past participle of ‘to turn, or ‘to have torn’) and often (but not always) visible as a funnel cloud

The windstorm is often referred to as a twister, whirlwind or cyclone. Tornadoes come in many shapes and sizes, and they are often visible in the form of a condensation funnel originating from the base of a cumulonimbus cloud, with a cloud of rotating debris and dust beneath it.

Types of Tornadoes

Various types of tornadoes include the multiple vortex tornado, land spout, and waterspout.

- Waterspouts are characterized by a spiraling funnel-shaped wind current, connecting to a large cumulus or cumulonimbus cloud.
- These spiraling columns of air frequently develop in tropical areas close to the equator and are less common at high latitudes.
- Waterspouts are whirling columns of air and mist that form most frequently during warm seasons over oceans, harbors, and lakes. They're often called "tornadoes overwater," but not all waterspouts are true tornadoes.

Speed

- Most tornadoes have wind speeds less than 110 miles per hour (180 km/h), are about 250 feet (80 m) across, and travel a few miles (several kilometers) before dissipating.
- The most extreme tornadoes can attain wind speeds of more than 300 miles per hour (480 km/h), are more than two miles (3 km) in diameter, and stay on the ground for dozens of miles (more than 100 km).

- The most violent tornadoes are capable of tremendous destruction with wind speeds of up to 300 mph.
- They can destroy large buildings, uproot trees and hurl vehicles hundreds of yards. They can also drive straw into trees.

Distribution

- Tornadoes occur most frequently in North America (particularly in central and southeastern regions of the United States colloquially known as '***tornado alley***'), Southern Africa, northwestern and southeast Europe, western and southeastern Australia, New Zealand, Bangladesh and adjacent eastern India, and southeastern South America.
- Tornadoes have been reported on all continents except Antarctica. They are most common on continents in the mid-latitudes (between 20° and 60° N and S), where they are frequently associated with thunderstorms that develop in regions where cold polar air meets warm tropical air.

Appearance

- A tornado is not necessarily visible; however, the intense low pressure caused by the high wind speeds and rapid rotation usually cause water vapor in the air to condense into cloud droplets due to adiabatic cooling.
- This results in the formation of a visible funnel cloud or condensation funnel.
- Tornadoes may be obscured completely by rain or dust. In the United States, tornadoes are around 500 feet (150 m) across on average and travel on the ground for 5 miles (8.0 km)

Colors

Tornadoes can have a wide range of colors, depending on the environment in which they form.

- Condensation funnels that pick up little or no debris can be gray to white.
- While traveling over a body of water (as a waterspout), tornadoes can turn white or even blue.
- Slow-moving funnels, which ingest a considerable amount of debris and dirt, are usually darker, taking on the color of debris.
- Tornadoes in the Great Plains can turn red because of the reddish tint of the soil,
- Tornadoes in mountainous areas can travel over snow-covered ground, turning white.
- Lighting conditions are a major factor in the appearance of a tornado.
- Tornadoes which occur near the time of sunset can be many different colors, appearing in hues of yellow, orange, and pink.

Sound

- Tornadoes rotate cyclonically (counterclockwise in the northern hemisphere and clockwise in the southern).
- Various sounds of tornadoes have been reported, mostly related to familiar sounds.
- Popularly reported sounds include a freight train, rushing rapids or waterfall, a nearby jet engine, or combinations of these.
- Funnel clouds and small tornadoes are reported as whistling, whining, humming, or the buzzing of innumerable bees or electricity.
- Many tornadoes are reported as a continuous, deep rumbling or an irregular sound of "noise".

Characteristics

- Happen anytime and anywhere
- Bring intense winds, over 200 MPH
- Look like funnels
- Destructive storms also cause strong gusts of wind, lightning strikes, and flash floods.
- Tornadoes can strike quickly with little or no warning
- Vary in speed from being stationary to 70 miles per hour.
- With a loud roar that sounds similar to a freight train,
- Most deaths and injuries in tornadoes result from individuals being struck by flying debris.
- People are sometimes injured or killed by being rolled across the ground by the high winds.
- A few people appear to have been killed by being carried aloft and then dropped from a great height.

Tornado Outbreaks

Outbreaks are classified according to the number of tornadoes reported:

- Small (6 to 9 tornadoes),
- Medium (10 to 19), and
- Large (more than 20 tornadoes).

Outbreaks are also classified according to the area affected:

- in local outbreaks, one or only a portion of one state is affected;
- in regional outbreaks, two or three states contain all or almost all the tornadoes;
- in national outbreaks, tornadoes are reported in many states.

Tornado Intensity

Tornado intensity is not estimated directly from measured wind speeds but it is commonly estimated by analyzing damage to structures and then correlating that damage with the wind speeds.

- The Enhanced Fujita Scale recognizes tornadoes of six different intensities ranging in number from EF0 to EF5.
- For many purposes, these can be grouped into three broader categories—weak, strong, and violent.
- The notion of developing such a scale for use in comparing events and in research was proposed in 1971 by the Japanese American meteorologist T. Theodore Fujita.

