AIR PRESSURE: PATTERN AND DISTRIBUTION

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AIR PRESSURE

- Like any other material object the air also has weight.
- The pressure of air at a given place is defined as a force exerted in all directions in consequence of the weight of all the air above it.
- Thus the mass of a column of air above a given point determines the atmospheric pressure at that point.

AIR PRESSURE

- The standard sea level pressure is given as 1013.25 millibars at a temperature of 15°C and at latitude of 45°.
- This pressure is equivalent to 29.92 inches or 760 millimeters of height of mercury in barometer.

AIR PRESSURE

- Air is highly compressible, such that its lower layers are much more dense than those above.
- Fifty percent of total mass of air is found below 5km.
- The average density decreases from about 1.2kg per cubic metre at the surface to 0.7kg per cubic metre at 5000m, close to the extreme limit of human habitation.

AIR PRESSURE

- Pressure is measured as a force per unit area.
- A force of 100000 newtons acting on 1 square metre corresponds to the Pascal (PA) which is the Systeme International (SI) unit of pressure.
- Meteorologists still commonly use the millibar (mb) unit; 1 millibar = 100 Pascal (or 1 hPa; h= hecto)
- The atmosphere exerts a force of 101325 newtons per square metre.
- To simplify this large number the national Weather Service adopted the millibar (mb), which equals 100 newtons per square metre.

AIR PRESSURE

- Pressure readings are made with mercury barometer, which in effect measures the height of the column of the mercury that the atmosphere is able to support in a vertical glass tube.
- The atmosphere is able to support a mercury column in the tube of about 760 mm (apprx. 1013 mb)

AIR PRESSURE

- The sea level pressure is approximately 100000 Pa or 1000mb.
- The Global mean value is 1013.25 mb.
- On average, nitrogen contributes about 760mb, oxygen 240mb and water vapour 10mb.
- Each gas exerts a partial pressure independent of the others

AIR PRESSURE

- Air pressure is proportional to density as well as temperature and the change in either temperature and density will cause a corresponding change in pressure.
- The equation called the 'the gas law' describes the relationship between pressure, temperature and density:

$$PV=RT$$

P- Pressure

V- Volume

R- Constant

T- Temperature

AIR PRESSURE

- The amount of water vapour contained in a volume of air influences its density.
- The molecular weights of nitrogen and (N_2) and oxygen (O_2) are greater than that of water vapour (H_2O).
- As the water content of an air mass increases, lighter water vapour molecules displace heavier nitrogen and oxygen molecules.
- Thus humid air is lighter than dry air.
- In summery, cold dry air produces high surface temperature than warm humid air.

AIR PRESSURE

- Atmospheric pressure, depending as it dose on the weight of the overlying atmosphere, decreases with height.
- The rate of change of air pressure with height is dependent gravity multiplied by the air density.
- With increasing height, the drop in air density causes a decline in this rate of pressure decrease.
- The temperature of the air also affects this rate which is greater for cold dense air.

AIR PRESSURE

- The relationship of pressure and height is so significant that meteorologists often express elevation in millibars.
- 1000mb represents sea level, 500 mb about 5500m and 300 mb about 9000m.

AIR PRESSURE

- The standard sea level pressure is given as 1013.25 millibars at a temperature of 15°C and at latitude of 45°.
- The pressure recorded at various stations shows marked variation. Highest sea level pressure recorded was 1084 mb (Agata, Siberia) in Dec. 1968; lowest recorded sea level pressure is 870mb (Typhoon Tip) in october , 1979.

AIR PRESSURE

- All the weather changes are closely related to pressure variations.
- High values of air pressure produce clear and stable weather while low atmospheric pressure brings bad weather.

AIR PRESSURE

- Pressure Gradient:

  the decrease of pressure between two points along a line perpendicular to the isobars divided by the distance between the points is called the pressure gradient. It is also known as barometric slope.
- Isobars drawn closely on a weather map represent a steep pressure gradient, while the isobars drawn further apart indicate a week pressure gradient.

Pressure variation
Diurnal and Seasonal

- There is definite rhythm in the rise and fall of mercury in barometer during 24 hours.
- Insolation heating and radiation cooling are the principle reasons for this variation in pressure.
- There are two maxima and two minima of pressures during 24 hours. Kendrew calls this semi-diurnal variation.
- At the time of equinoxes, the two maxima of pressure are recorded at 10 am and 10 pm, while the two minnima are observed at 4am and 4 pm.

Pressure variation
Diurnal and Seasonal

- Annual pressure variation in the tropical regions is larger than in any other regions of the world.
- Over the continents the high pressures are generally recorded during the cold season, while over the oceans they are observed during the warm season.

