2018

INTEGRATED LEARNING PROGRAMME, ILP

IASBABA

[GEOGRAPHY-CLIMATOLOGY]

Integrated Learning Programme 2018 is a step towards 'Enabling a person located at the most remote destination a chance at cracking AIR 1 in UPSC/IAS'

Contents

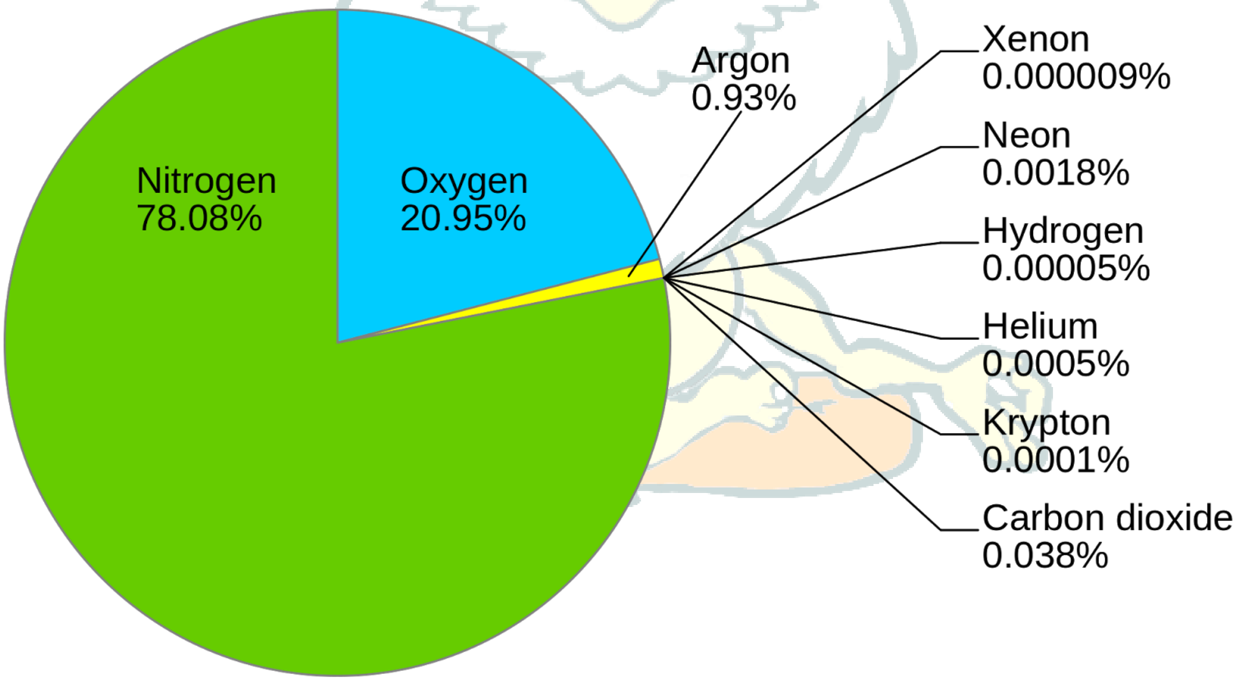
Note- World Climate related aspects will be covered in upcoming Geography Block as per Plan.

Atmosphere

The envelope of gases surrounding the earth is called the atmosphere. It forms a protective boundary between the outer space and the biosphere. It is a mixture of gases that is odorless, colourless, tasteless and formless mixed and blended **so thoroughly that it acts like a single gas.**

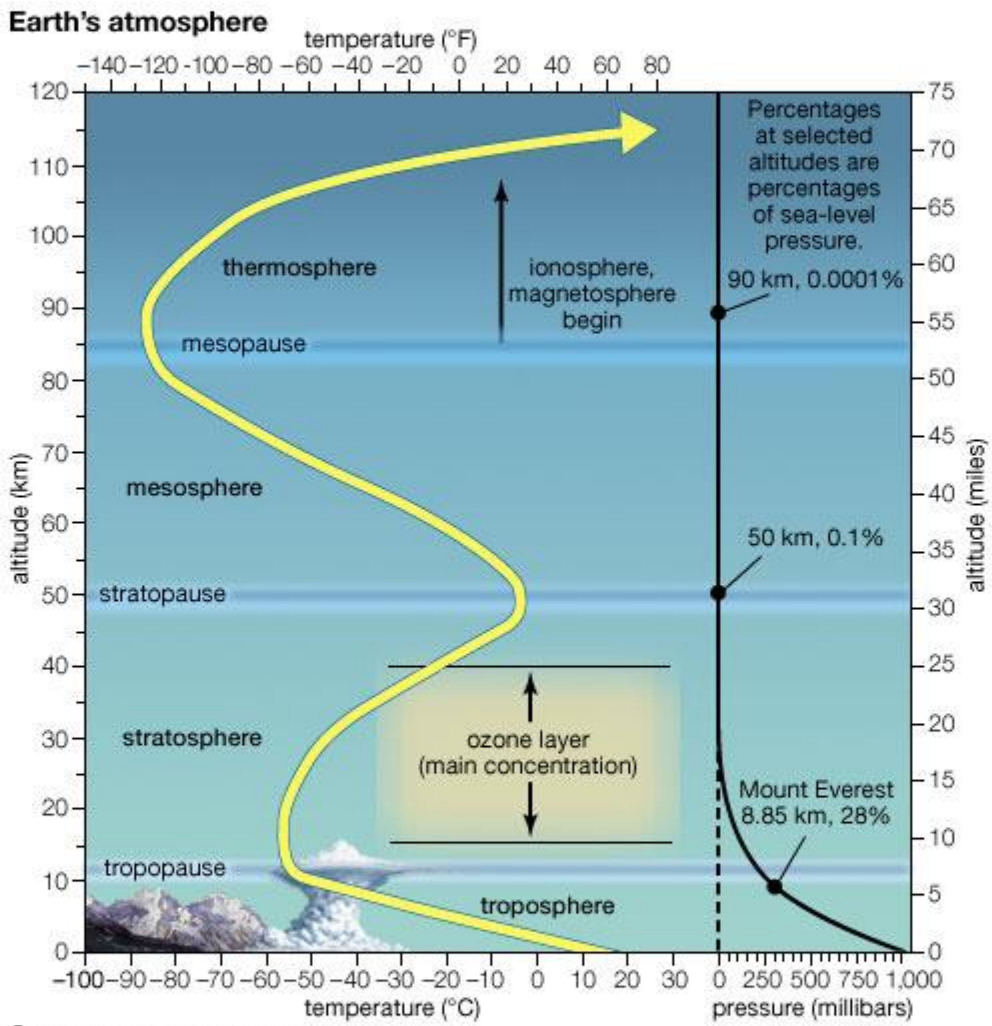
The gases of the present atmosphere are not the direct residue of the early stage of earth's formation. They are a product of progress through volcanic eruptions, hot springs, chemical breakdowns of solid matter and redistribution from biosphere.

Composition of Atmosphere



The proportion of the main gases in the atmosphere is shown in the figure above. A unit of **dry air** consists of 78.084% Nitrogen, 20.946% Oxygen, 0.934% Argon, 0.036% Carbon dioxide and the remaining other trace gases.

Layers of Atmosphere



The atmosphere can be divided into different layers according to composition, density, pressure and temperature variations.

Based on Composition:

According to its composition, broadly it is divided into two layers – homosphere and heterosphere.

Homosphere: It extends from the earth's surface up to the altitude of 80km. even though the atmosphere rapidly decreases in density with increasing altitude, the composition of the gases remains uniform in the homosphere. The exceptions in the homosphere are the concentration of Ozone (O_3) in stratosphere from almost 19-50 km and variation of water vapour and dust particles in the lower atmosphere. This uniform composition was attained approximately 600 million years ago.

Heterosphere: the gases in this layer are not evenly mixed. It begins over 80km and extends upto 10,000 km. however, for all scientific purposes the upper limit of atmosphere is taken as 480km as earth's gravitational pull becomes negligible after it. The atmosphere above it is called exosphere and it contains individual atoms of light gases like hydrogen, helium etc.

Based on Change in temperature:

On the basis of change in temperature the atmosphere is broadly divided into four layers:

Troposphere: It is the lower most layer of atmosphere. It extends up to 18km at equator, 13 km at mid latitude and about 8km at poles. It contains approximately 90% of the total mass of the atmosphere. The entire weather phenomenon takes place in this layer. It contains all the water vapour, dust particles, clouds etc.

In troposphere the temperature decreases with increase in height. The average rate of decrease of temperature with height is called normal lapse rate and it is equal to 6.4o C/km. the rate of decrease of temperature is not constant everywhere. The local rate of decrease is called local lapse rate. The minimum temperature attained in this layer is -57 degree C.

Stratosphere: It lies above the troposphere and extends uniformly across the globe up to 50km. In this layer the temperature increases with increase in height. The temperature varies from -57 to 0 degree C. This layer is characterized with the presence of Ozonosphere. Ozone is highly reactive oxygen molecule made up of three atoms. Ozone absorbs the high frequency ultra violet radiations. Because of this absorption the temperature of the layer increases. The energy absorbed is used in chemical reactions causing the formation of ozone gas. Ultra violet rays are highly harmful for living organism including plants, animals as well as humans. Absorbing these radiations ozone layers makes a protective layer around us.

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

Thermosphere: This is a region extending from 80km to 480km. It contains the functional ionosphere. The temperature rises very sharply in this layer as the gas molecules absorbs the short wave radiations coming from the sun. The temperature can reach as high as 1200o C, but despite such high temperature the thermosphere is not as 'hot' as we expect it to be. As the density of air is so low in this layer, the energy is not easily transferred; hence the hotness is not felt.

Ionosphere: This is the zone containing charged particles called ions. It lies from upper mesosphere to thermosphere. The charged particles are ionized by absorption of cosmic rays, gamma rays, X-rays and shorter wavelengths of ultraviolet rays. It is in this layer that incoming space vehicles and meteorites begin to heat due to friction. Above this layer i.e. above 480km, atomic oxygen is prevalent and beyond that first helium is more common and then hydrogen atoms predominate.

Solar Constant

The average value of incoming solar radiation (INSOLATION) received at the thermopause ie. 480km above the earth's surface, when the earth is at average distance from the sun is called solar constant. The average value of solar constant is estimated to be 1.968 calories per cm2 per minute.

The energy emitted by the sun is received by the earth in the form of electromagnetic radiations. The quantity of radiations is about 1.968 calories/cm2/ minute. A calorie is that amount of energy which is required to raise the temperature of one gram of water by one degree Celsius.

Several processes deplete the solar radiation as it passes through the earth's atmosphere like

Reflection: The radiations are reflected back in the space by the surface and atmosphere of earth. The total reflection of the incoming solar radiation is called albedo and is expressed in terms of percentage of insolation. Clouds are the most important reflectors by far. Their reflectivity ranges from 40 to 90% depending upon the thickness and type of cloud.

Absorption: Some of the energy is absorbed and raises the temperature of the surface.

Scattering: It is the process by which small particles, with size comparable to the wavelength of the radiations deflects the radiations in different direction. The direction of radiation changes as it keeps on scattered by the particles.

Transmission: Some radiation passes through the atmosphere without reflection, refraction, absorption, or scattering. This is called transmission.

Concept of Twilight (dawn and dusk)

Twilight is the time between day and night when there is light outside, but the Sun is below the horizon.

The diffused light that occurs before the sun rise and sun set gives valuable working hours for humans. Light that is scattered by the gas molecules and reflected by water vapour and dust particles cause illumination of atmosphere. Such effects can be enhanced due to the presence of pollution and other suspended particles as those in volcanic eruptions and forest fires etc.

In the morning, twilight begins with dawn, while in the evening it ends with dusk. A number of atmospheric phenomena and colors can be seen during twilight. **Astronomers define the three stages of twilight – civil, nautical, and astronomical** – on the basis of the Sun's elevation which is the angle that the geometric center of the Sun makes with the horizon.

Civil Twilight

Civil twilight occurs when the Sun is less than 6 degrees below the horizon. In the morning, civil twilight begins when the Sun is 6 degrees below the horizon and ends at sunrise. In the evening, it begins at sunset and ends when the Sun reaches 6 degrees below the horizon.

Civil dawn is the moment when the geometric center of the Sun is 6 degrees below the horizon in the morning.

Civil dusk is the moment when the geometrical center of the Sun is 6 degrees below the horizon in the evening.

Civil twilight is the brightest form of twilight. There is enough natural sunlight during this period that artificial light may not be required to carry out outdoor activities. Only the brightest celestial objects can be observed by the naked eye during this time.

Several countries use this definition of civil twilight to make laws related to aviation, hunting, and the usage of headlights and street lamps.

Nautical Twilight, Dawn, and Dusk

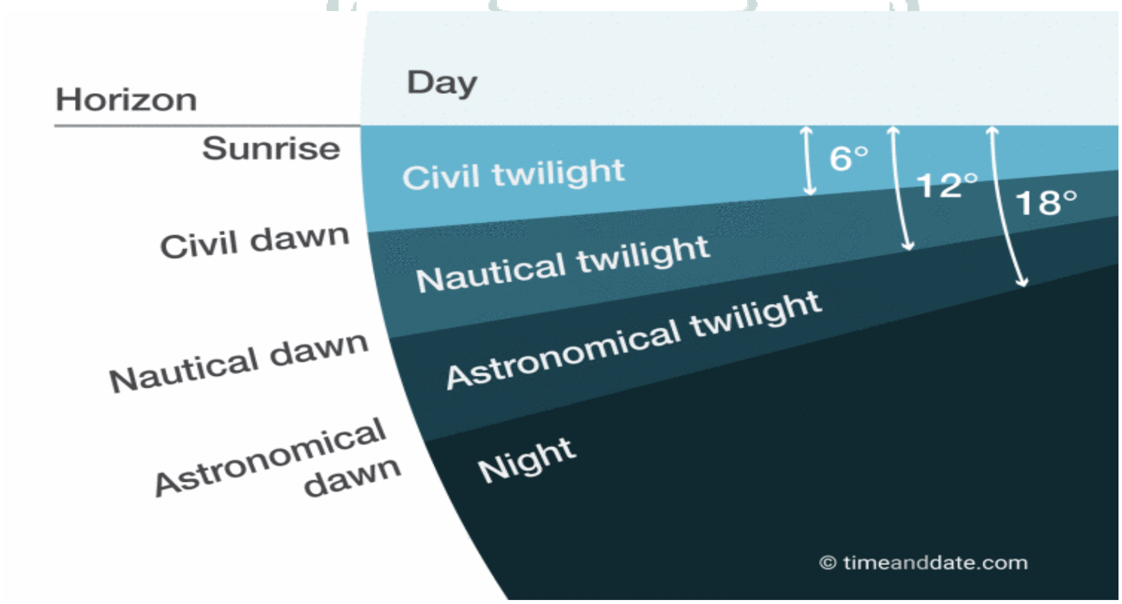
Nautical twilight occurs when the geometrical center of the Sun is between 6 degrees and 12 degrees below the horizon. This twilight period is less bright than civil twilight and artificial light is generally required for outdoor activities.

