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Distance Learning Programme

UPSC Mains

World Geography

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WORLD GEOGRAPHY

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Pressure & Wind Systems

Chapter 11

The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the air or atmospheric pressure. The atmospheric pressure is expressed in units of millibar. At sea level the average atmospheric pressure is 1,013.2 millibar. Due to gravity, the air at the surface is denser and hence has higher pressure. Air pressure is measured with the help of a mercury barometer or the aneroid barometer. The pressure decreases with height. At any elevation it varies from place to place and its variation is the primary cause of air motion, i.e. wind which moves from high pressure areas to low pressure areas.

Distribution of Pressure on Earth's Surface

Horizontal distribution of air pressure on the earth's surface is closely related with that of temperature because the factors which control the distribution of temperature on the earth's surface equally govern the distribution of pressure as well. Unequal distribution of insolation over the surface, differential heating of land and water and different albedo of the earth surface are main factors which affect the distribution of pressure on the earth's surface. However one more factor comes into play during the development of pressure belt which is Coriolis force due to rotation of earth.

Pressure Belts

Based on the distribution pattern of surface pressure on a rotating earth with uniform surface (In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level), there are seven alternate low and high pressure belt on the earth's surface. These pressure belts are not permanent in nature. They oscillate with the apparent movement of the sun. In the northern hemisphere in winter they move southwards and in the summer northwards.

- Equatorial low pressure belt
- Subtropical high pressure belt – Northern hemisphere
- Subtropical high pressure belt – Southern hemisphere
- Subpolar low pressure belt – Northern hemisphere
- Subpolar low pressure belt – Southern hemisphere
- Polar high pressure belt – Northern hemisphere
- Polar high pressure belt – Southern hemisphere

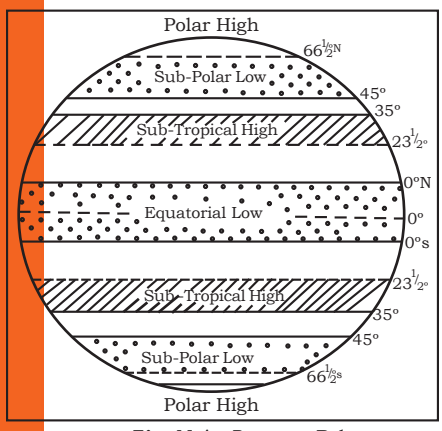


Fig: *Major Pressure Belts*

Equatorial Low Pressure Belt

It exists between 10°N to 10°S latitude. It is a thermally induced belt caused by high insolation and the convective rise of air (updraft). This region observes vertical cloud like

cumulonimbus with thunder & lightning and afternoon shower between 2 to 4 pm followed by atmospheric stability with absolute calm. This region is also referred to as doldrums due to absence of air movement and generation of intense low pressure. It is believed that the ships sailing through doldrums gets stuck for weeks if they do not have enough sail power to move forward. This belt represents the zone of convergence of N-E and S-E Trade winds.

Sub Tropical High Pressure Belt

It exists between 25° to 35° latitudes in both the hemisphere. It is dynamically induced high pressure zone. This is caused by the subsidence of cold and dry air (downdraft) due to the mechanical force produced by air accumulated aloft. The air accumulation is caused by air coming from the equatorial region which descends after becoming heavy. Coriolis force and geostrophic effect are contributing factors for accumulation of air. Hot tropical deserts are developed in the western side of continents in this zone as subsiding air is warm and dry that discourage rainfall.

This zone of high pressure is called 'Horse Latitude' because of prevalence of frequent calms. In ancient times, the merchants carrying horses in their ships had to throw out some of the horses while passing through this zone of calm in order to lighten their ships. This is why this zone is called 'Horse Latitude'

Sub Polar Low Pressure Belt

It exists along 60° to 65° latitude in both the hemisphere. It is dynamically induced pressure belt but thermal factors cannot be ignored. It is a zone of convergence of warm and cold air masses and also known as temperate convergence zone. Development of fronts as well as temperate cyclone and frequent change in weather conditions are the common phenomena observed here.