Basic Atmospheric Pressure Pattern

- Low Pressure System:

  when the isobars are circular or elliptical in shape, and the pressure is lowest at the centre, such pressure system is called a low or cyclone or depression.
- A line of low pressure is called a trough. In a trough the isobars are V shaped. The axis of trough is NE to SW.
- Thus a cyclone is a closed system of isobars whose centre serves as the focus for convergent circulation.
- Wind direction: counter clockwise in Northern hemisphere and clockwise in southern hemisphere.
- A low pressure system is semi permanent and mobile.

Basic Atmospheric Pressure Pattern

- High Pressure System:

  these pressure systems are characterized by high pressure centres. These are called **highs** or **anticyclone**.
- When the isobars are elliptical in shape, the system is called **ridge or a wedge of high pressure.**

Vertical structure of Cyclones and Anticyclones

- On the basis of distribution of temperature within the system the cyclones and anticyclones are classified as:

  Cold core cyclone and warm core cyclone

  Cold core anticyclone and warm core anticyclone

Vertical structure of Cyclones and Anticyclones

- Cold core cyclone: temperature is lowest at the centre.
- Air pressure registers rapid change upward.
- With increasing elevation barometric slopes become steeper.
- Lows produced at the earths surface intensify aloft.
- They are formed in the upper air
- Semi permanent Icelandic and Aleutian lows are examples.

Vertical structure of Cyclones and Anticyclones

- Warm core cyclones: temperature is highest at the centre.
- At a certain height from the earths surface the horizontal pressure gradient vanishes, the low becomes non existent.
- At higher levels the low turns into a high.
- Generally originate at or near the surface.
- Desert regions of eastern California or Arizona are examples

Vertical structure of Cyclones and Anticyclones

Cold- core anticyclone

- low temperature at the centre, capped by lows.
- Develop over the Arctic and Antarctic regions in winter.

Warm core anticyclone

- Highest temperature at centre
- At higher elevations isobars bulge out upward
- Intensifies with increasing altitude
- Develops in the south eastern states of the USA during summer.

General Characteristics of Cyclone and Anticyclone

- Pressure changes more rapidly in cold air than in warm air.
- The axis of the low tilts towards the cold side
- The axis of the high tilts towards the warm side

Horizontal Distribution of Pressure

- Horizontal distribution of air pressure on the earth's surface is shown by isobars.
- Factors which control the distribution of temperature on the earth's surface equally govern the distribution of pressure as well.

Horizontal Distribution of Pressure

- Distribution pattern on a non rotating earth with homogeneous surface:
- Earth is heated unevenly because of three factors: unequal distribution of insolation over its surface, differential heating of land and water and different albedos of the earth's surface.
- The equatorial region which receives maximum insolation must have high temperature and consequently low pressure
- On the contrary polar regions have high pressure due to small amount of insolation received by the surface.
- There should be gradual increase of pressure from equator to the poles.

Horizontal Distribution of Pressure

- In reality high pressure have been recorded between 25 to 35 degrees of latitudes and low pressures have been recorded between 50 to 60 degrees of latitudes in both the hemispheres.
- Besides temperature earth's rotation also affects the distribution of pressure on the earth's surface.

Horizontal Distribution of Pressure

- Distribution Pattern on a rotating and homogeneous earth:
- Some of the air rising from the equator and moving towards the poles in the upper atmosphere is turned aside by earth rotation or by other dynamic processes.
- The result is that not all the rising from the equator goes to the poles some settles down near the subtropical regions in cells.
- The subsiding air currents create subtropical high pressure cells between 25-35 degrees of latitudes in both the hemispheres.

Horizontal Distribution of Pressure

- Two factors are responsible for the subsidence of air in this zone - 1. when the rising air currents move away from the equatorial region the latent heat of condensation keeps them warm and buoyant.
- But radiational cooling results in their increased density in the upper atmosphere.
- This accounts for the subsidence of cold and dense air in the subtropical region.
- Secondly with increasing distance from the equator the coriolis force gets stronger , so that the poleward moving air are deflected into nearly a west to east flow as they get near the subtropics. Thus the coriolis force produces a blocking effect causing convergence aloft. This results in general subsidence near the subtropics.

Horizontal Distribution of Pressure

- Because the subsiding air currents are relatively drier, the weather in this zone remains fair and dry.
- Relative humidity of the of the descending air currents is reduced due to adiabetic heating.
- This is the reason behind the location of all hot desert in this zone.