Nautical dawn occurs when the Sun is 12 degrees below the horizon during the morning.

Nautical dusk occurs when the Sun goes 12 degrees below the horizon in the evening.

The term, *nautical twilight*, dates back to the time when sailors used the stars to navigate the seas. During this time, most stars can be easily seen with naked eyes.

In addition to being important to navigation on the seas, nautical twilight also has military implications. For example, the United States' military uses nautical twilight, called *begin morning nautical twilight* (BMNT) and *end of evening nautical twilight* (EENT), to plan tactical operations.



Astronomical Twilight, Dawn, and Dusk

Astronomical twilight occurs when the Sun is between 12 degrees and 18 degrees below the horizon.

Astronomical dawn is the time when the geometric center of the Sun is at 18 degrees below the horizon. Before this time, the sky is absolutely dark.

Astronomical dusk is the instant when the geographical center of the Sun is at 18 degrees below the horizon. After this point, the sky is no longer illuminated.

The duration of dawn and twilight is a function of latitude because the angle of sun above horizon determines the distance travelled by the light in the atmosphere. Lower angle produces longer dawn and twilight periods. At the equator, the light is almost perpendicular hence the dawn and twilight is 30-45 min long while at poles there is about 7 weeks of dawn and 7 weeks of twilight leaving only 2.5 months of near darkness.

Temperature

- The average temperature of the Earth is about 16 degree C, but its distribution is not uniform. The spatial distribution of the temperature is determined by the following factors:

- **Latitude:** The insolation largely depends on the latitude. The intensity of insolation decreases from equator to poles. In addition to this the day length and seasons also depends upon the latitude. Hence lower latitude records high temperature as compared to higher latitudes.

- **Altitude:** As we know that temperature decreases with altitude in troposphere. Thus , worldwide mountainous areas experiences lower temperatures than the areas near sea level lying on the same latitude.

- **Cloud cover:** According to the meteorologists, everyday almost 50% of sky across globe is covered with clouds. Cloudy days are relatively colder than sunny days while cloudy nights are warmer than clear nights. The maximum cloud cover is recorded in equatorial areas hence highest temperature is not recorded at equator while it is recorded in tropical deserts having clear skies.

- **Distance from the Sea:** Places near the sea gets sea breeze during day and land breeze during night. Hence the temperatures are moderate in these regions while both diurnal range of temperature and yearly range of temperature increases as we go away from the ocean. The temperatures in interior of the continent are more extreme.

- **Winds:** The role of prevailing winds is quite significant in the distribution of temperature. The cold winds blowing from higher latitude towards the lower latitude causes a drop of temperature while local winds of Africa blowing towards Mediterranean like Khamsin, Sirocco, Gibli increase the temperature.

- **Topography:** The temperature distribution also depends upon the topographic features of the earth. For example the side of mountain facing the sun receives more heat than the one opposite to it.

- **Ocean Currents:** Ocean currents also affect the distribution of temperature on land and oceans. The warm ocean currents carries warm water from the tropics towards the higher latitudes while cold currents bring cold water from higher latitudes to lower latitudes. At the same latitude, a coast encountering a cold current will have lesser temperature than the one encountering the warm current. For example, the Gulf Stream raises the temperature of the Norway coast by 5 degree C, while the Labrador Current reduces the temperature of Canada coast by 8 degree C.

Mapping Patterns of Air Temperature

Isotherms, lines connecting points of equal air temperature are used to map the geographic pattern of temperature across the earth's surface. The spacing of isotherms depicts the temperature gradient across a portion of the Earth's surface. Widely spaced isotherms indicate a small change in temperature over distance and closely spaced isotherms indicate large changes in temperature.

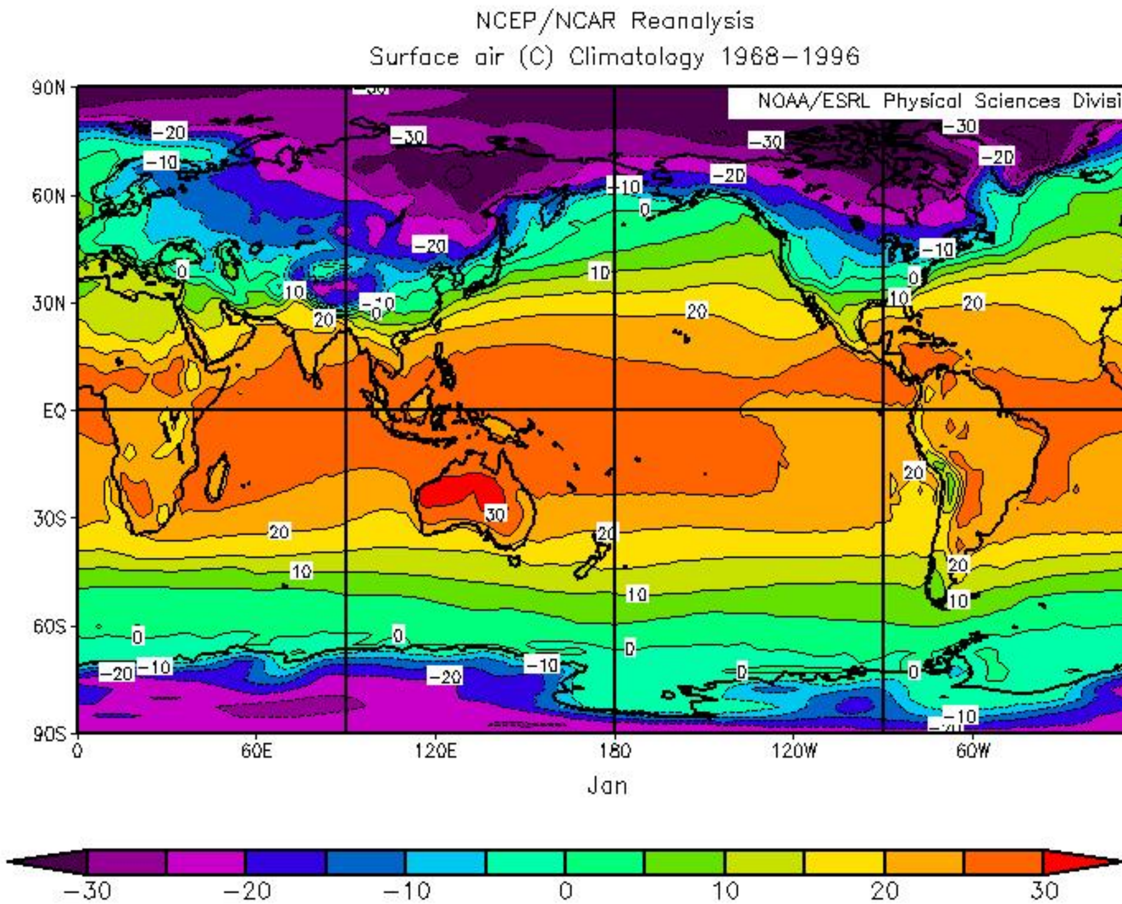


Fig: Average January isotherm.

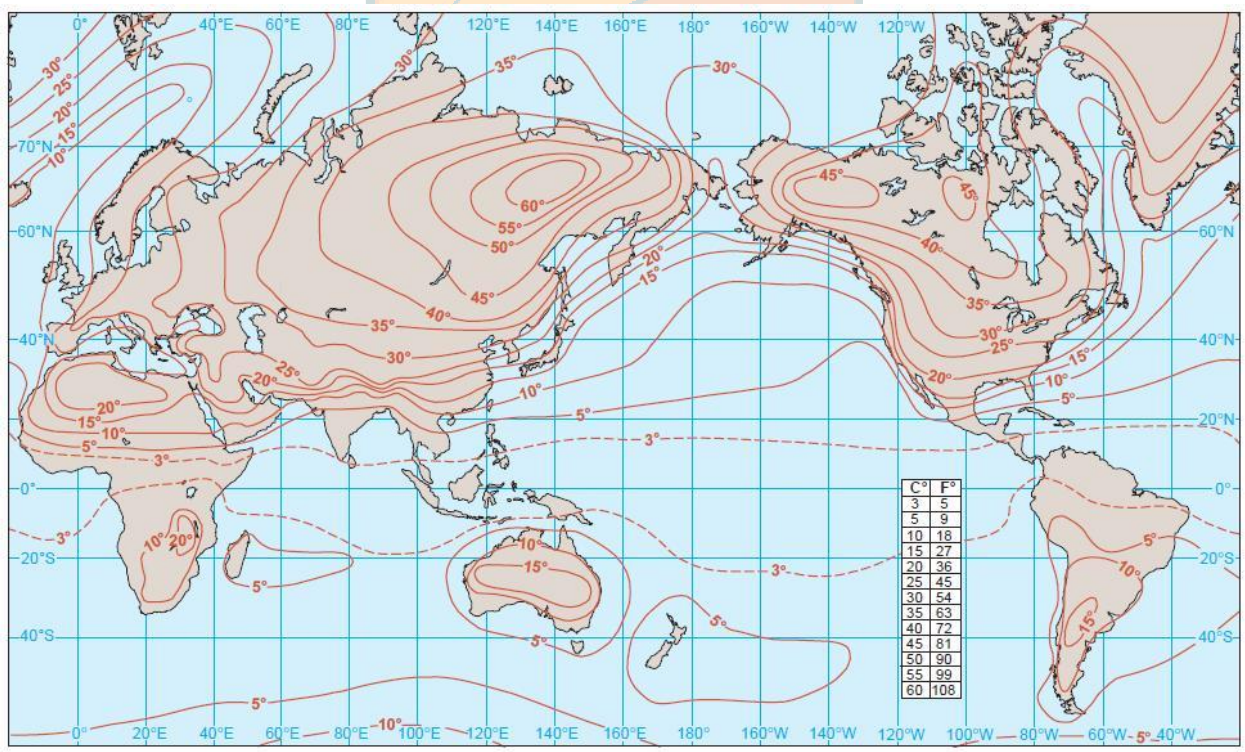
We can certainly see the effect of differential heating of oceans and continents in the average January and July temperature maps depicted in the figures. The isotherms are more linear (straight across) in the Southern hemisphere. Isotherms bend much more between seasons in the Northern Hemisphere than in the Southern Hemisphere. The Southern hemisphere is more uniformly water than the Northern hemisphere. Large landmasses in the Northern hemisphere cause isotherms to bend toward the equator in winter and poles in summer as they change their temperature much more than the water. Air temperatures over land fluctuate more because land changes its temperature much more rapidly than ocean water does. Thus they shift north and south much more over land through the year than they do over water.

(Kindly note how the isotherms are shifting on the land. You might get a question on the shift in prelims.)

Annual Range of Temperature

The difference of the mean monthly temperature of January and July at a place is known as annual range of temperature. The highest range of temperature is recorded in sub polar region in Siberia where average range of temperature is up to 64^{o}C. The southern hemisphere on the other hand produces relatively little annual range in mean temperature. This because of the fact that northern hemisphere have larger land area while it is comparatively very less in southern hemisphere hence temperature range is moderate.

Remember that annual range of temperature at a place is dependent on how far the place is from the ocean and latitude. Lesser the maritime effect, higher is the annual range i.e. difference between the mean highest and mean lowest temperature.



3.23 Annual range of air temperature in Celsius degrees

The annual range of air temperature is defined as the difference between January and July means. Near the Equator, the annual range is quite small. In continental interiors, however, the range is much larger—as large as 60°C (108°F) in eastern Siberia.

Diurnal Range of Temperature

The difference of the highest and the lowest temperature in a day at a place is called the diurnal range of temperature. Desert areas record the highest diurnal range of temperature as during the day the temperature gets very high while during night the temperature sharply falls giving a high temperature range.

The diurnal range is markedly different across the latitudes. At equator the diurnal range is higher than the annual range of temperature while at the poles the diurnal range almost becomes zero as there is day for 6 months and night for 6 months.

Also the daily range of temperature on the land is higher than it is on the oceans. There are several reasons for the low range over the oceans. First the heat capacity of water is very high i.e. the water takes higher time to heat up and also once heated it cools down slowly. Secondly, there is a mixing of surface water with the water below that modifies heating and cooling.

Also the solar radiations penetrate water to greater depth than it does on land.

Heat Budget

The global heat budget is the balance between the heat received by solar radiations and outgoing heat. The net difference between the incoming solar radiations and outgoing heat is zero.

The average temperature of earth is around $15^{o}C$ which is conducive for the growth of life on earth. Had there been a surplus of heat i.e. the heat trapped by the earth is more than the heat released, than the temperature would have been ever increasing making earth inhabitable. Also if the heat released was more than the heat received, the temperature would have gradually reduced again making the earth lifeless.

Insolation: The energy trapped by the earth is called insolation. It is estimated at 480km above the earth's surface to be 1.968 $cal/cm^{2}/min$. this is called solar constant. The amount of solar radiation reaching any place during one day depends upon:

1) The area and nature of the surface

2) The inclination of the rays of the sun

3) The transparency of the atmosphere.

4) The position of earth in its orbit.

The amount of insolation received at a place varies with the sun moving in the horizon from morning to evening. It also changes yearly as the tilt of the earth changes. Insolation is the single energy input driving the earth's atmospheric system.

Albedo: The fraction of radiation reflected back in the space from the earth's atmosphere and surface without causing any heating is called Albedo. The average albedo of earth is 0.31 i.e. 31%. The value of albedo depends upon the surface on which the radiation is falling. For example the albedo of snow can be as high as 0.9 while it is much lower for a darker surface, as it absorbs more heat.

In general, darker colours have lower albedo and lighter colours have more albedo. On water surface, the angle of the solar rays also affects albedo values; lower angles produce reflection than do higher angles. Also smooth surfaces increases albedo while rougher surfaces reduce it.

