1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	Atmospheric circulation and weather systems – Part 1
Module Id	kegy_11001
Pre-requisites	Basic understanding of temperature, pressure and winds.
Objectives	After reading this lesson, learners will be able to know about: • Understand the concept of atmospheric pressure and diffrent types of pressure belts. • Define the controlling factors of the pressure system • Define the horizontal and verticle distribution of pressure • Discuss the factors affecting the velocity and direction of wind. • Explain the world distribution of sea level pressure.
Keywords	Pressure, Gradient, Isobar, Pressure Belts, Coriolis, Barometer

2. Development Team

Role	Name	Affiliation
National MOOC Coordinator (NMC)	Prof. Amarendra P. Behera	CIET, NCERT, New Delhi
Program Coordinator	Dr. Mohd. Mamur Ali	CIET, NCERT, New Delhi
Course Coordinator (CC) / PI	Prof. Aparna Pandey	DESS, NCERT, New Delhi
Course Co-Coordinator / Co-PI	Dr. Archana	CIET, NCERT, New Delhi
Subject Matter Expert (SME)	Rajeev Kumar Sinha	St. Xavier's Sr. Sec. School, Delhi
Review Team	Dr. Uttam kumar	MMH College, CCS University, Ghaziabad

As we know that the rotation of the earth and the solar energy causes wind to circulate around the globe. The large-scale motion of wind in the atmosphere over time and space is called the general circulation of the atmosphere, which includes both the horizontal and vertical circulation of the wind. The ocean water also sets in motion by the general circulation of the atmosphere, which influences the earth's climate.

ATMOSPHERIC PRESSURE

The atmosphere consists of air molecules in rapid random motion. Air has mass and weight. Therefore, it also exerts pressure on the surface of the earth. The pressure exerted by a weight of a column of air contained in a unit of area at a given place and time from the mean sea level to the top of the atmosphere is termed as ***atmospheric pressure.*** It is the cumulative force of all molecules colliding with any surface in contact. Atmospheric pressure is proportional to density and temperature. Therefore, a change in either temperature or density will cause a corresponding change in pressure. It can be expressed with an equation:

PRESSURE= DENSITY x TEMPERATURE x CONSTANT

The atmospheric pressure is expressed in units of milibars (mb) or Pascals. At sea level, the average atmospheric pressure is 1013.25 mb (one **mb** is equal to the force of one gram on a square centimeter). The atmospheric pressure is measured by the instrument called ***barometer***. There are two kinds of barometers- mercury and aneroid. The ***Fortin barometer*** is the most commonly used barometer. Due to gravity the air near the surface is denser hence has higher pressure. The pressure dereases with height beacuse at higher elevations, there are fewer **air** molecules above a given surface than a similar surface at **lower** levels. Decline in air pressure indicate poorer weather and rising air pressure better weather. The differences in air pressure is the result of a complex set of factors. However, the underlying cause of these diffrences is simply related with *unequal heating of Earth's land- sea surface*.The pressure data are shown on surface weather maps by means of isobars. ***Isobars*** are the imaginary line connecting places of equal air pressure (iso= equal, bar= pressure). The *spacing* of isobars indicates the amount and direction of pressure change occuring over a given distance and is expressed as the ***pressure gradient***. It is shown by the spacing of isobars on the weather maps. Closely spaced isobars indicate a steep pressure gradient whereas widely spaced isobars indicate a weak pressure gradient. It can be expressed as:

Pressure gradient = pressure change/ distance

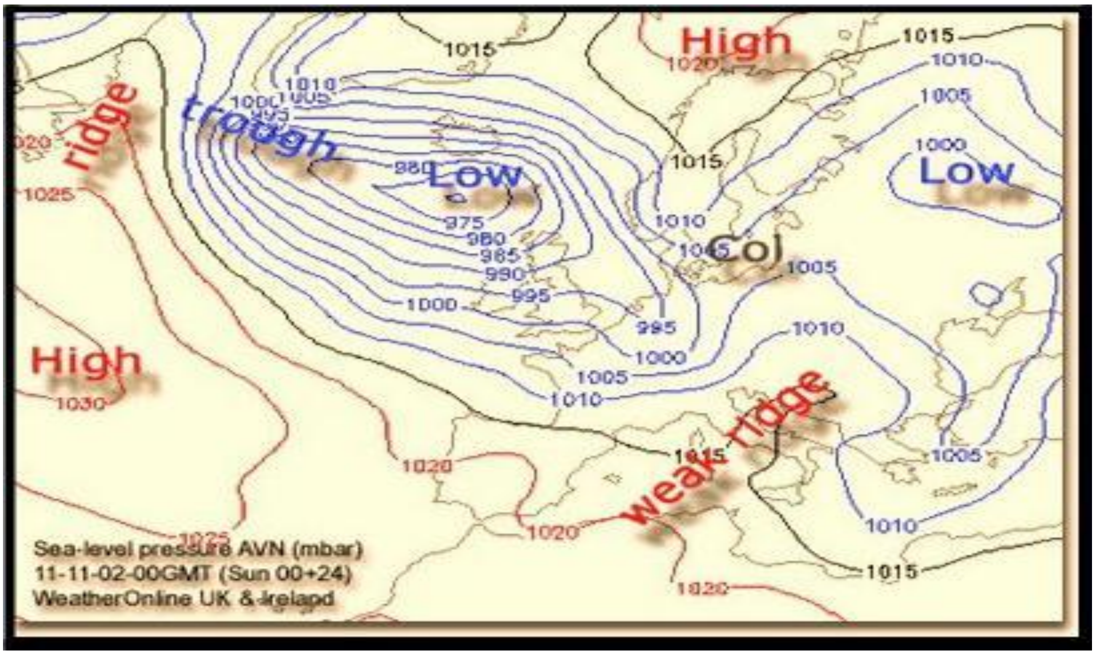

Fig. No. 01 Sea Level Pressure and Pressure Gradient

Source: http://www.weatheronline.co.uk/reports/wxfacts/isobars1.gif

TYPES OF ATMOSPHERIC PRESSURE

1. HIGH PRESSURE- The areas having low temperature will have high pressure. A high-pressure area, also known as ***high*** or **anticyclone** is a region where the atmospheric pressure at the surface is greater than its surroundings.

Winds from high-pressure areas flow outward from their centers towards the lower pressure areas. Gravity adds to the forces causing this general movement, because the higher pressure compresses the column of air near the center of the area into greater density – and so greater weight compared to lower pressure, lower density, and lower weight of the air outside the center.

However, because the planet is rotating underneath the atmosphere, and *frictional forces* arise as the planetary surface drags some atmosphere with it, the airflow from center to periphery is not direct, but is twisted due to the ***Coriolis effect*** (Coriolis effect is an inertial force described by the French engineer-mathematician *Gustave-Gaspard Coriolis* in 1835) . The effect of the Coriolis force is an apparent deflection of the path of an object that moves within a rotating coordinate system. The object does not actually deviate from its path, but it appears to do so because of the motion of the coordinate system. If viewed from above this twist in wind direction is in the same direction as the rotation of the planet.

The strongest high-pressure areas are associated with cold air masses which push away out of polar regions during the winter when there is less sun to warm neighboring regions. These Highs weakens and change character once they move over relatively warmer water bodies.

Somewhat weaker but more common are high- pressure areas caused by atmospheric subsidence, that is, areas where large masses of cooler drier air descend from an elevation of 8 to 15 km after the lower temperatures have precipitated out the lighter water vapor. (H 2O is about half of the molecular weight of the other two main constituents of the atmosphere - Oxygen and Nitrogen.