Polar High Pressure Belt

It exists near the poles between 75° to 90° latitude in both the hemispheres. It is thermally induced pressure belt but the role of dynamic factors cannot be denied. The region observes the subsidence of cold and dry air which causes the high pressure. The subsiding air is converted into anti cyclone due to the coriolis' effect and leads to the outflow of air in the form of gale. These gales are known as blizzard in North America and buran in Siberia.

Seasonal Variations in Pressure Distribution

Pressure and Wind Patterns: January

On the January, a very strong high-pressure centre, called the Siberian high, is positioned over the frozen landscape of northern Asia. A weaker polar high is located over the chilled North American continent. These cold anticyclones consist of very dense air that accounts for the weight of these air columns. In fact, the highest sea-level pressure ever measured, 1084 millibar (32.01 inches of mercury) was recorded in December 1968 at Agata, Siberia.

The polar highs are prominent features of the winter circulation over the northern continents. Subsidence within these air columns results in clear skies and divergent surface flow. The resulting winds are called polar easterlies.

As the Arctic highs strengthen over the continents, a weakening is observed in the subtropical anticyclones situated over the oceans. Further, the average position of the subtropical high tends to be closer to the eastern margin of the oceans in January than in July. The centre of the subtropical high located in the North-Atlantic (sometimes called Azores high) is positioned close to the northwest coast of Africa.

Also shown on the January map but absent in July are two intense semi permanent low-pressure centers: Named the Aleutian low and the Icelandic low, these cyclonic cells are situated over the North Pacific and North Atlantic, respectively. They are not stationary cells, but rather the composite of numerous cyclonic storms that traverse these regions. In other words, so many cyclones are present that these regions of the globe are almost always experiencing low pressure, hence the term semi permanent.

Remember that cyclones are travelling low-pressure centre with low-level convergence and an upward flow. As a result, the areas affected by the Aleutian and Icelandic lows experience cloudy conditions and abundant winter precipitation. The cyclones that form the Aleutian low are produced as frigid air, directed by the Siberian high, flow off the continent of Asia and overruns comparatively warm air over the Pacific.

The strong temperature contrast creates a steep pressure gradient that becomes organized into a counter clockwise rotating storm cell. Nevertheless, with the large number of cyclonic storms that form over the North Pacific and travel eastward, it should be no surprise that the coastal areas of southern Alaska receive abundant precipitation. This fact is exemplified by the climate data for Sitka, Alaska, a coastal town that receives 215 centimetres (85 inches) of precipitation each year, over five times that received in Churchill, Manitoba, Canada. Although both towns are situated at roughly the same latitude, Churchill is located in the continental interior far removed from the influence of the Aleutian low.

Pressure and Wind Patterns: July

The pressure pattern over the Northern Hemisphere changes dramatically with the onset of summer as increased amounts of radiation strike the northern landmasses. High surface temperatures over the continents generate lows that replace the winter highs. These thermal lows consist of warm ascending air that Induces inward directed surface flow. The strongest of these low-pressure centres develops over southern Asia. A weaker thermal low is also found in the south western United States.

During the summer months, the subtropical highs in Northern Hemisphere migrate west-ward and become more intense than during the winter months. These strong high-pressure centers dominate the summer circulation over the oceans and pump warm moist air onto the continents that lie to the west of these highs. This results in an increase in precipitation over parts of eastern North America and Southeast Asia.

During the peak of the summer season, the subtropical high found in the North Atlantic is positioned near the island of Bermuda, hence the name Bermuda high. (Bermuda is located about 1500 kilometres, or 900 miles, east of the South Carolina coast). Recall that in the Northern Hemisphere winter, the Bermuda high is located near Africa and goes by the alias Azores high.

Winds

The horizontal motion of air parallel to the pressure gradient force and perpendicular to the isobar is called wind. It always blows from high pressure to low pressure and acts as a medium for the transfer of heat and moisture from one place to another.