Heat budget

The global radiation budget has three major components:

1) Solar radiation in coming at the outer limits of the atmosphere(Q)

2) The planetary albedo(a)

3) Outgoing long wave radiation from the earth to space.(L)

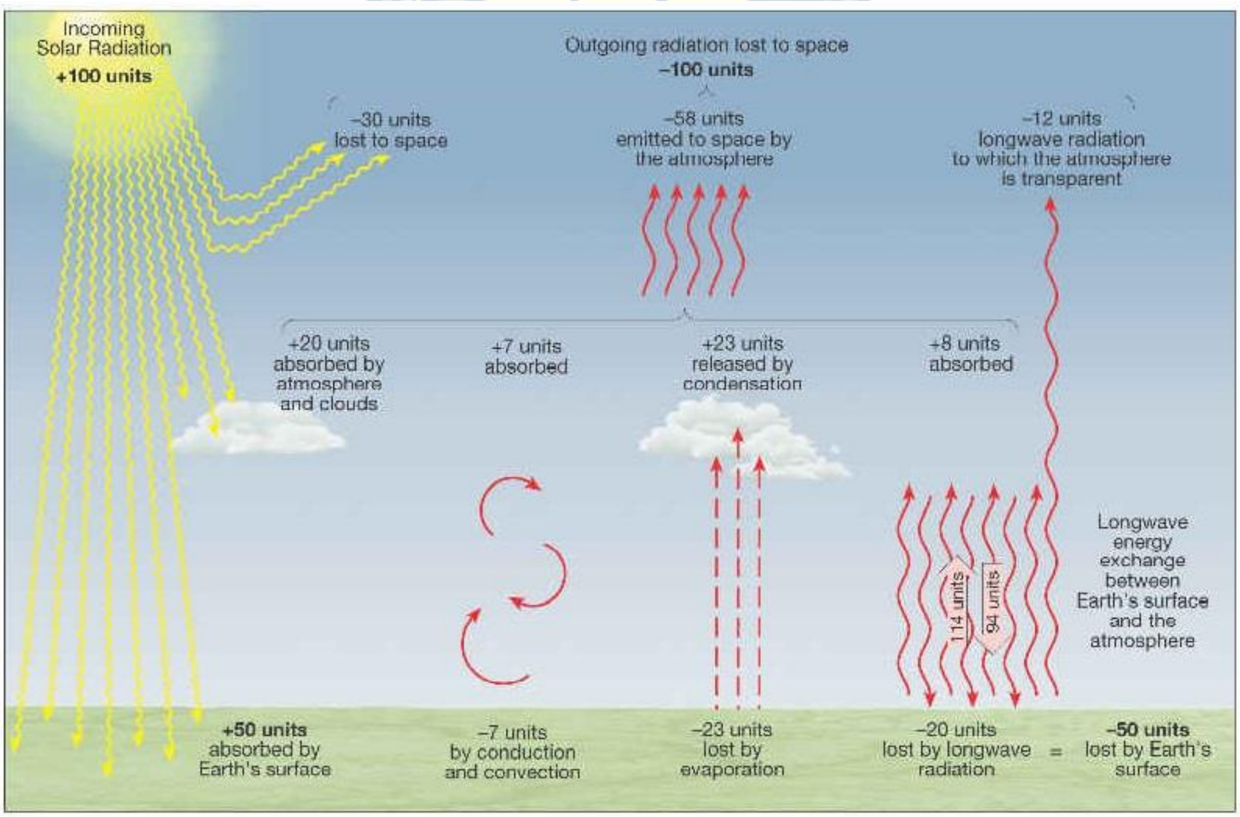
Thus the basic form of equation for the earth and its atmosphere is

R = Q (1-a) – L

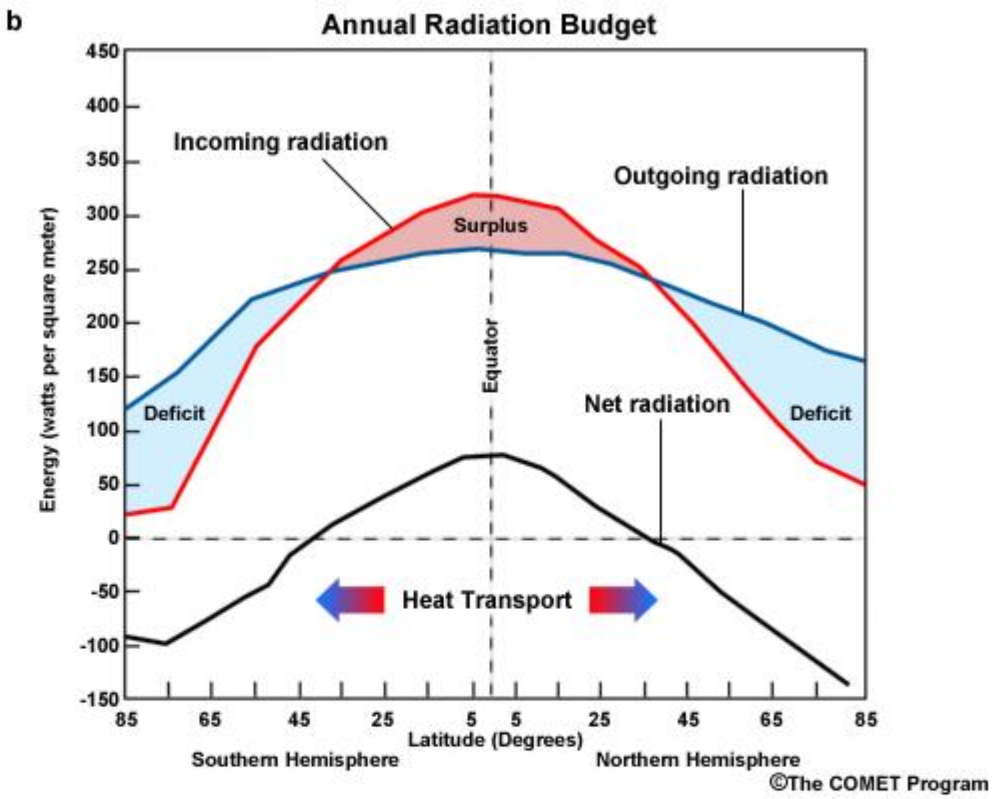
Here, R is radiation balance (surplus or deficit) and (1-a) is the percentage of total insolation which is absorbed by the earth and atmosphere. Of the total incoming radiation about 26% is reflected by the clouds and gas molecules without heating the air, 4% is reflected to space from the earth's surface. Hence the mean albedo of earth is taken as 30%.

Almost 20% of insolation is absorbed in the atmosphere by gases, clouds and suspended particles. The earth's surface absorbs 50% of the insolation either directly or after scattering by the clouds and atmosphere. Thus, approximately 70% of total insolation is effective in heating the earth and its atmosphere.

Everybody in the universe radiates at certain wavelength. Higher the temperature of the body, shorter is the wavelength hence higher energy. The earth is also a radiating body. In contrast to sun which radiates at 6000^{o}C, earth has an average temperature of 15^{o}C. It emits terrestrial radiation at much larger wavelength. The atmosphere has the ability to absorb a large part of this long wave radiation. This ability of atmosphere to allow the short infrared radiations coming from sun to penetrate while absorbing the long wave radiations and not allowing them to escape easily is called Greenhouse effect or in more appropriate terms Atmospheric effect. Besides the long wave radiations from the earth's surface, there is also radiation from cloud layers, gases (especially water vapour and carbon dioxide) and dust to space. The total amount of energy reaching the earth over a considerable period of time is equaled to total outward losses.



However, at a particular place the radiation balance is rarely balanced. At lower latitudes there is an annual surplus of energy receive while at higher latitudes there is an annual deficit. At higher latitudes the energy received is much lower than the tropics as the radiations received are slant. Energy received is lower than the energy radiated. While at tropics the case is opposite. The complete weather phenomenon takes place in order to distribute this heat on earth. This can be shown by the following graph.



Atmospheric Circulation

The movement of air in the atmosphere is called atmospheric circulation. Earth's atmospheric circulation is an important transfer mechanism for both energy and mass. The process occurs to balance the energy surplus of tropics and energy deficit of poles. The atmospheric circulation takes place by the movement of air in atmosphere. It can be horizontal and vertical.

The horizontal movement of air is called a Wind. Winds are generally named after the direction from which they are coming. For example, a wind blowing from sea towards land is called sea breeze, a wind blowing from East to West is called an Easterly etc.

The vertical movement of air is called an updraft, if the air parcel is moving up and a downdraft, if the air parcel is moving down.

(Note: Kindly note the difference between winds and drafts. Generally people think that any movement of air is called wind.)

In atmospheric circulation the speed and direction of winds is controlled by several factors. They are-

Gravitational force of Earth: the gravitational pull of earth is practically uniform, equally compressing the atmosphere uniformly. The air pressure and density of air decreases with increase in altitude.
Pressure gradient: the rate of change of pressure of air is called pressure gradient. The air moves from high pressure area to low pressure area.
Coriolis force: It is a deflecting force experienced due to rotation of earth. Because of coriolis the air appears to turn towards its right in the northern hemisphere and towards its left in the southern hemisphere. The coriolis always acts in the perpendicular direction of the motion of air. It is zero at the equator and increases towards the poles.
Friction force: It is a drag force which causes resistance to the motion of air as it flows on the surface. It decreases with height above the surface. The effect of surface friction is felt up to the height 500m above the surface. It varies with surface texture, wind speed, time of day and year and atmospheric conditions.

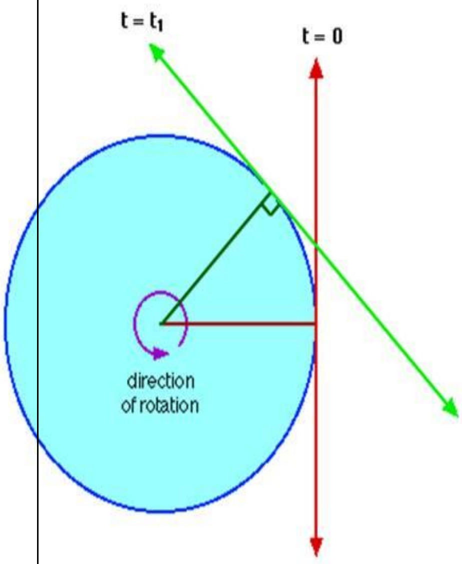
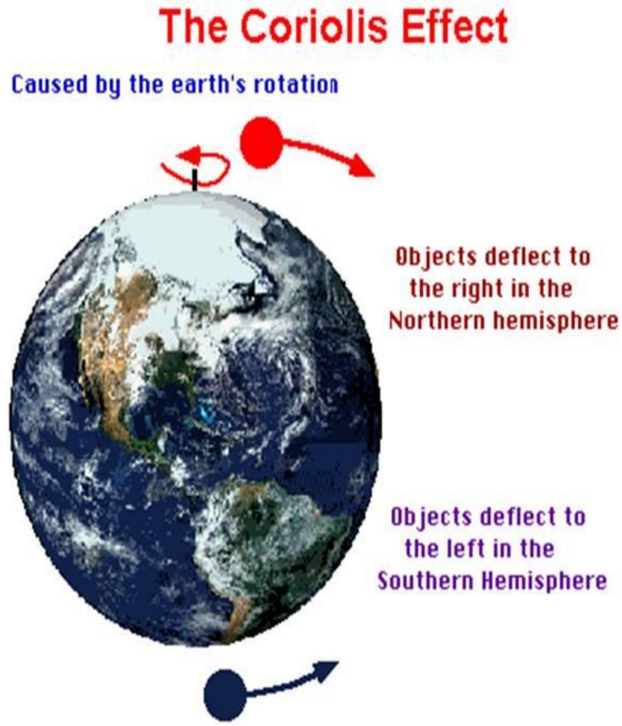
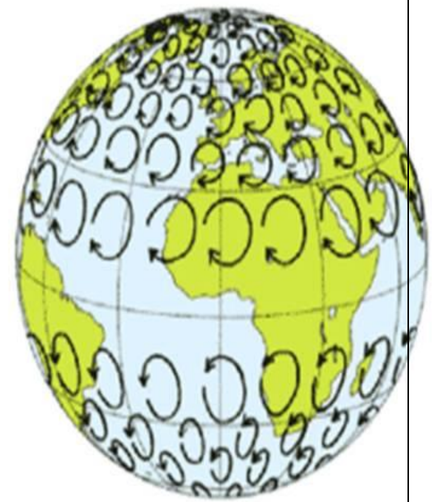


Figure 2: Change in the direction of "East" in a rotating system.

http://www.eyrie.org/~dvandom/Edu/newcor.html



http://www.theozonehole.com/coriolis.htm



http://en.wikipedia.org/wiki/Coriolis_effect

Coriolis Force

- Due to the rotation of the Earth
- Objects appear to be deflected to the right (following the motion) in the Northern Hemisphere
- Speed is unaffected, only direction