Many of the features of Highs may be understood in context of middle-or meso-scale and relatively enduring dynamics of a planet's atmospheric circulation. For example, massive atmospheric subsidence occurs as part of the descending branches of ***Ferrel cells*** and ***Hadley cells***. The Hadley Cell encircles the globe from the equator to about 30° latitude in both the hemisphere. The high-pressure of this latitude causes the air near the surface to diverge. This causes air to descend from aloft to "fill in" for the air that is diverging away from the surface. Hadley cells also helps to form the ***subtropical ridge***, steer tropical waves and tropical cyclones across the ocean and is very active during the summer. These subtropical ridges also known as ***subtropical high*** or ***horse latitudes,*** plays important role in the formation of most of the tropical deserts of the world.

On weather maps, high-pressure centers are identified by the English letter H. Weather maps in other languages may use different letters or symbols.

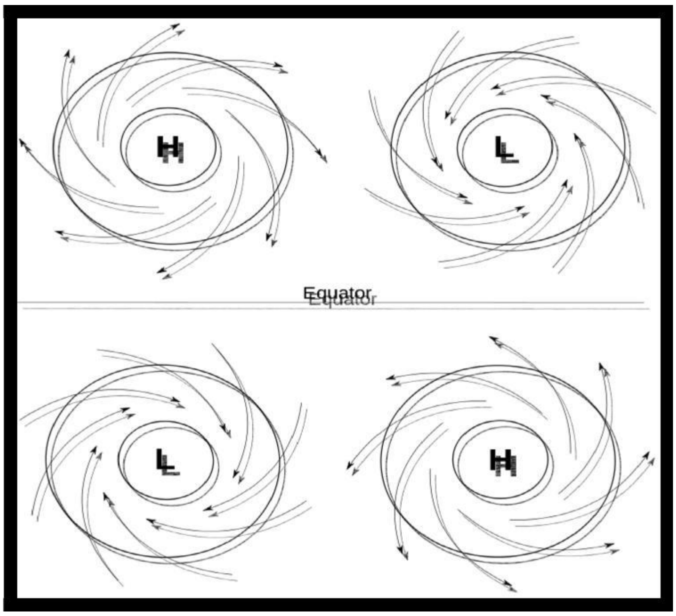

Fig. No; 02 Cyclonic and Anticyclone Movement

Source:https://upload.wikimedia.org/wikipedia/commons/thumb/9/9b/High_and_low_pressure_N_and_S.svg/714px-High_and_low_pressure_N_and_S.svg.png

2. LOW PRESSURE- The areas having high temperature will have low pressure. A low-pressure area is also known as low or depression, and is a region where the atmospheric pressure is lower than that of surrounding environment. Low-pressure systems form under areas of wind divergence that occur in the upper levels of the troposphere. The formation process of a low-pressure area is known as cyclogenesis. Within the field of meteorology, atmospheric divergence aloft occurs in two areas. The first area is on the east side of upper troughs, which form half of a Rossbywave within the Westerlies (a trough with large wavelength that extends through the troposphere). A second area of wind divergence aloft occurs ahead of embedded shortwave troughs, which are of smaller wavelength. Diverging winds aloft ahead of these troughs cause atmospheric lift within the troposphere below, which lowers surface pressures as upward motion partially counteracts the force of gravity.