Forces Affecting Velocity and Direction of Wind

We already know that the air is set in motion due to the differences in atmospheric pressure. The air in motion is called wind. The wind at the surface experiences friction. In addition, rotation of the earth also affects the wind movement. 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 - the pressure gradient force, the frictional force and the Coriolis force. In addition, the gravitational force acts downward.

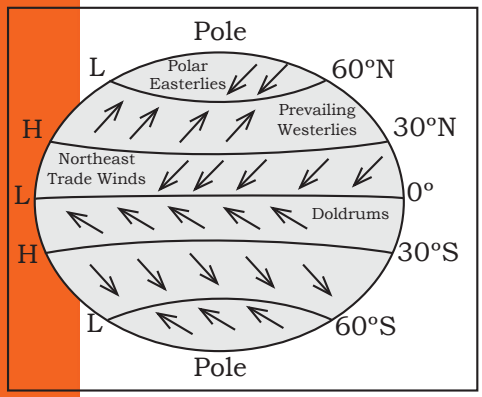
- **Pressure Gradient Force:** It originates due to the difference in the pressure between two places and acts perpendicular to the isobar. Narrowly spaced and widely spaced isobars indicate steep pressure gradient force and gentle pressure gradient force respectively.
- **Frictional Force:** It is a retarding force exerted by surface in the direction opposite to the direction on wind. It also reduces Coriolis force.
- **Coriolis Force:** It is an apparent force produced due to the rotation of earth. This phenomenon was first discovered by the French scientist Coriolis; hence this force exerted by the rotation of the earth is called coriolis force. The quantity of the force keeps increasing with increasing distances from the equatorial belt. It deflects the wind rightward in northern hemisphere and leftward in southern hemisphere. Due to its deflective power it can also produce gyratory motion. The Coriolis force is directly proportional to the angle of latitude. It is maximum at the poles and is absent at the equator.

Classification of Winds

Planetary Winds

The winds blowing through-out the year from one latitude to another in response to latitudinal differences in air pressure are called “planetary or prevailing winds”.

They are global in nature and are the result of global pressure distribution. Latitudinal variation of atmospheric heating, emergence of pressure belts, the migration of belts following apparent path of the sun, the distribution of continents and oceans and rotation of earth are the main factors responsible for the origin of the planetary winds.



These winds prevail throughout the year in a constant direction and, transport energy as well as maintain global heat balance. The planetary winds blowing on the surface of earth are:

Trade Winds

These are extremely steady winds blowing from sub-tropical high pressure areas (30°N and S) towards the equatorial low pressure belt. These winds should have blown from the north to south in Northern Hemisphere and south to north in Southern Hemisphere, but, they get deflected to the right in Northern Hemisphere and to the left in Southern Hemisphere due to Coriolis effect and Ferrel's law. Thus, they blow as north eastern trades in Northern Hemisphere and south eastern trades in Southern Hemisphere.

Trade winds are on shore along the eastern margin of continents and thus harbinger maritime condition especially during summer. These winds converge near equator & form ITCZ, Here these winds rises & causes heavy rainfall.

Inter Tropical Convergence Zone (ITCZ)
It is the zone of convergence of trade winds and the tropical air masses. It is fluctuating and oscillating line characterized by low pressure, rainfall and cloudiness. It is known to shift with the apparent migration of the sun. It shifts by 25° to 30° over continent and 10° to 15° over the oceanic surface in summer time. It is called NITCZ in northern hemisphere and SITCZ in southern hemisphere.

Westerly Winds

They also originate from sub tropical high pressure belt and move towards subpolar low pressure belt and, prevail between 35° to 60 ° latitudes. They are also permanent but more intense during winters. They transport warm and moist air toward the pole.