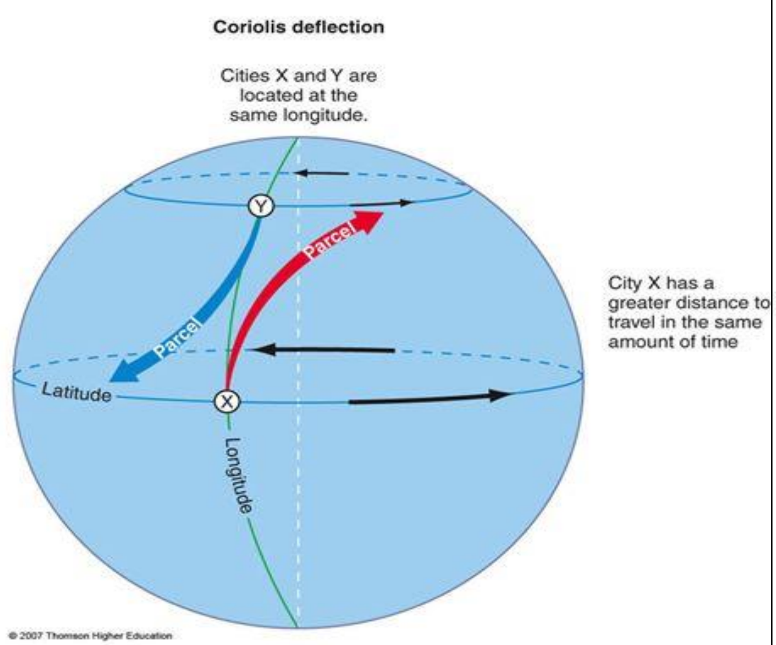
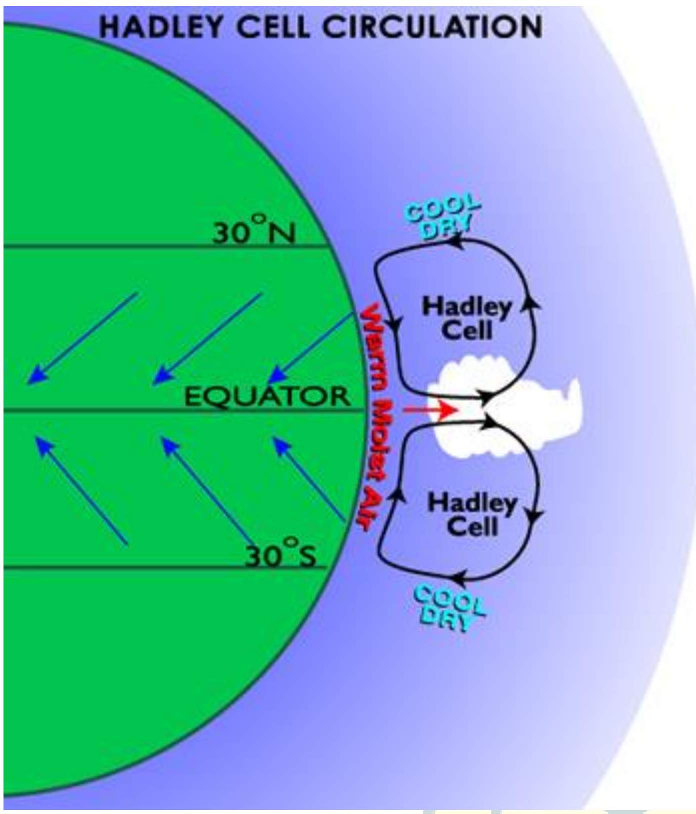


Fig. 6-9, p. 165

Meridional Circulation

The concept of meridional circulation was first put forward by **Sir George Hadley** in 1735. He postulated that the air circulates in giant cells in both the hemispheres where cold air falls at the pole and moves along the surface towards the equator. Where the air coming from the poles collides and rises up and travels towards the pole in upper atmosphere completing the convectional loop.



But later it was found that instead of one giant loop there are three different loops forming in the atmosphere which causes global pressure belts and global winds.

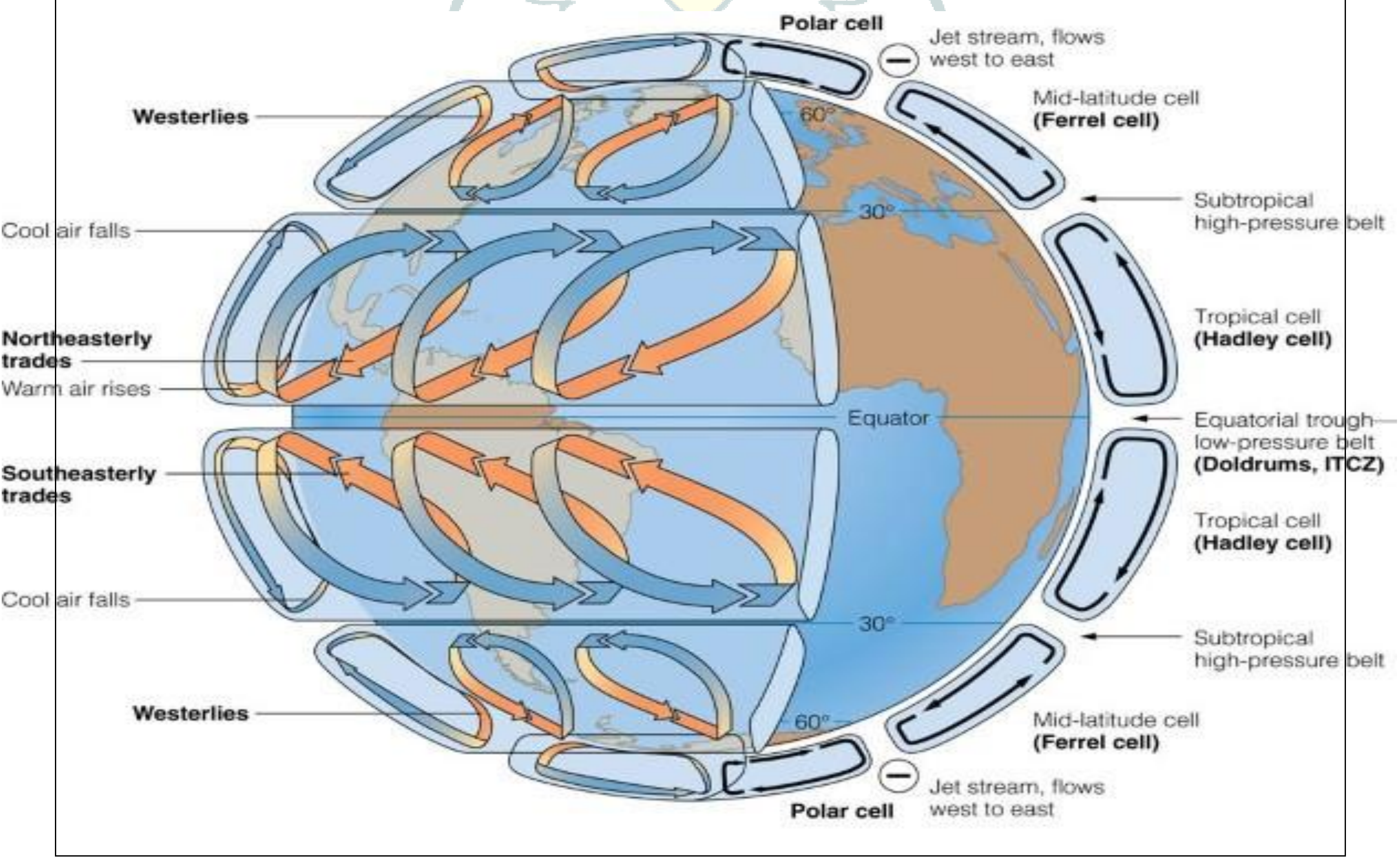
This tri cellular model was given by Palmer in 1951. The three different loops are called **Hadley cell, ferrel cell and polar cell.**

Tropical or Hadley cell: there are two Hadley cells found in both hemispheres between 30oN and S latitudes. The heated air rises near the equator in Inter Tropical Convergence Zone (ITCZ), flowing pole ward aloft, it descends at the latitude 30o-40o. This descend causes a high pressure belt known as sub-tropical high pressure belt. This descending then flows either toward the pole or towards the equator. The winds flowing towards the equator turns towards their right in northern hemisphere and towards their left in southern hemisphere due to coriolis. These are called trade winds or tropical easterlies.

Similarly, the winds flowing from tropical high pressure belt towards the poles appears to move west to east. They are called Westerlies.

Ferrel cell: The mid latitude circulation cells are known as Ferrel cells. The winds blowing from the tropical high pressure belt towards the poles encounters high density cold air coming from the poles and rises near 600N and S latitude and move towards tropics in upper air circulation and descends at tropical high pressure belt.

Polar cell: The air that has grown cold over the polar surface starts flowing towards the equator. It encounters the warm air coming from the tropics. As there is high density difference the air does not easily intermix but ascends and moves towards the poles completing the third loop. The surface winds coming from poles towards the subpolar low pressure belt are swift and because of high coriolis effect near the poles, turns towards their right in northern hemisphere and left in Southern Hemisphere. Since they appear to come from east, they are called polar easterlies.



Planetary or Permanent Winds

The trade winds or easterlies, the anti-trade winds or westerlies and polar easterlies are called planetary winds. These winds follow a defined track throughout the year.

Trade winds: these are the winds with an easterly component which blow from sub-tropical high pressure belt to equator. They derive their name from the Latin word "trado" which means constant direction. The trade winds blow with great regularity over the oceans throughout the year.

The main function of the trade winds is to remove surplus heat from the sub-tropical high pressure belts by evaporating great quantity of water vapour from the tropical oceans. This process helps in maintaining the global heat balance. Although quite, the tropical cyclones are experienced in this belt. In general the speed of the trade winds varies from 15-30 km/h.

Doldrum: the quite zone at ITCZ is called the doldrums. The air appears to be stagnant in this belt. Earlier ships used to get stuck in this region because of the absence of the wind.

Horse latitudes: the sub-tropical high pressure belt of the oceans of North Pacific and North Atlantic oceans is known as horse latitudes. This is a belt of weak variable winds and frequent calms.

Westerlies: These are the permanent winds blowing from sub-tropical high pressure belts towards sub polar low pressure belts in both the hemispheres. They blow with great frequency and regularity. The general direction of the Westerlies is from south west to north east in northern hemisphere and from North West to south east in southern hemisphere. The weather in these areas is marked by constant possession of depressions of temperate cyclones and anti-cyclones moving east wards.

Polar Easterlies: The polar easterlies blow between 60 and 90 degree in the Polar Regions. They are generally sporadic and of low velocity. From the polar areas cold air tends to move towards the equator. The polar easterlies are quite pronounced in the southern hemisphere. Being cold and dry polar winds give very little precipitation.

Planetary Winds

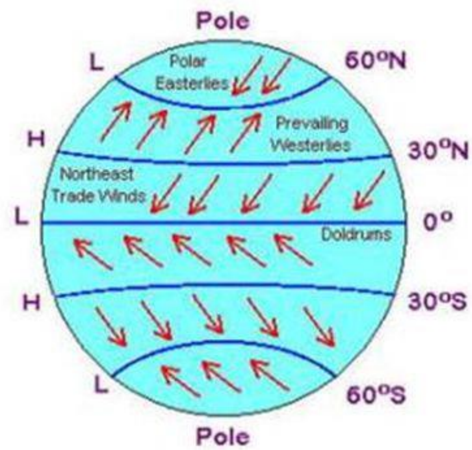
Planetary winds are winds that blow out from high pressure belt to low pressure belts.

There are three types of Planetary winds

1.Trade Winds

2.The Westerlies

3.The Easterlies



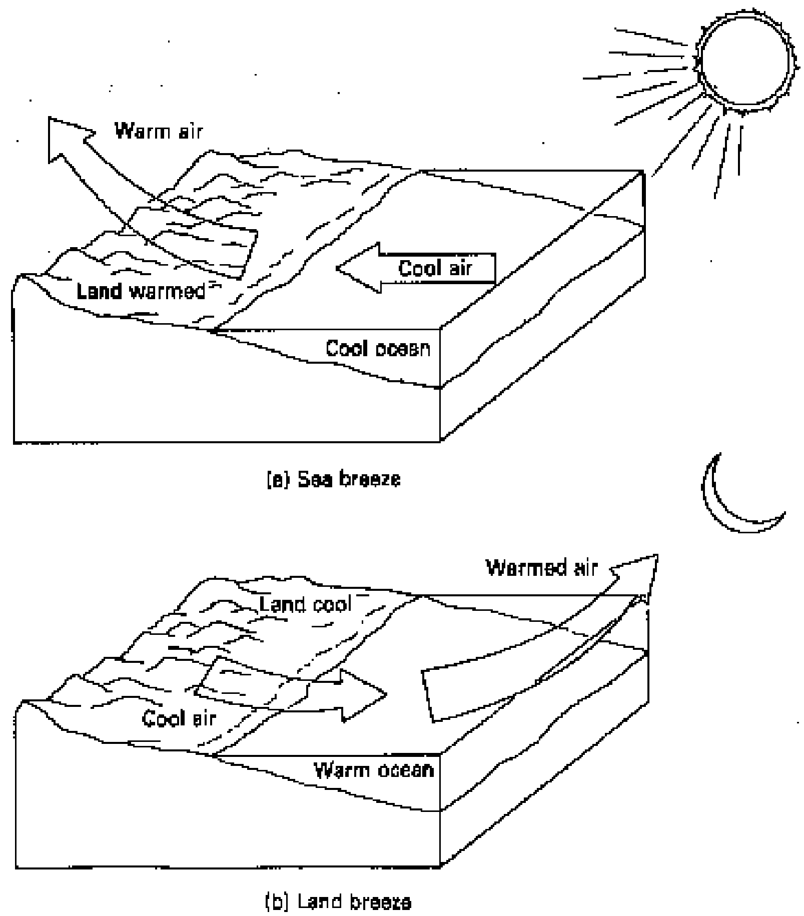
Local Winds

There are several winds which develop in response of the local terrain. They are known as the local winds. They have a significant impact in the weather conditions of a place and psychology of the society. Some of the prominent local winds are:

Land and Sea breeze: these winds develop as a consequence of the differential heating of the land and sea surfaces. During the day, the land heats up faster and become warmer than the water off shore. Because of this a low pressure area is created over the land surface and relatively high pressure area on sea surface. This causes wind to blow from sea towards the land. This is called sea breeze. On contrary during night, the land loses its heat relatively faster than the sea, hence a breeze starts flowing from land towards the sea surface. This is called land breeze.

These winds are periodic winds and regulate the temperature in coastal areas. The sea breeze has a soothing effect on the weather and increases the efficiency of the people.