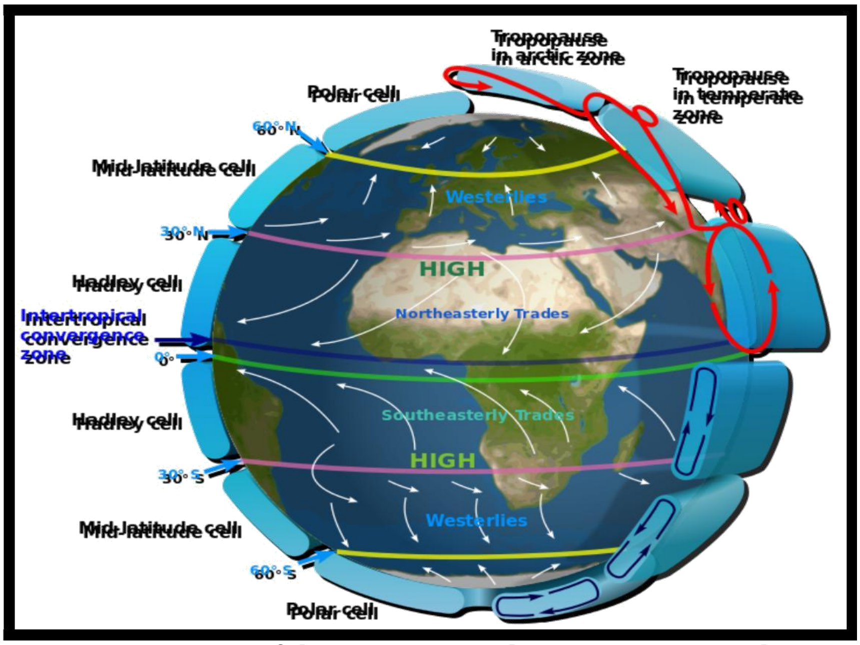

Fig. No; 03 Impact of the Rotating Earth on Pressure Distribution

Source: https://upload.wikimedia.org/wikipedia/commons/9/9c/Earth_Global_Circulation_-_en.svg

Thermal lows form due to localized heating caused by greater sunshine over deserts and other landmasses. Since localized areas of warm air are less dense than their surroundings, this warmer air rises, which lowers atmospheric pressure near that portion of the Earth's surface. Large-scale thermal lows over continents help drive monsoon circulations. Low- pressure areas can also form due to organized thunderstorm activity over warm water. When this occurs over the tropics in concert with the ***Inter Tropical Convergence Zone*** (ITCZ), it is known as a *monsoon trough*. Monsoon troughs reach their northerly extent in August and their southerly extent in February. When a convective low acquires a well-hot circulation in the tropics, it is termed a ***tropical cyclone***. Tropical cyclones can form during any month of the year globally, but it appears normally during the month of November in either of the hemisphere.

Therefore, it can be said that there is an inverse relation between temperature and pressure. This pressure difference is the cause behind the movement of winds. The winds move from the high-pressure region to the low-pressure region.

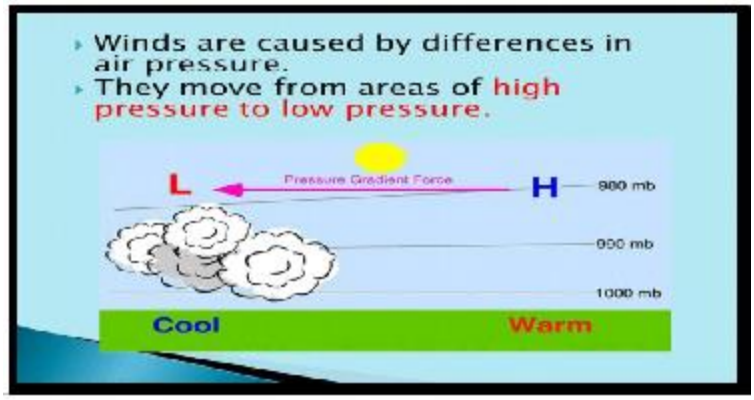

Fig. No: 04 Winds Movement

Source: http://images.slideplayer.com/26/8762796/slides/slide_2.jpg

FACTORS CONROLLING PRESSURE SYSTEM

The following are the major factors controlling the pressure system:-

1) **ALTITUDE VARIATION :** The pressure decreases with height. Pressure is maximum at the sea level and decreases moving upward because the cold air sets down and warm air goes up. At any elevation it varies from place to place and its variation is the primary cause of air motion.

2) **TEMPERATURE:** There is an inverse relation between pressure and temperature. Air expands when heated and becomes lighter and is compressed and heavier when cooled. The air pressure rises when temperature falls and when the temperature rises than pressure falls. This causes variations in the atmospheric pressure. You already know that air in horizontal motion is wind. The wind redistributes the heat and moisture across the globe, thereby, maintaining a constant temperature for the planet as a whole.

3) **EARTH ROTATION:** As we know that, the earth is rotating on its axis so the rotation of the earth causes the air at the poles to be thrown away towards the equator.