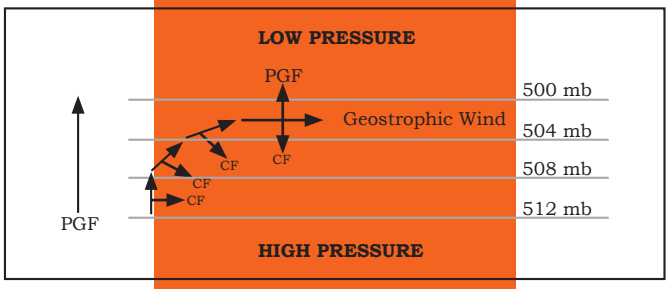
Westerly causes formation of fronts along sub polar low pressure zone and transport cyclone toward the western margin. The British type of climate or the western European type of climate is produced by the westerly which causes rainfall throughout the year. In the southern hemisphere they are uninterrupted and blow with gale force. They are known as roaring forties along 40°S, furious fifties along 50°S and shrieking sixties along 60°S.

Polar Easterlies

The Polar easterlies blow from the Polar high pressure area to the Temperate low pressure area. On their equator ward journey they are deflected westward to become North easterlies in the Northern hemisphere and South easterlies in the Southern hemisphere

These are extremely cold winds that come from the Tundra and Icecap regions of the poles. The Polar Easterlies are more regular in the southern hemisphere in comparison to the northern hemisphere. These polar cold winds converge with the warm easterlies near 60° latitudes and form the Polar front or Mid Latitude front. This mid-latitude front becomes the centre of the origin of the Temperate Cyclones.

Geostrophic Wind
■ The upper atmosphere, 2 - 3 km above the surface, is free from frictional forces and the direction as well as speed of wind is controlled by the pressure gradient force and the Coriolis force only.



- When isobars are straight and when there is no friction, the pressure gradient force is balanced by the Coriolis force and the resultant wind blows parallel to the isobar. This wind is known as the geostrophic wind.

Periodic Winds/Seasonal Winds

Periodic winds change their direction periodically with the change in season, e.g., Monsoons, Land and Sea Breezes, Mountain and Valley Breezes.

Monsoon Winds

These are seasonal winds and refer to wind systems that have a pronounced, seasonal reversal of direction. According to 'Flohn', monsoon is a seasonal modification of general Planetary Wind System. Monsoons cause wet and dry seasons throughout much of the tropics. Monsoons always blow from cold to warm regions. It blows from sea to land during summers & land to sea during winters, due to differential in heating of continents & oceans → Halley's law. In summers, sun shines vertically over Tropic of cancer resulting in high temp. & low pressure in central Asia, while pressure is sufficiently high at Bay of Bengal & Arabian Sea. This induces air flow from Sea to land & induces heavy rainfall in India & neighboring countries. In winters, sun shines vertically over tropic of Capricorn, hence N – W part of India grows colder than Arabian Sea & Bay of Bengal which results in reversal of monsoon in India. Above theory of differential heating was replaced by shifting of ITCZ for monsoon in India & neighboring countries.

Land Breeze and Sea Breeze

The land and sea absorb and transfer heat differently due to the difference in their specific heat. Land heats up faster during the day and becomes warmer than the sea. Therefore, warm air rises over the land giving rise to a low pressure area, whereas the sea is relatively cool and the pressure over sea is relatively high. The pressure gradient emerging from sea to land due to the difference in the pressure between sea and land during day time triggers the wind to blow from sea to land. This wind is called sea breeze. During the night the land loses heat faster and becomes cooler than the sea. Now the pressure gradient is from the land to the sea which triggers the wind to blow from land to sea. This wind is known as land breeze.

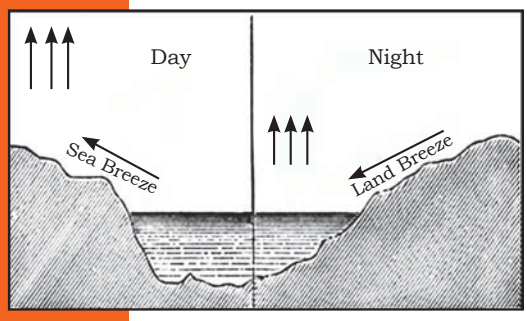


Fig: *Land Breeze and Sea Breeze*