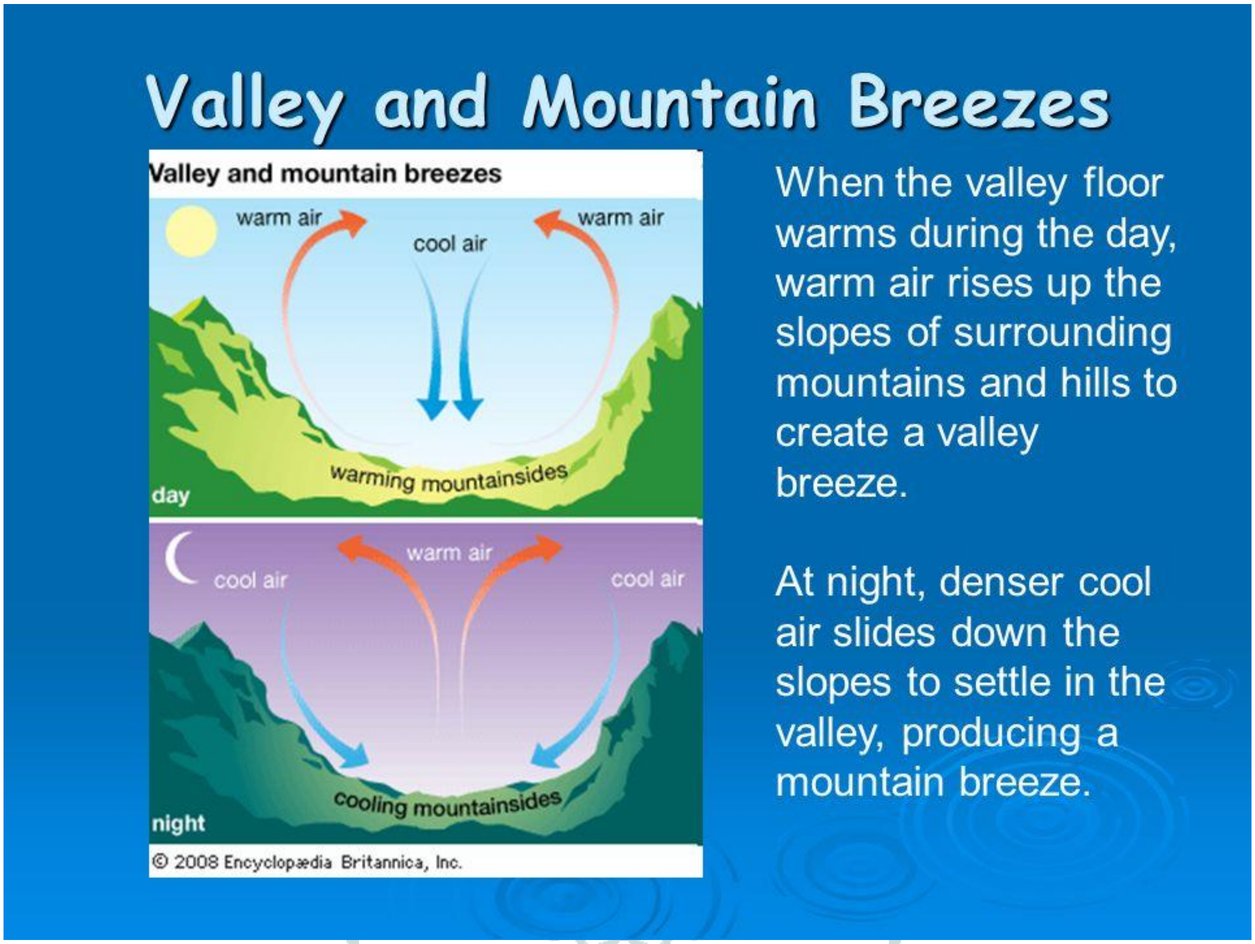
Land-Sea Breezes



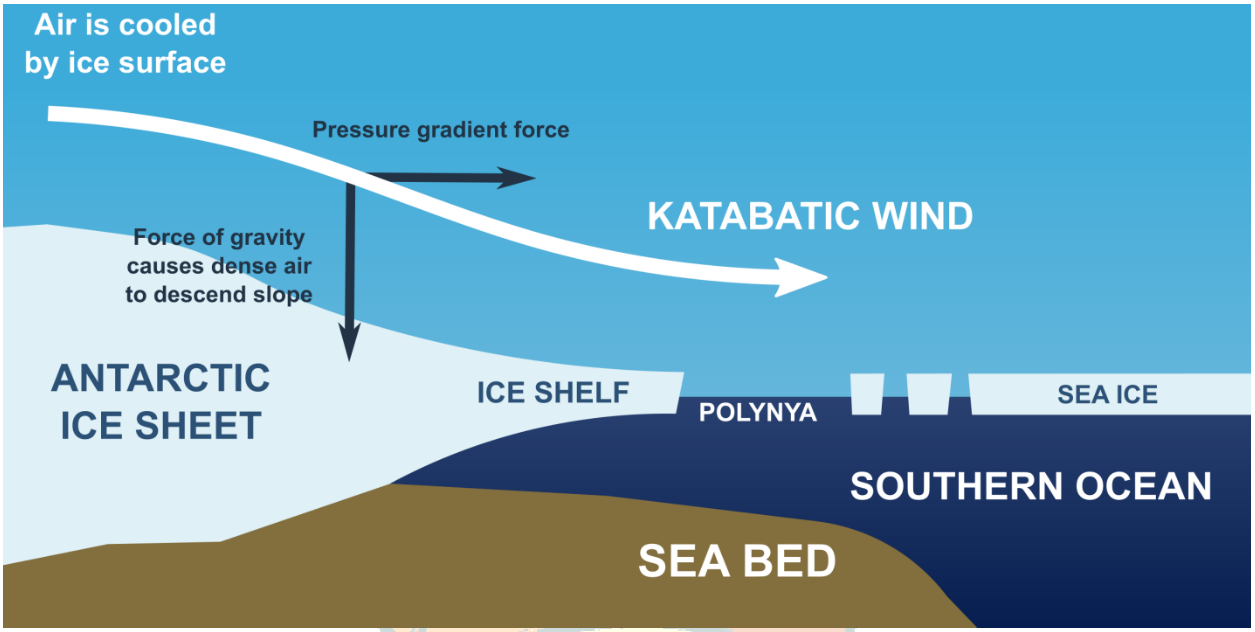
Gross& Gross, 1996.
Oceanography: A view of Earth.
7th edition.

These winds are more pronounced in tropical and sub-tropical latitudes as differential heating is more here.

Mountain and Valley breeze: The mountain and valley breeze also has direction reversal in every 12 hours like land and sea breeze. Mountain air cools rapidly at night and valley air heats up rapidly during day. Thus warm air raises upslope during the day and at night; the cooler air subsides down slope into the valley.



Katabatic winds (gravity drainage winds): They are significant on a large scale than mountain and valley winds under certain conditions. These winds are usually stronger than mountain or valley winds. For these winds to blow, an elevated plateau or highland is essential, where layers at the surface cool, become denser and flow down slope. The ferocious winds that can blow off the ice sheets of Antarctica and Greenland are Katabatic in nature.



Some of the local winds, their region of occurrence and characteristics are given blow:

- **Blizzard:** It is intensely cold fast blowing wind accompanied by snow. Blows in North America.

- **Bora (Adriatic Sea):** it descends from mountains during the winter season. It blows with a speed of 120-150km/h. its duration may be from three to five days.

- **Brickfielder:** it blows from the desert of Australia during the summer season(December to February)

- **Buran:** it blows in central Asia and Siberia. It is a strong cold north easterly wind which reduces the temperature up to -30oC.

- **Chili:** it is a hot dry wind which blows from the Sahara Desert towards the Mediterranean Sea through Tunisia.

- **Gibli:** it blows from the Sahara Desert towards Mediterranean Sea through Libya. It is an extremely hot local wind.it blows during the summer season. It may last for 3-5 days. This wind has extreme effects. Due to heat the government declares the holiday.

- Because of this the shade temperature reaches up to 60 degree C. Sometimes the tyres of the car melt and stick to the road. Even the dry grass catches fire. People shelter themselves in the basements.

- **Haboob:** it is a similar hot wind blowing towards the Mediterranean through Sudan.

- **Karaburn:** it blows from March to May and leads to hazy weather. It is also responsible for deposition of loess in Huwang Ho valley.

- **Khamsin:** hot wind blows in Egypt for about 50 days.

- **Loo:** it blows in summer season in India in northern plains. It is a hot dry wind and raises the temperature. Loo follows a three day cycle. It starts blowing at 9am in the morning till 5 in evening. On its third day, it is accompanied by a storm in the evening called Aandhi and causes little shower taking the temperature down.

- **Mistra:** it blows in Rhone valley of France. It a cold wind blowing during winters. It has adverse effects on orchards.

- **Pampero:** cold and dry wind blowing during winter season in Pampas (Argentina).

- **Samoon:** Hot wind blowing during summers in Iran.

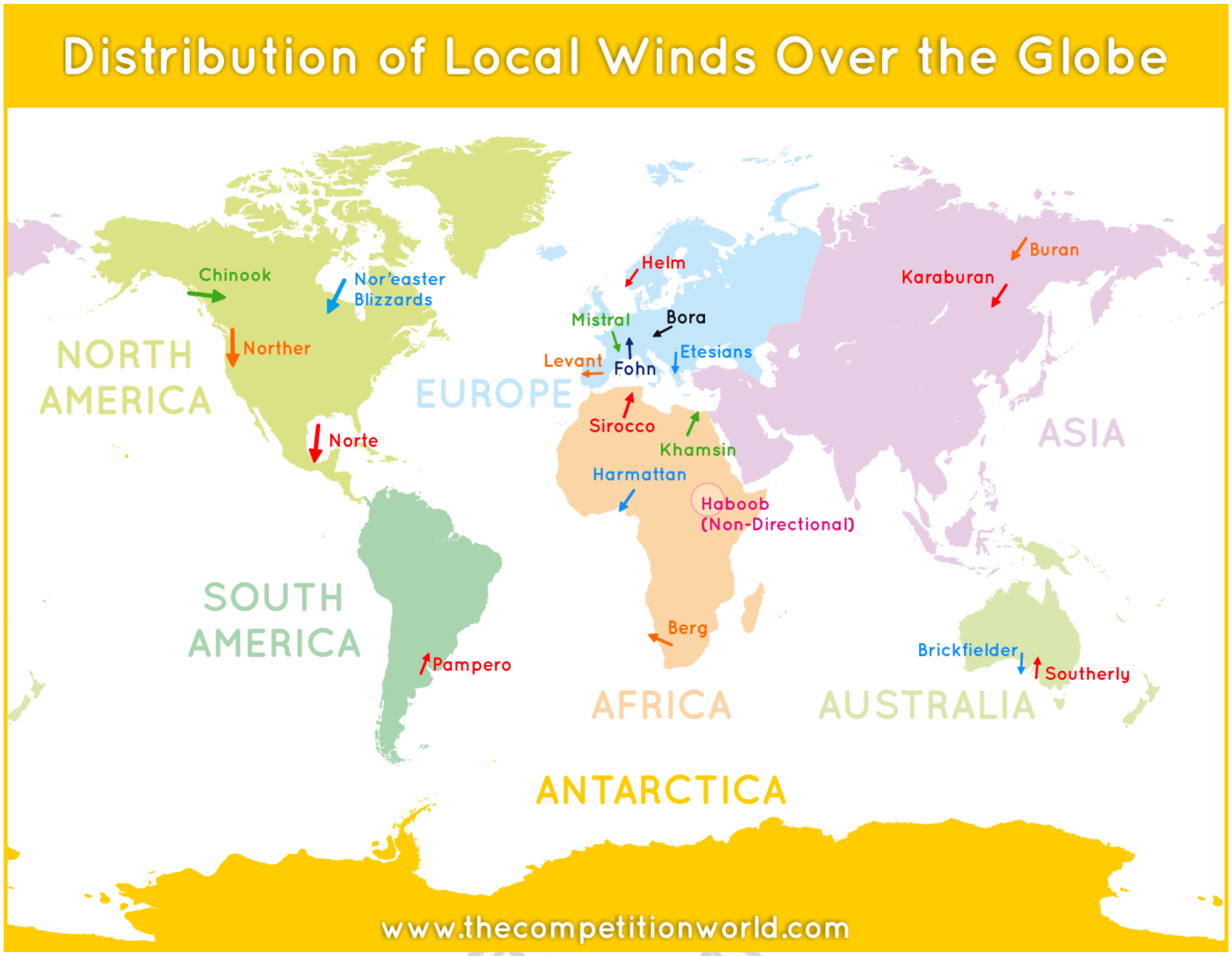
- **Simoon:** Hot wind blowing during summers in Saudi Arabia.

- **Sirroco:** hot and humid wind blowing from Sahara to Sicily during April to July.

- **Foehn:** it descends from the Alps in Germany. It helps in melting of snow during winter season.

- **Berg:** a hot dry wind blowing down the Great Escarpment from the high central plateau to the coast (South Africa)

- **Chinook (snow or ice eater):** it blows in USA and Canada between December and March. It descends on the leeward side of the mountain. It is warm and dry and causes the snow to melt. It has a soothing effect on weather and society.



Distribution of Local Winds Over the Globe
Chinook
Nor'easter
Blizzards
NORTH AMERICA
Norther
Norte
Helm
Mistral
Bora
Levant
Fohn
Etesians
EUROPE
Sirocco
Khamsin
Harmattan
Haboob
(Non-Directional)
Buran
Karaburan
ASIA
SOUTH AMERICA
Pampero
Berg
AFRICA
Brickfielder
Southerly
AUSTRALIA
ANTARCTICA
www.thecompetitionworld.com

Atmospheric Stability and Cloud Formation

(**Note:** This is the most technical part of Climatology. We have tried to explain it in as lucid language as possible. Kindly read it carefully to properly understand the phenomenon.)

Meteorologists use the term 'parcel' to define a small body of air. Temperature and humidity conditions define a parcel's ability to take off from the ground. Stability refers to the tendency of a parcel of air with its water vapor to either to remain stationary or to ascend or descend. A stationary parcel is called Stable while an Ascending or descending parcel is called unstable.

An air parcel is considered unstable when it continues to rise until it reaches an altitude where the surrounding air has density similar to its own.

As a parcel ascends its pressure decreases with height. Due to decrease of pressure, there is a drop in temperature of the air parcel. As there is no external heat exchange, the process is called Adiabatic process. As the temperature is reduced, it is called adiabatic cooling. The point to be remembered is that, it is different from environmental lapse rate. In case of environmental lapse rate, the temperature decrease with increase in altitude but the air is not moving from its place. In case of Adiabatic cooling, the air parcel itself is moving and there is a drop of temperature in air parcel. **The rate of change of temperature is called Adiabatic rate of cooling.**

Similarly as the parcel descends, the pressure in parcel increases hence there is an increase in temperature. This is called Adiabatic heating.

Condition for instability: When the Adiabatic lapse rate of cooling is lower than the local lapse rate, there is a condition for unstable air.

Cloud Formation

Cloud formation occurs when there is unstable air condition. As the air rises it starts cooling adiabatically. As the humidity present in it is in vapour form, it is called dry adiabatic rate. As the temperature reaches the dew point, the vapour starts condensing into small droplets forming clouds. The height which the condensation starts is called condensation limit. If the parcel is still unstable it will rise more, now because liquid water is present, it is wet adiabatic cooling. The wet adiabatic rate is higher than dry adiabatic rate.