Horizontal Distribution of Pressure

The magnitude of horizontal variations in the atmospheric pressure is much smaller than that of the vertical variations in the atmospheric pressure. The sea level pressure generally varies from 950 mb to 1050 mb. The minimum and the maximum sea level pressure has been observed in Siberia 1084 mb and in the Pacific Ocean 876 mb respectively.

Small differences in pressure are highly significant in terms of the wind direction and velocity. Horizontal distribution of pressure is studied by drawing isobars at constant levels.

An area having low pressure which is also called low is associated with wind direction defined as cyclone. The shape of the low may vary from circular to elliptical. A low with elongated isobars is called trough. Whereas an area having high pressure which is also called high is associated with the wind direction called anticyclone. It has clockwise movement in the northern hemisphere and anticlockwise in the southern hemisphere.

In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level for purposes of comparison.

Horizontal distribution of pressure can be studied better by dividing the world into four pressure belts: -

A) Equatorial Low Pressure Belt

B) Sub-Tropical High Pressure Belt

C) Sub-Polar Low

D) Polar High Pressure Belt

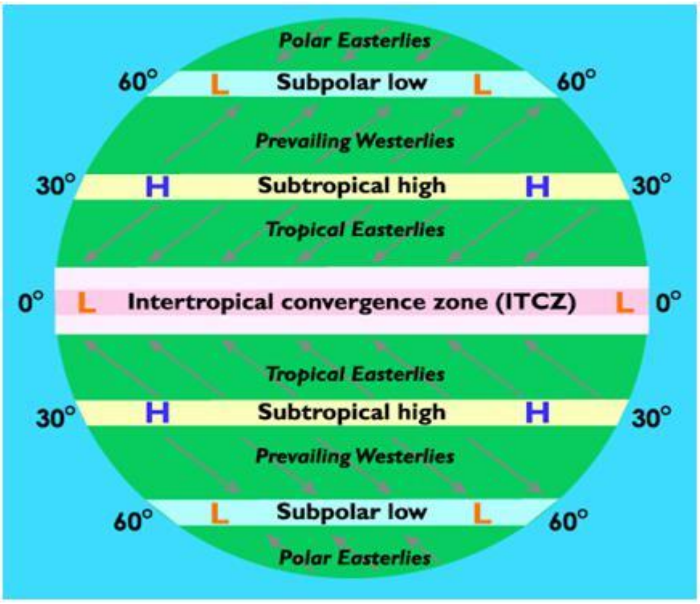

Fig. No.: 05 Pressure Belts of The World

Source: https://gkmads.files.wordpress.com/2014/10/aa.png

A. EQUATORIAL LOW PRESSURE BELT: It lies between 10°N and 10°S. Its outer margins shifts north and south of the Tropic of Cancer and Tropic of Capricorn respectively, due to apparent movement of the Sun. It is thermally produced low pressure belts. Here the pressure is more uniform than that in other parts of the world. Surface winds are generally abscent since winds approching this region begin to rise vertically near its margin. It is therefore, a region of extremely calm air and is called the ***doldrums***. This is the zone of convergence of trade winds blowing towards the equator from the sub-tropical belts of high pressure, therefore it is also called inter tropical convergence zone.

B. SUB-TROPICAL HIGH PRESSURE BELT: This belt is located between 25°N and 35°S. This belt is broken into a number of high pressure cells. This is dynamically induced high preesure belt because, the high pressure is caused due to the subsidence and pilling of the air and not due to tempareture. A calm condition with varieble and feeble winds is created in this region. These regions are often refferd to as ***'horse latitudes'*** because in early days, the sailing vessels with the cargo of horse found it difficult to sail under such calm conditions. The sailors used to throw the horses in the sea to make the vessels lighter for smooth sailing and hence, the name.