TORNADO

Source: https://jamesmdow.com

WATERSPOUT

Source: https://www.dailymail.co.uk

EL NINO AND LA NINA

The terms El Niño and La Niña refer to periodic changes in Pacific Ocean sea surface temperatures that have impacts on weather all over the globe.

- In the Pacific Ocean near the equator, temperatures in the surface ocean are normally very warm in the western Pacific and cool in the eastern Pacific.
- This helps to generate heavy rains over southeastern Asia and northern Australia and keeps parts of Pacific coastal South America relatively dry.
- This “normal” pattern of Pacific sea surface temperatures is disrupted periodically by El Niño and La Niña
- It is a naturally occurring phenomenon that occurs roughly every 3-7 years.
- ***El Niño*** (the warm phase) and ***La Niña*** (the cold phase), typically last for 9-12 months each, but in rare cases can last over multiple years.

El Niño/Southern Oscillation (ENSO)

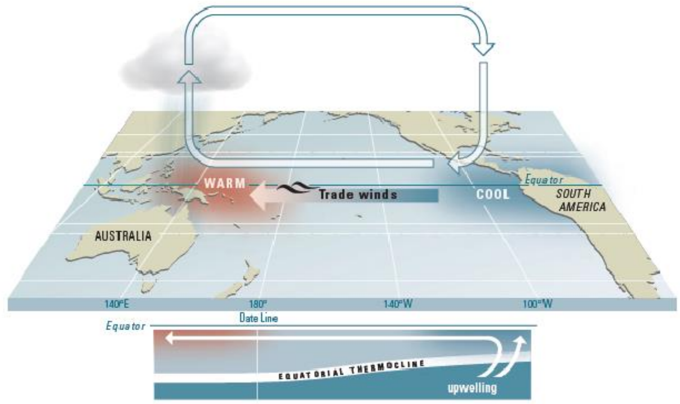
- "ENSO" refers to the El Niño/Southern Oscillation, the interaction between the atmosphere and ocean in the tropical Pacific that results in a variation between below-normal and above-normal sea surface temperatures and dry and wet conditions over the course of a few years.

- While the tropical ocean affects the atmosphere above it, so too does the atmosphere influence the ocean below it.
- One layer of the Pacific Ocean that is influenced by ENSO is the thermocline. The thermocline marks the transition between the warm upper water and the cold deep water in the Pacific Ocean.
- The upward currents along the equator (or *upwelling*) are strongest across this transition zone. The depth of the thermocline has a direct relationship with water surface temperatures.
- When the thermocline is closer to the water surface, upwelling of cold, nutrient rich deep-water is transported up from the bottom layers, leading to cooler temperatures at the water surface.
- The interaction of the atmosphere and ocean is an essential part of El Niño and La Niña events (the term coupled system is often used to describe the mutual interaction between the ocean and atmosphere).

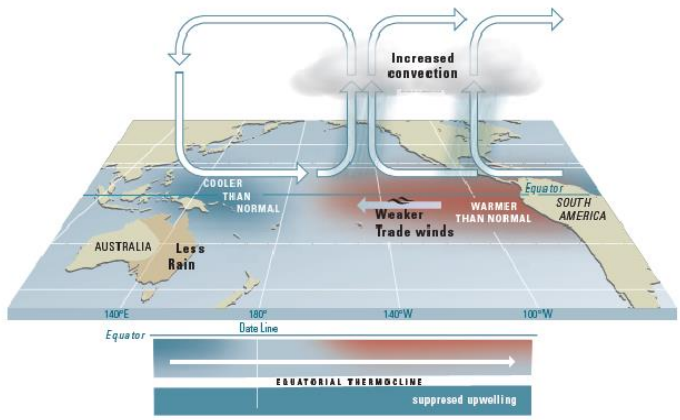
- During an El Niño, sea level pressure tends to be lower in the eastern Pacific and higher in the western Pacific while the opposite tends to occur during a La Niña. This see-saw in atmospheric pressure between the eastern and western tropical Pacific is called the "***Southern Oscillation"***, often abbreviated as the "***SO"***.

Since El Niño and the Southern Oscillation are related, the two terms are often combined into a single phrase, the **El Niño-Southern Oscillation, or ENSO**. Often the term ENSO Warm Phase is used to describe El Niño and ENSO Cold Phase to describe La Niña.