Hence we can say the basic conditions for the formation of clouds are-

- There should be moisture content in air.
- There should be unstable condition of air so that air ascends.
- There should be dust particles present in air to act as condensation nuclei so that condensation occurs.

Types of clouds:

Cloud is an aggregate of moisture droplets and ice crystals that are suspended in air and have great density and extent to be visible. Clouds can be classified on the basis of shape and altitude.

Clouds can be put into three main groups:

- **High Altitude clouds:** These are found 20,000ft or higher above the land surface. Cirrus, Cirrostratus and Cirrocumulus are the cloud types found here.
- **Middle Altitude Clouds:** These are found between 6,500ft to 20,000ft above the land surface. Altostratus and Altocumulus are the cloud types found here.
- **Low Altitude Clouds:** These cloud types can be found from ground level to about 6,500ft above it. They include Stratus, Stratocumulus and Nimbostratus clouds.
- **Vertical Clouds:** These are clouds that extend from the lower to the higher altitude s of the atmosphere. They form by thermal convection or frontal lifting, sustained by powerful convectional current that hold and push the moisture in the clouds further upward. An example of a vertical cloud is the Cumulonimbus cloud.
- **Foggy Clouds:** These form close to the ground. Sometimes they make visibility very poor such that you can hardly see more than 60 away.

Cloud Names:

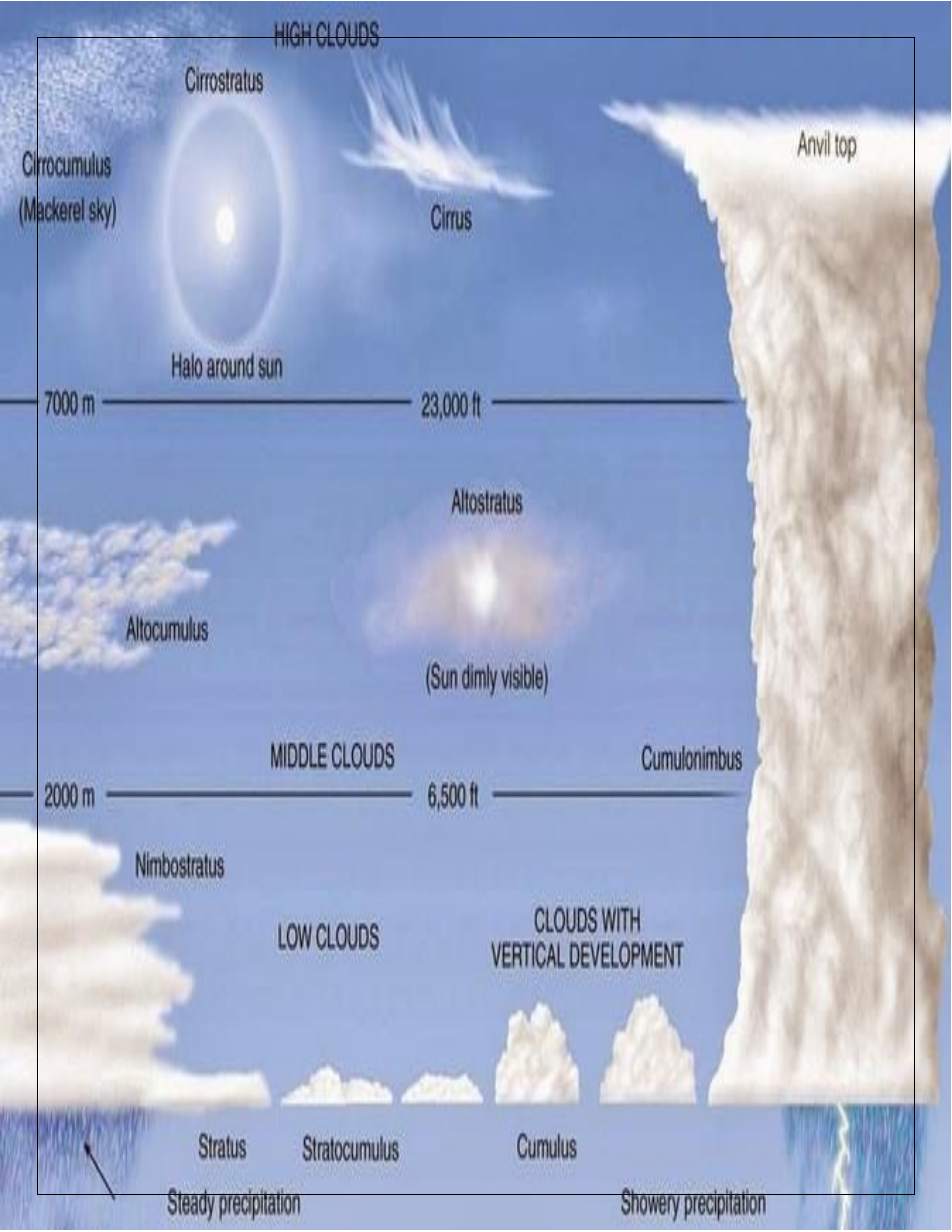
- There are 4 primary clouds, which have specific features of their own. These are Cirrus (meaning curl), Stratus (meaning spread over), Cumulus (meaning pile or heap), and Nimbus (meaning water or rain bearing). They are often combined with many other names to describe other secondary cloud types.

These three basic forms can occur in three altitudinal classes:

- **Low:** ranging from the surface to 2000m. These can be stratus or cumulus. Stratus clouds appear dull, grey, and featureless. When they yield precipitation, they are called nimbostratus. Cumulus clouds on the other hand appear bright and puffy like heap of grinned cotton. They float in varied forms. Vertically developed cumulus cloud can reach up to great heights beyond low middle and high altitudes. When they cause rain they are called cumulonimbus clouds. These look like anvil shaped and they causes thunder and lightning and torrential rainfall.

- **Middle:** stratus and cumulus clouds in the range of 2000m to 6000m come under this category. They are denoted by a prefix alto. They contain both water droplets as well as ice crystals.

- **High:** they lie beyond 6000m. They contain only ice crystals. These are whispy filaments, usually white except when coloured during sun rise and sunset, are termed as cirrus.


HIGH CLOUDS
Cirrostratus
Cirrocumulus
(Mackerel sky)
Cirrus
Anvil top
Halo around sun
7000 m
23,000 ft
Altostratus
Altocumulus
(Sun dimly visible)
MIDDLE CLOUDS
Cumulonimbus
2000 m
6,500 ft
Nimbostratus
LOW CLOUDS
CLOUDS WITH
VERTICAL DEVELOPMENT
Stratus
Stratocumulus
Cumulus
Steady precipitation
Showery precipitation

Forms of Precipitation

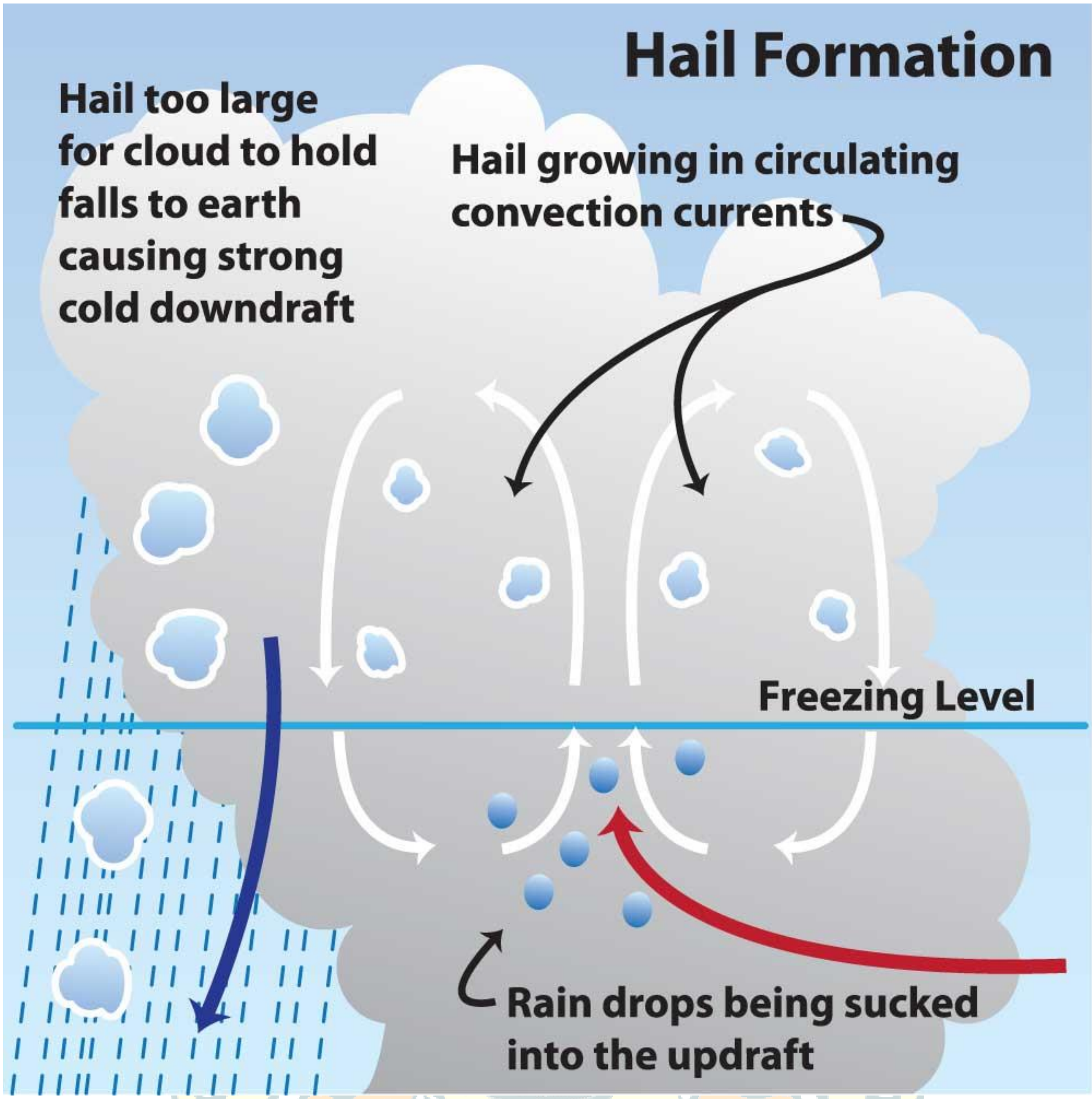
Rain: rain is in the form of liquid droplets. Whenever the rain drops fall from high altitude clouds some of them evaporate while passing through the layer of dry air. On occasions, falling raindrops completely evaporate before reaching the ground. Such rainfall is called virga. On contrary, when there is thick cloud cover and lower air is moist, there is heavy downpour. In this type of rainfall the raindrops are large and more numerous. Generally the second type of rainfall is more frequent.

Drizzle: when the drops of rain are very small and are of uniform size and seem to float in the air, it is called drizzle. The radius of drops is less than 500 microns. The relative humidity in the inter-layers of air between the cloud base and the ground is often nearly 100%.

Snow: it is a precipitation of white and opaque crystals of snow. This occurs when the cloud formation occurs below 0 degree C.

Sleet: it is a type of precipitation in the form of mixture of rain and snow. It is a frozen rain which forms when rain while falling to the earth passes through a layer of very cold air mass. Sometimes sleet may grow into hailstorms when violent vertical currents are produced in the atmosphere.

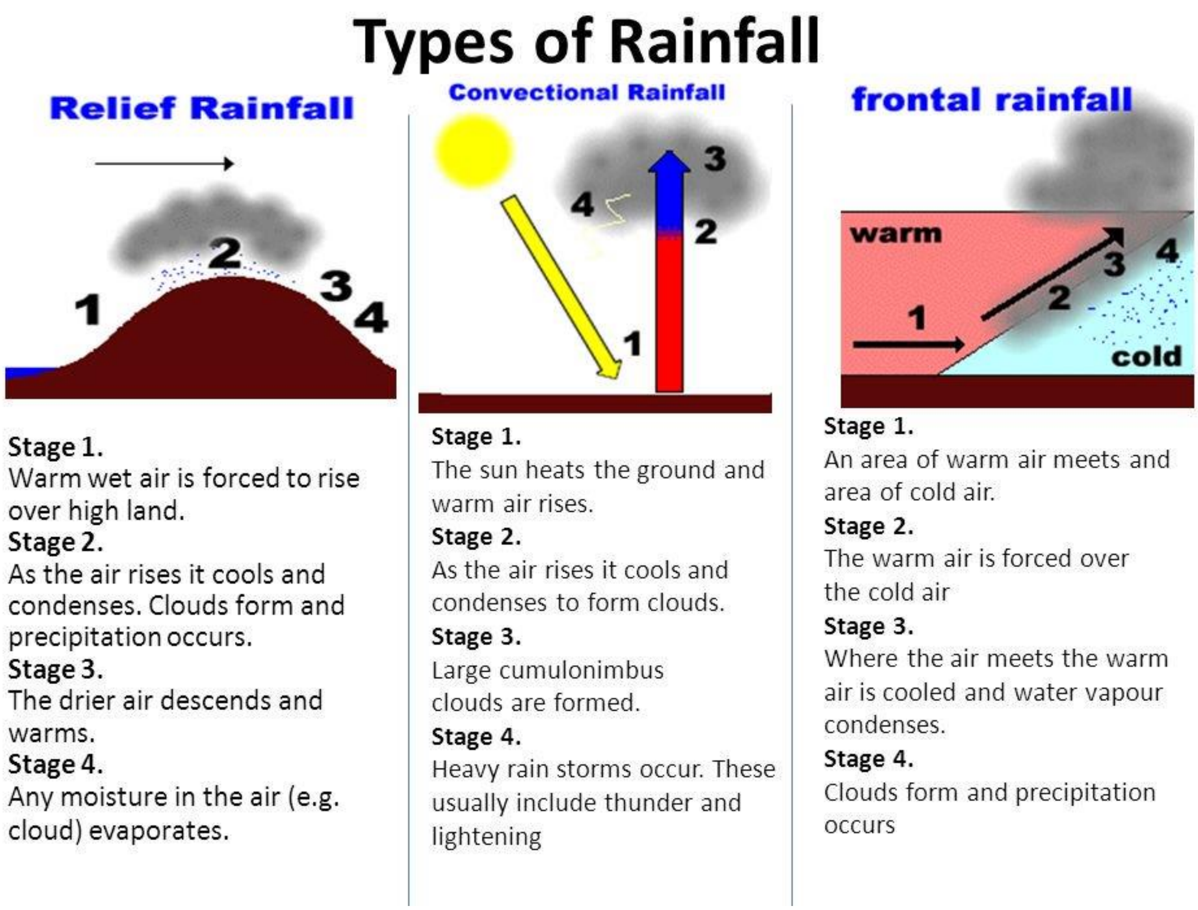
Hail: It falls in the form of small ice pellets. Hail is the most destructive form of precipitation produced in violent thunderstorms or cumulonimbus clouds. The hail consists of concentric layers of ice alternating with layers of snow. Its structure resembles to that of onion.