C) **SUB-POLAR LOW*: -*** The belt is located between 45°N and S latitudes and the Arctic and Antarctic Circles respectively. These low pressure celles are well developed in the north Atlantic and north Pacific regions. The low pressure is caused by rising and converging air. Due to a great contrast between the temperature of the winds from subtropical and polar source regions. Cyclonic storms are produed. In southern hemishphere it exists as a contiguous low-pressure belt, because of the absence of landmasses in these latitudes.

D) **POLAR HIGH PRESSURE BELT:** This belt is having high pressure because of persistent low temperature that makes the air cold and heavy. It extends around the poles and is source region of polar easterlies. The polar high is comparatively stronger in the southern hemisphere because of the location of Antarctica.

Vertical Variation of Pressure

There is longest column of air over the sea therefore atmospheric pressure is highest at the sea levels. The column of the air and the density of air decreases with increasing altitude. There is a complex relation between pressure and altitude. The pressure decreases rapidly with height by 1mb per 10m in the lower atmosphere, but it does not always decrease at the same rate. Whereas in the upper layers the pressure generally decreases with altitude at a declining rate. The vertical variation in pressure is very high in comparison to the horizontal variation in pressure. The vertical pressure gradient is also determined by the temperature distribution During the winter in the lower atmosphere, the pressure declines more rapidly. The following table gives the average pressure and temperature at selected levels of elevation for a standard atmosphere.

Table: Standard Pressure and Temperature at Selected Levels

Level	Pressure (mb)	Temperature (°C)
Sea Level	1,013.25	15.2
1 km	898.76	8.7
5 km	540.48	-17.3
10 km	265.00	- 49.7

World Distribution of Sea Level Pressure

The world distribution of sea level pressure in January and July has been shown in *figures*. Near the equator, the sea level pressure is low and the area is known as equatorial low. Along 30° N and 30° S are found the high-pressure areas known as the subtropical highs. Further pole wards along 60°N and 60°S, the low-pressure belts are termed as the sub polar lows. Near the poles, the pressure is high and it is known as the polar high. These pressure belts are not permanent in nature. They oscillate with the apparent movement of the sun. In northern hemisphere they move southwards in winter and northwards in the summer.

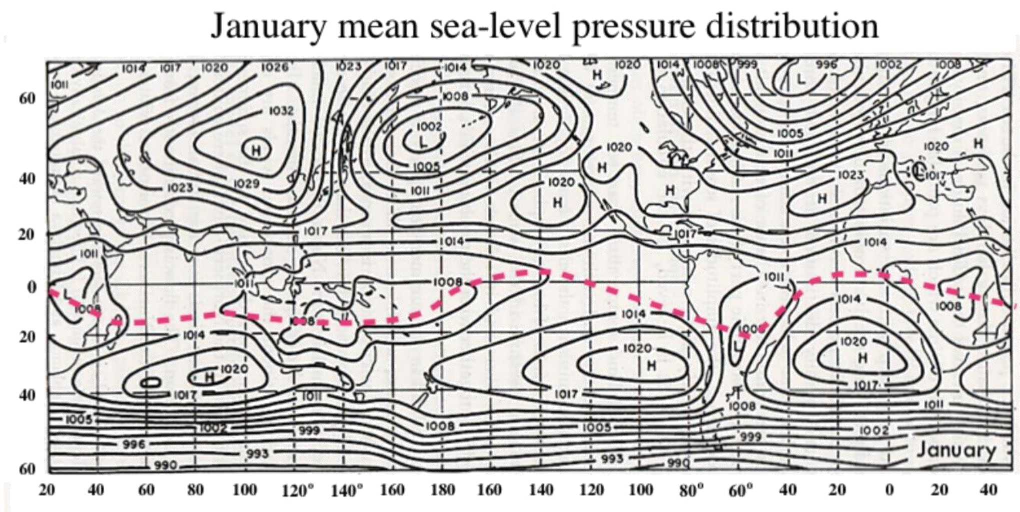

Fig. No: 06 January Mean Sea-Level Pressure Distribution

Source:http://nptel.ac.in/courses/119102007/basic%20meteorology%20and %20oceanography/images/fig2.19.png