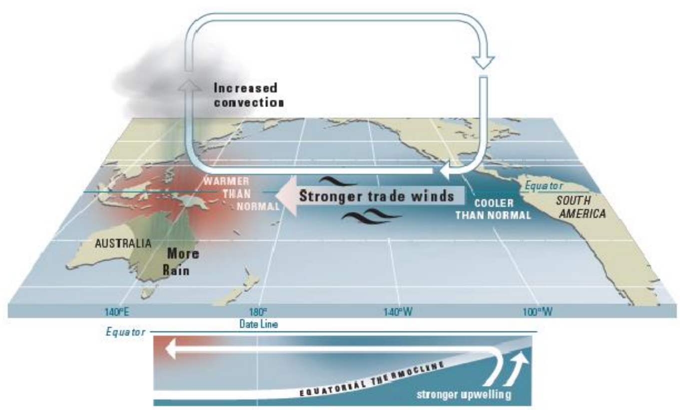
Neutral situation



El Niño episode



La Niña episode

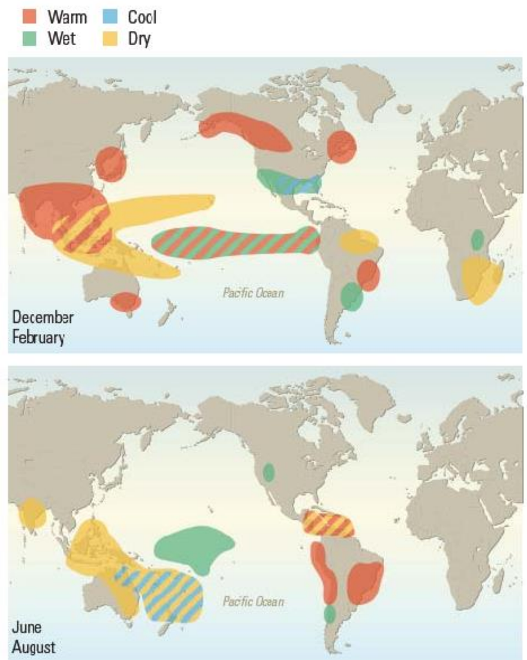


Significance

- During El Niño, surface water in the central and eastern equatorial Pacific Ocean is unusually warm.
- Trade winds blowing from east to west weaken
- The warm surface waters that typically stay in the western Pacific are able to move east along the equator.
- Rainstorms follow the warm water to the central and eastern Pacific
- Dry conditions affect northern Australia and Southeast Asia, and wetter conditions impact Pacific coastal South America.
- El Niño can impact U.S. weather by bringing milder conditions to northern areas and wetter conditions to the south (not every El Niño event affects the U.S. in the same way).

El Niño regional impacts

El Niño global impacts for winter (December – February) and for summer (June – August).



Source: US National Oceanic and Atmospheric Administration.

La Niña is characterized by the opposite process:

- The trade winds strengthen
- Warm water and rainstorms are pushed to the far western equatorial Pacific over Indonesia.
- This results in cooler surface water in the equatorial Pacific Ocean, dry conditions in Pacific coastal South America, and much wetter conditions in northern Australia and Southeast Asia.
- La Niña usually impacts U.S. weather by bringing cooler weather to the northwest and warmer weather to the southeast (though just like El Niño, not every La Niña event affects U.S. weather identically).

El Niño and Climate Change:

- The ENSO and El Niño events are phenomena of natural climate variability with global impacts, but are not directly related to climate change.
- The influence of climate change on the frequency and intensity of El Niño events is uncertain.
- There is high confidence that ENSO will remain the dominant mode of inter-annual climatic variability throughout the 21st century and also that ENSO-induced rainfall variability will intensify due to changes in moisture availability.
- More frequent extreme events such as droughts and intense precipitation are expected in the course of ongoing climate change.

El Niño and global temperatures

- On a global scale, El Niño events lead to higher average land and ocean temperatures.
- 15 out of the 16 highest monthly global land and ocean average temperatures ever recorded since 1880 have occurred between February 2015 and July 2016, which coincides with the El Niño 2015 and 2016 period.

Health issues

- In many African regions, El Niño-caused drought conditions
- It is followed by unusually high rainfall amounts that come along with an increased risk for vector-borne diseases such as malaria, and outbreaks of other communicable diseases including measles and cholera. Cholera outbreaks were

reported in Honduras and Nicaragua as well as in Tanzania, later spreading out further to Kenya, Chad and Somalia.

- In the latter countries, an additional nearly 90,000 people are affected by Rift Valley Fever (FAO, 2016b).
- High rates of malnutrition, exacerbated by food shortages, makes affected populations even more susceptible to these types of diseases.

Southern Oscillations and Monsoon

- The system of Southern Oscillations was worked out by Sir Gilbert Walker.
- It is a seesaw pattern of meteorological changes that are often observed between Pacific and Indian Ocean.
- It has been established that when surface pressure is high over the Pacific, air pressure over Indian Ocean tends to be low.
- Prevalence of low air pressure over Indian Ocean during winter season is a sign of 'positive southern oscillations'.
- The chances of favorable monsoon are generally linked with 'positive southern oscillations'.
- On the contrary, if air pressure is high over Indian Ocean during winter season, it denotes the 'negative southern oscillations' which means that coming monsoon will be weak.
- Southern Oscillations has a period ranging between 2 to 7 years.

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