Hail Formation
Hail too large for cloud to hold falls to earth causing strong cold downdraft
Hail growing in circulating convection currents
Freezing Level
Rain drops being sucked into the updraft

Types of Rainfall

On the basis of mode of occurrence, the rainfall can be classified into three categories:

- **Convectional rainfall:** it occurs in the areas of intense heat and abundant moisture. Solar radiation is the main source of heat to produce convectional currents in air. The belt of doldrums and equatorial region generally records this type of rainfall. This type of rainfall is not much effective for crops as most of the water is drained off in the form of surface drainage.
- **Orographic rainfall:** This type of rainfall occurs from vertical uplift of an air stream by the topographic barriers. This type of rainfall occurs on the windward side of the mountain ranges. On windward side also the amount of rainfall starts decreasing after certain height.
- **Cyclonic or frontal rainfall:** cyclonic rainfall occurs when deep and extensive air masses converge and move upward which lead to their adiabatic cooling. We will discuss about cyclones in further details.



Cyclones

Frontogeneses and Temperate Cyclones:

Air mass: An air mass is a distinctive, homogenous, body of air in terms of temperature, humidity and lapse rate that takes on the moisture and temperature characteristic of its source region. For example, if an air mass is formed over Canada it will be very cold and dry.

Classification of air masses:

Air masses are classified on the basis of source region, latitudinal position, and temperature and moisture properties. The two main categories of air masses are:

- Tropical or sub-tropical
- Polar or sub- polar

The sub division of these groups is made according to whether the source region is oceanic or continental. They are also sub-divided according to what modifications the air masses experience as they move from their source regions.
To identify the different types of air masses, letter symbols are placed first in the designation. Following that the source region is indicated: Tropical (T), Polar (P), Equatorial (E), Arctic (A) and Antarctic (AA).
'k' (for the German kalt) for the air colder than the underlying surface or 'w' for air warmer than the surface.
On the basis of origin it can be maritime and continental.

Air mass	Symbol	Source region	Properties
Maritime equatorial	mE	Warm ocean in the equatorial zone	Unstable, warm, very moist
Maritime tropical	mT	Warm ocean in the tropical zone	Warm, moist
Continental tropical	cT	Subtropical deserts	Warm, dry
Maritime polar	mP	Midlatitude oceans	Cool, moist(winter)
Continental Polar	cP	Northern continental interiors	Cold, dry(winter)
Continental arctic and continental antarctic	cAA	Regions near north and south poles	Very cold, very dry, very stable

The border between the two air masses with contrasting physical properties is known as fronts. A warm front marks the leading edge of a sector of warm air. Cold front denotes the influx of cold air.

The development of fronts and frontal wave forms are known as Frontogenesis. Frontogenesis occurs in well-defined areas.

Cyclones:

Any rotating low pressure system is known as a cyclone. In other words, a thermally or dynamically caused low pressure area of converging and ascending air flows is known as a cyclone. Cyclones may be classified as

- Temperate cyclones
- Tropical cyclones

Temperate Cyclones: the temperate cyclones occur in the mid latitude of both the hemisphere. These cyclones are born along the polar front, particularly in the region of Icelandic and Aleutian sub –polar low pressure areas in the northern hemisphere.

Cyclogenesis: Development and strengthening of mid latitude wave cyclone is known as cyclogenesis. This is called **the polar front theory**, given by Bjerkness in 1918. On an average, a temperate cyclone takes 3-10 days to progress through the stages of development.

The period of cyclone from its inception to its termination is called the 'life cycle of cyclone' which is completed through six successive stages.

Stage A: the first stage involves the convergence of two air masses of contrasting physical properties and direction.

Stage B: it is called 'incipient stage' during which the warm and cold air masses penetrate into the territories of each other.

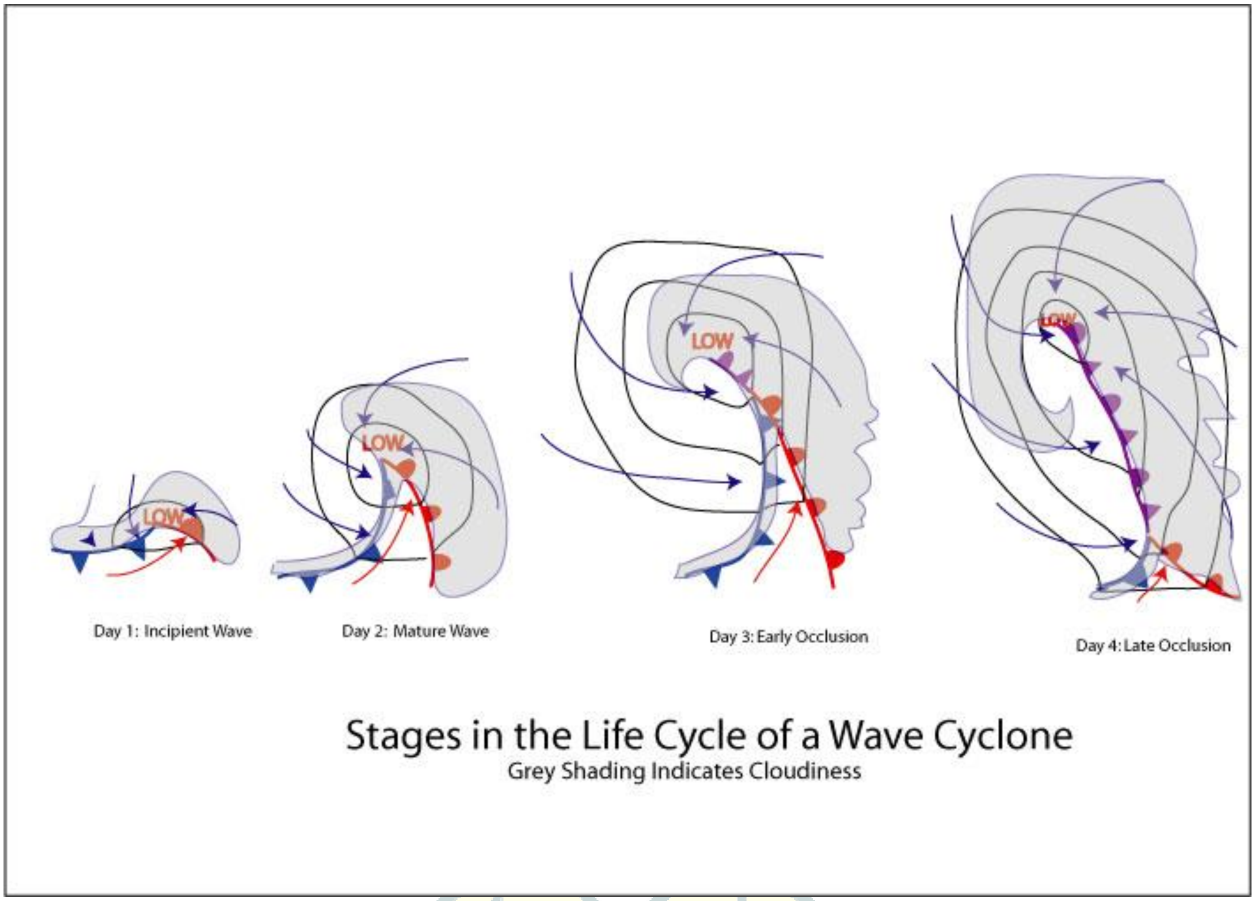
Stage C: it is mature when the cyclone is fully developed and isobars become almost circular.

Stage D: warm sector is narrowed in extent due to advancement of cold front at a faster rate than a warm front, and cold front comes nearer to warm front.

Stage E: this stage starts with the occlusion of cyclone when the advancing cold front finally overtakes the warm front and occluded front is formed.

Stage F: in the final stage, warm sector completely disappears, occluded front is eliminated and ultimately cyclone dies out.

To understand and visualize the formation of Extra – tropical Cyclones, watch the following Video: https://www.youtube.com/watch?v=Vwo9cuDxmVk



Characteristics of Temperate Cyclone:

- The temperate cyclone moves counter clockwise in northern hemisphere and clockwise in southern hemisphere.
- It may be 1600km wide, thus a single cyclone may cover the whole Europe.
- The isobars are elliptical in shape.
- The cold air mass moves faster than the warm air mass.
- These cyclones move at a gentle pace of 5-25km per hour.
- They give light showers which are highly beneficial for the crops and human health and efficiency.
- In the ending part of cyclone there is thunder and lightning.
- Each cyclone is followed by a clear weather.

Tropical Cyclones

It is a weather system of low pressure, originating in the tropics within a single air mass, but may move into temperate waters if water temperature is high enough to sustain it.

Tropical cyclone gets its energy from latent heat of condensation. The energy in an average hurricane may be equivalent to more than 10,000 atomic bombs the size of Nagasaki bomb.

These storms range in size from a few kilometers to several hundred kilometers in diameter. In the middle is an eye that can be as large as 65km across. The total area involved may be as much as 52000 sq km. the tropical cyclones originate between 10o and 25 degree latitudes in both the hemispheres.

Conditions conducive for tropical cyclone:

- There should be continuous supply of abundant warm and moist air.
- The sea temperature in lower latitude should be around 26-27 degree C.
- Existence of weak tropical depression.
- There should be presence of coriolis force.

Characteristics of tropical cyclones:

- The isobars are generally circular, and close to each other resulting into steep pressure gradient.
- They may be a thousand kilometers in diameter and about 15km in height.
- The central area is designated as an 'eye' of cyclone. The eye of cyclone is surrounded by clouds so high and dense that the day time sky above looks dark. The central part of the tropical cyclone has clear sky in which the air descends from the above.
- They do not have fronts.
- They derive their energy from the latent heat.
- The clouds in the cyclone are cumulonimbus having vertical extension up to about 12-15km.
- They give torrential rainfall.
- Majority of tropical cyclones decay when they come over the land or when they recurve northward over oceans.

Origin of Tropical Cyclone:

The origin of the tropical cyclones is not well understood. A tropical cyclone generally develops from a small tropical depression. Tropical depressions forms easterly waves, areas of lower pressure within the easterly trade winds. When air containing the disturbance is heated by the proximity of tropical waters with a temperature of about 26 degree C or more, circular winds begin to blow in the vicinity of the wave, and some of the warm humid air is forced upward. Condensation begins, and the storm takes shape. Under ideal conditions, the embryo storm reaches hurricane status (i.e. with wind speed in excess of 118 km per hr) in two to three days.

Understand Tropical Cyclone: https://www.youtube.com/watch?v=SSx_gisp24w

Places of occurrence:

- The Caribbean Sea and the Gulf of Mexico.
- The northwest pacific from the Philippines to the China Sea.
- The Pacific Ocean west of Mexico.
- The South Indian Ocean east of Madagascar.
- The North Indian Ocean in the Bay of Bengal.
- The Arabian Sea.

Nomenclature:

Large tropical cyclones are called Hurricanes in the North Atlantic and Eastern Pacific, Typhoons in China, Taiphoo in Japan, cyclone or chakravaat in Bay of Bengal, Baguio in Philippines and Willi Willies in Australia.

Tropical Cyclones and Society:

In general the tropical cyclones are destructive. The tropical cyclones can cause loss of the life and property damage. The destructive force of winds to over 300km/hr is self-evident. Torrential rains can cause serious flooding when the storm moves onto land. But the most danger lies in the storm surge, a mass of water driven by the storm known as transgression of sea. Occasionally, there may be sea waves up to 12m in height.

The destructive nature of tropical cyclones may be seen from the fact that in Bangladesh, on 13th November, 1970 a tropical cyclone with wind speed of more than 200km per hour roared up to the mouth of Padma river, carrying with it masses of water up to 12m height. Water and wind clawed at the aggregation of small islands. In only about 20 mins at least 300000 lives were lost and estimates ranged 1 million dead along with huge property damage.

Cyclone, Hurricane, Typhoon

What is the difference between "hurricane", "cyclone" and "typhoon"?