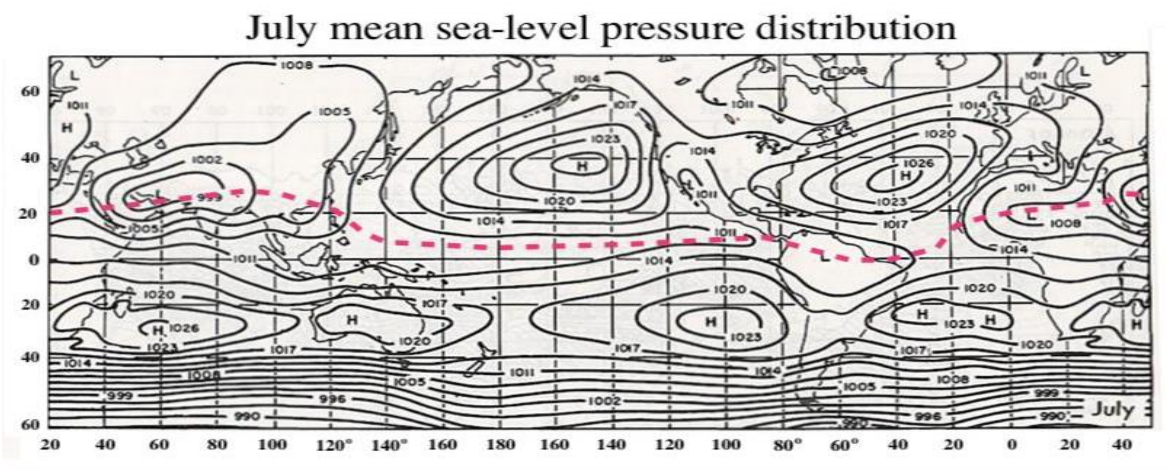

Fig. No: 07 July Mean Sea-Level Pressure Distribution

Source :http://nptel.ac.in/courses/119102007/basic20meteorology%20and%20oceanography/images/fig2.20.png

Forces Affecting the Velocity and Direction of Wind

You already know that the air is set in motion due to the differences in atmospheric pressure. Wind velocity is a fundamental atmospheric quantity. Wind speed is caused by air moving from high-pressure areas to low-pressure areas usually due to change in temperature. Wind speed is commonly measured with an instrument called ***anemometer***. The wind at the surface experiences friction. In addition, rotation of the earth also affects the wind movements. The force exerted by the rotation of the earth is known as the *Coriolis force.* Thus, the horizontal winds near the earth surface respond to the combined effect of three forces –

a) The pressure gradient force

b) The frictional force

c) The Coriolis force.

Pressure Gradient Force

The temperature differences lead to the difference in the air pressure and the differences in atmospheric pressure produces a force and this pressure gradient force actually drives the air from the high pressure areas to the low-pressure areas. The rate of change of pressure with respect to distance is the pressure gradient. The pressure gradient is strong where the isobars are close to each other and is weak where the isobars are apart. Let us take an example of an equatorial region and the polar region. Air in the equatorial area is warm due to more solar energy than the air in the Polar Regions so the warm air of the equatorial region rises and then moves horizontally towards the polar region. As the air cools, it sinks back down towards the warmer equatorial region.

Frictional Force

It affects the speed of the wind. It is highest at the surface and its influence generally extends up to an elevation of 13 kms. Over the sea surface, the friction is minimal. The surface of the earth exerts a frictional force on the air blowing just above it and that acts to change the wind direction and slow it down. Actually, it is the terrain condition, which directly affects how much friction is going to be exerted. For example, the plain areas exert less frictional force and cause minimal change in the velocity and direction of the wind whereas the rugged terrains like hilly and mountainous areas slow down the velocity of the wind and may change the direction of the wind.