Hurricane, cyclone and typhoon are different terms for the same weather phenomenon: torrential rain and maximum sustained wind speeds (near center) exceeding 119 kilometers per hour:

- In the western North Atlantic, central and eastern North Pacific, Caribbean Sea and Gulf of Mexico, such a weather phenomenon is called "hurricanes".
- In the western North Pacific, it is called "typhoons"
- In the Bay of Bengal and Arabian Sea, it is called "cyclones"
- In western South Pacific and southeast India Ocean, it is called “severe tropical cyclones”
- In the southwest India Ocean, it is called “tropical cyclones”

Temperature Inversion

Usually as we move up in troposphere from the surface, the temperature decreases with increase in altitude. But sometimes due to local conditions, the temperature, instead of decreasing, increases with height. This phenomenon is called temperature inversion. This is also known as negative lapse rate. **The different types of inversions may be classified as –**

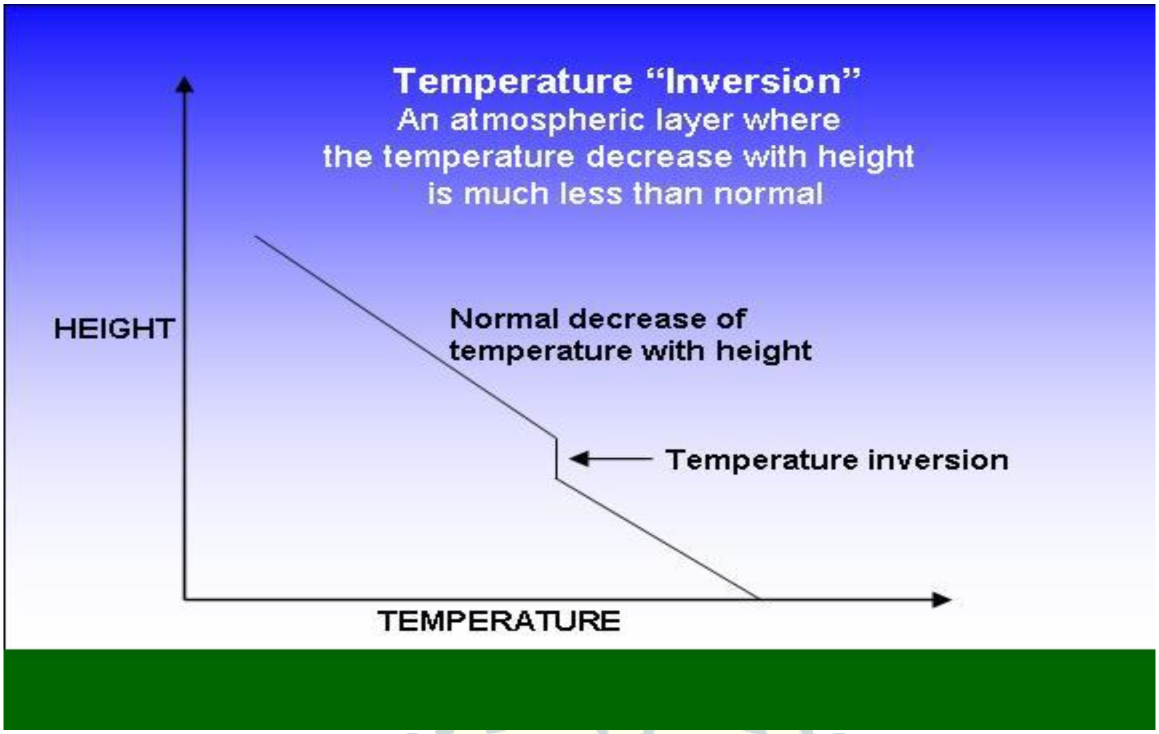
Low level or ground surface inversion: this is the condition where temperature near the ground increases, rather than decreasing with elevation. This type of inversion occurs generally in tropical and sub- tropical regions during the period of long winter nights.

This inversion however, disappears with sunrise. The duration and height of surface inversion increases pole wards. Following conditions are required for ground surface inversion:

- Long winter nights Cloudless calm skies
- Dry air and low relative humidity
- Calm atmosphere or slow movement of air Snow covered surface

Upper air inversion: it occurs when the warm air is transported upwards into the cold air due to eddies. It may be caused due to compression of the descending air as it happens in the case of subtropical high pressure belts.

Frontal inversion: it is caused by horizontal and vertical movement of air. The temperate cyclones are formed by convergence of warm westerlies and cold polar air, and thus the warm air overlies the cold air. The presence of warm air above and cold air below reverses the normal lapse rate and inversion of temperature occurs.



Social relevance of temperature inversion:

The inversion of temperature and its duration affects adversely the society and economy of the region of its occurrence. Some of the important consequences of temperature inversion are-

Occurrence of fog: there develops clouds in contact with the ground (fog) with visibility usually restricted less than 1km. in the urban areas, the fog mixed with smoke takes the shape of smog. While fog is injurious to crops, the smog is considered as a health hazard. In 1952, about 4000 people died of smog in London. Breathing problems, asthma and bronchitis etc. are common problem in Delhi and big cities of the northern India during the winter season.

Road accidents: the frequency of road, railways and air accidents increases during foggy conditions due to low visibility. The trains and flights are often delayed.

Damage of crops: the winter crops like wheat, barley, mustard, vegetables, chilies, potato etc. are seriously damaged. The sugarcane crop in the northern plains of India. Especially in UP, Punjab and Haryana develops the disease of red rod which reduces the sugar content.

Vegetation: Orchards are closely influenced by the inversion of temperature. The lower valleys of Alps Mountains are almost without settlements, while the upper slopes are inhabited.

Upper Atmospheric Circulation

Jet Streams:

Jet streams are high speed winds that occur in narrow bands of upper air westerlies. The width of this air band can be 160-480km wide and 900-2150m thick, with core speed exceeding 300km/hr. such is their strength that aircraft routes which run counter to jet movements are generally avoided. Jets are coincident with major breaks in the tropopause.

Jet streams can be classified as follows:

Polar front jet stream: this is a thermally induced jet stream and it flows parallel to surface fronts. They flow west to east in a sinusoidal fashion. It is strongest at 200-300mb level and swings between 40-60 degree latitude. It is found in both the hemispheres. Its band is non-continuous but flows all-round the year. It can reach up to 160-200 km/hr.

Tropical westerly jet streams: they also flow all-round the year. They flow to conserve the angular momentum in upper atmosphere. They are found at the pole ward limit of

Hadley cell around 30 degree N and S latitude. It follows a more fixed pattern than polar jet stream. It is strongest on Indian sub-continent. The maximum speed can reach up to 300km/hr. the subtropical westerly jet do not seem to affect surface weather as much as the polar fronts jets do.

Tropical easterly jet: they are seasonal jet streams flowing east to west. These are only found in northern hemisphere and generates only in summer season. These are also thermally induced.

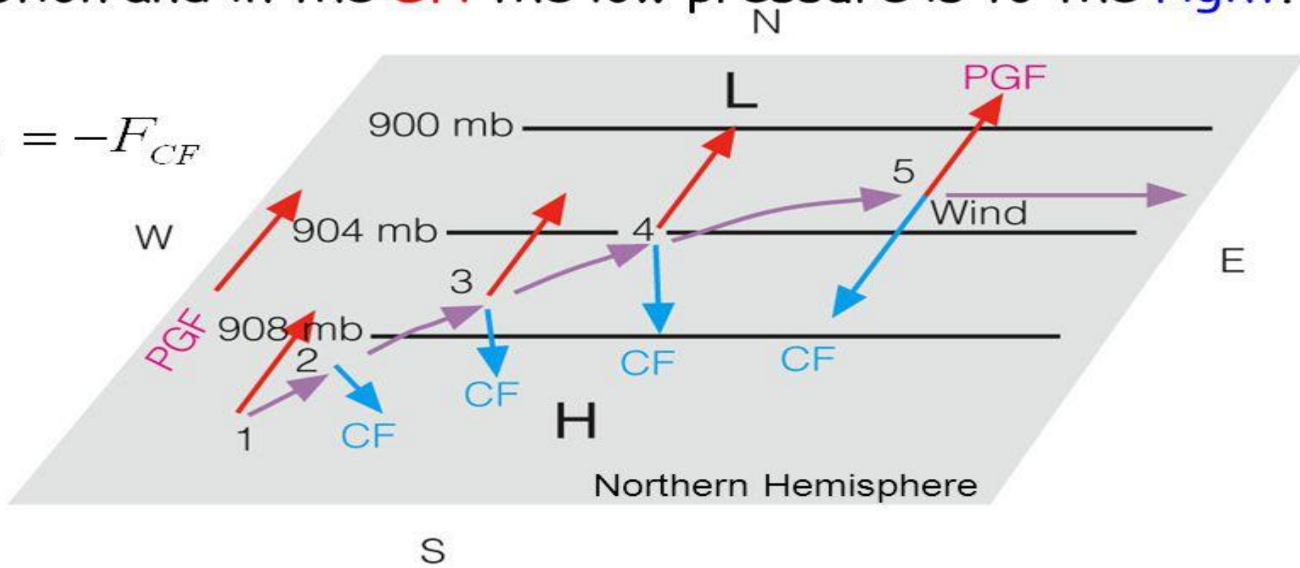
Geostropic Winds: Geostropic winds are those which flows parallel to isobars. These are found in upper atmosphere.

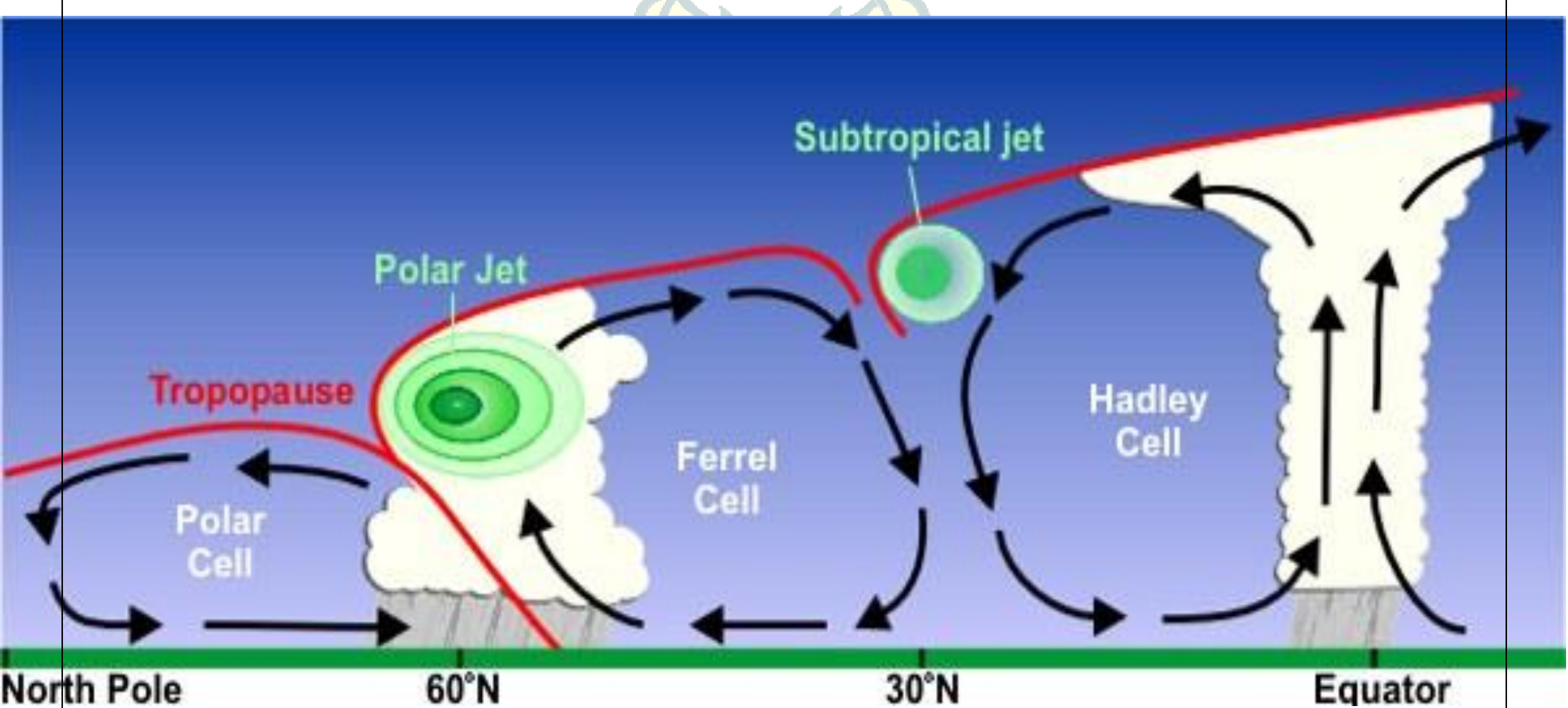
In upper atmosphere, only two forces are present which influences the direction of wind. They are pressure gradient and Coriolis force. At this height friction is not present. As the pressure gradient acts on a parcel of air, it starts moving from high pressure to low pressure. As it moves, the coriolis acts on it perpendicular to its direction changing its direction. As the velocity of wind increases the coriolis also increases making it more and more parallel to isobars. A time comes when the pressure gradient force becomes equal to Coriolis force, nullifying each other. At this time the wind flows at uniform velocity as net force is zero and it will flow parallel to isobars.

Geostrophic Winds: direction

- The pressure gradient force balances the Coriolis force.
- Typically occur at higher altitudes (>1 km).
- The winds are parallel to the isobars.
- In the NH the low pressure is to the left of the wind direction and in the SH the low pressure is to the right.

$$F_{PGF} = -F_{CF}$$





Fun with Climate: D

Some interesting conversations (with High Order Thinking) these days:

Boy Friend (BF, a UPSC aspirant at Rajendernagar): Hey.. How was your day?

Girlfriend: (non-UPSC): Hey, it was good. It was such a cold romantic day. I had a nice hot coffee and thought about you.

BF: Ohh.. Indeed.. cold it was.. You know there must have been a condition of temperature inversion. There was such a dense fog that I couldn't see my coaching center across the road. You know what temperature inversion is? When with increase in height, the temperature instead of decreasing, increases.. Funny phenomenon right..

GF: @#$$%$^$^%$%^…. *BF BLOCKED*

BF (non-UPSC): It's good to see you after a long time. You should take a break from studies and come out more often. See it's such a beautiful day. Cool breeze, Dark clouds, such a romantic weather.

GF (A true UPSC aspirant): Hey, you know nothing. Those dark clouds are very notorious. They are called Cumulonimbus. They cause torrential rainfall with lightning and thunder. And they are so high, almost towering. That's why they are black. They absorb a lot of light and it's difficult for the light to penetrate them. And they are formed by strong updrafts… BABA told us that first dry adiabatic cooling takes place and then wet, and then these clouds are formed. And on the top of it, there must be an anvil shape too… Can you see that baby?? ????
Hey, where are you?

BF: @#$$%$^$^%$%^…. *GF BLOCKED*

Tropical Cyclone: Hey Temperate.. how is life?

Temperate Cyclone: Life's smooth man.. Following the same pattern as every year. Life has become so monotonous and boring. I like your life. So full of energy. You always arrive with thunder and lightning and violent winds. Everyone takes cognizance when you come. So unpredictable. You can arrive at your will. I must say.. you have an 'EYE' which I don't have.

Tropical: What are you saying dude!! I envy your life. People always welcome you. You bring winter rainfall in temperate region. You are so gentle and good for the health of people and of course beneficial for the crops. Look at me… People dread my arrival. They are scared of me. I wish I was as gentle as you.

Temperate: It is all about perception. We both are required. Your violence has taught humans a good lesson. Now they are always prepared for emergency. Also they have stopped destroying their mangrove forest which provides a natural barrier to decrease the intensity of sea surges. It's like we are giving them 'Carrot and Stick' lesson.

Tropical: See you are always positive. ☺ Probably that's why you are called the 'Extra – Tropical Cyclone.'

Note: Try to make these funny Conversations yourself. This will help you to remember the complex phenomenon.

Have a good learning experience.