Coriolis Force

The rotation of the earth on its axis generates force, which affects the direction of the wind. This force is causing deflection of winds and this deflection of wind due to the earth's rotation is called the Coriolis force. It deflects the wind to the right direction in the northern hemisphere and to the left in the southern hemisphere. The deflection is more when the wind velocity is high. The effect of the Coriolis force also differs accross the latitude. The Coriolis force is directly proportional to the angle of latitude. It is maximum at the poles and is absent at the equater. Due to the earth's rotation and the Coriolis force all free moving objects, like air, water, airplanes and even snowballs appear to leave their straight-line paths. Therefore, we can say that nothing is free from the effect of the Coriolis force.

The Coriolis force acts perpendicular to the pressure gradient force. The pressure gradient force is perpendicular to an isobar. The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind. Because of these two forces operating perpendicular to each other, in the low-pressure areas the wind blows around it. At the equator, the Coriolis force is zero and the wind blows perpendicular to the isobars. The low pressure is filled instead of being intensified. That is the reason why tropical cyclones are not formed near the equator.

If the earth would not have been rotating, this pressure gradient force would create only two single cell circulations of the wind i.e., one for the northern hemisphere and one for the southern hemisphere. But as the earth is rotating on its axis, we get multiple circulation of wind on the earth.

Pressure and Wind

The velocity and direction of the wind are the net result of the wind generating forces. The winds in the upper atmosphere 23 km above the surface, are free from frictional effect of the surface and are controlled mainly by the pressure gradient and the Coriolis force. When isobars are straight and when there is no friction, the pressure gradient force is balanced by the Coriolis force than the resultant wind blows parallel to the isobars. This wind is known as the ***geostrophic wind***.

The wind circulation around a low is called cyclonic circulation and the wind corculation around a high it is called anti-cyclonic circulation. The direction of winds around such systems changes according to their location in different hemispheres.

Pressure	Pressure	Pattern of wind direction	
system	condition at the Centre	Northern hemisphere	Southern hemisphere
Cyclone	Low	Anticlockwise	clockwise
Anti-cyclone	High	Clockwise	Anticlockwise

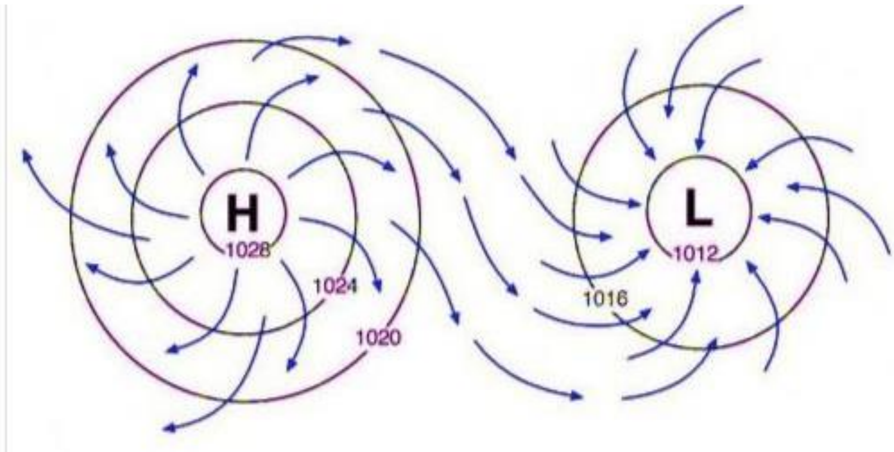

Fig. No : 08 Cyclone and Anti-cyclone In Northern hemishphere

Source:http://skompasem.cz/img/picture/4295/anticyklona-a-cyklona-na-severni-polokouli.jpg

The wind circulation at the earth's surface around low and high on many occasions is closely related to the wind circulation at higher level. Generally, over low-pressure area the air will converge and rise. Over high-pressure area, the air will subside from above and diverge at the surface. Apart from convergence, some eddies, convection currents, orographic uplift and uplift along fronts cause the rising of air, which is essential for the formation of clouds and precipitation.

Now we know that there are so many factor that determines the general circulation of the atmosphere but among all pressure and temperature are the most important factors. Due to the difference of temperature pressure varies and causes wind to circulate in the atmoshpere.