Horizontal Distribution of Pressure

- There are large belts of low pressure at about 50 to 65 degrees of latitudes in both the hemispheres which are called subpolar low pressure belts.
- Here the westerlies and polar easterlies meet to form a convergent zone.
- This region where the warm westerlies and cold polar easterlies clash is called polar front.
- The temperature does not account for the existence of this low pressure belt perhaps produced by the dynamic factors involved with the rotation of the earth.
- In polar regions there are polar highs caused by extremely low temperatures and subsiding air.

Horizontal Distribution of Pressure

- Thus the pressure belts we get are:
- Equatorial trough of low pressure
- 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 (Northern Hemisphere)
- Polar high (Southern Hemisphere)

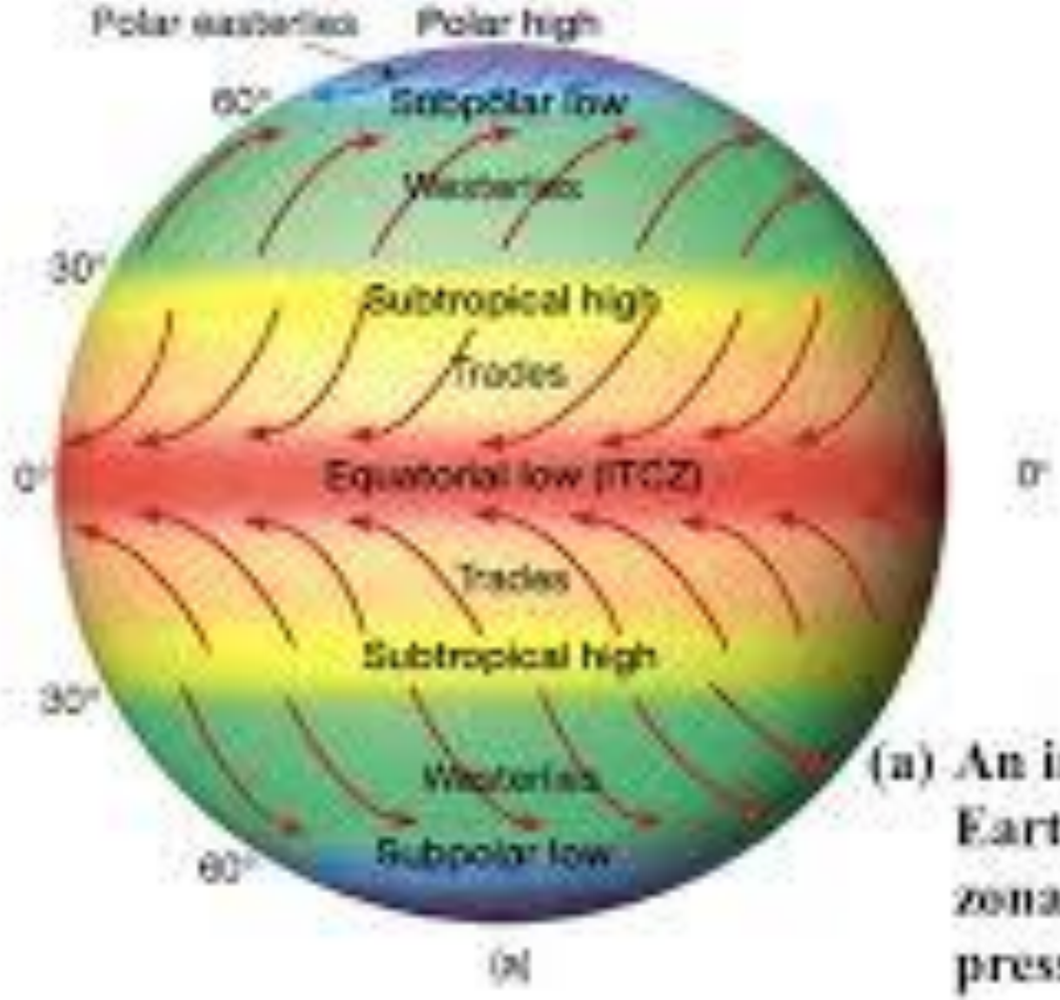
Horizontal Distribution of Pressure

- Observed distribution pattern:
- In the northern hemisphere the pressure belts are broken into cells due to preponderance of landmasses.
- The cells of high and low pressures are elongated in shape and extend in east-west direction.
- On the contrary the southern hemisphere is pre-eminently a water hemisphere and there is progressive diminution of land masses in higher latitudes.
- The only true zonal distribution of pressure exists in the region of sub-polar low in the southern hemisphere where the ocean is continuous.

Horizontal Distribution of Pressure

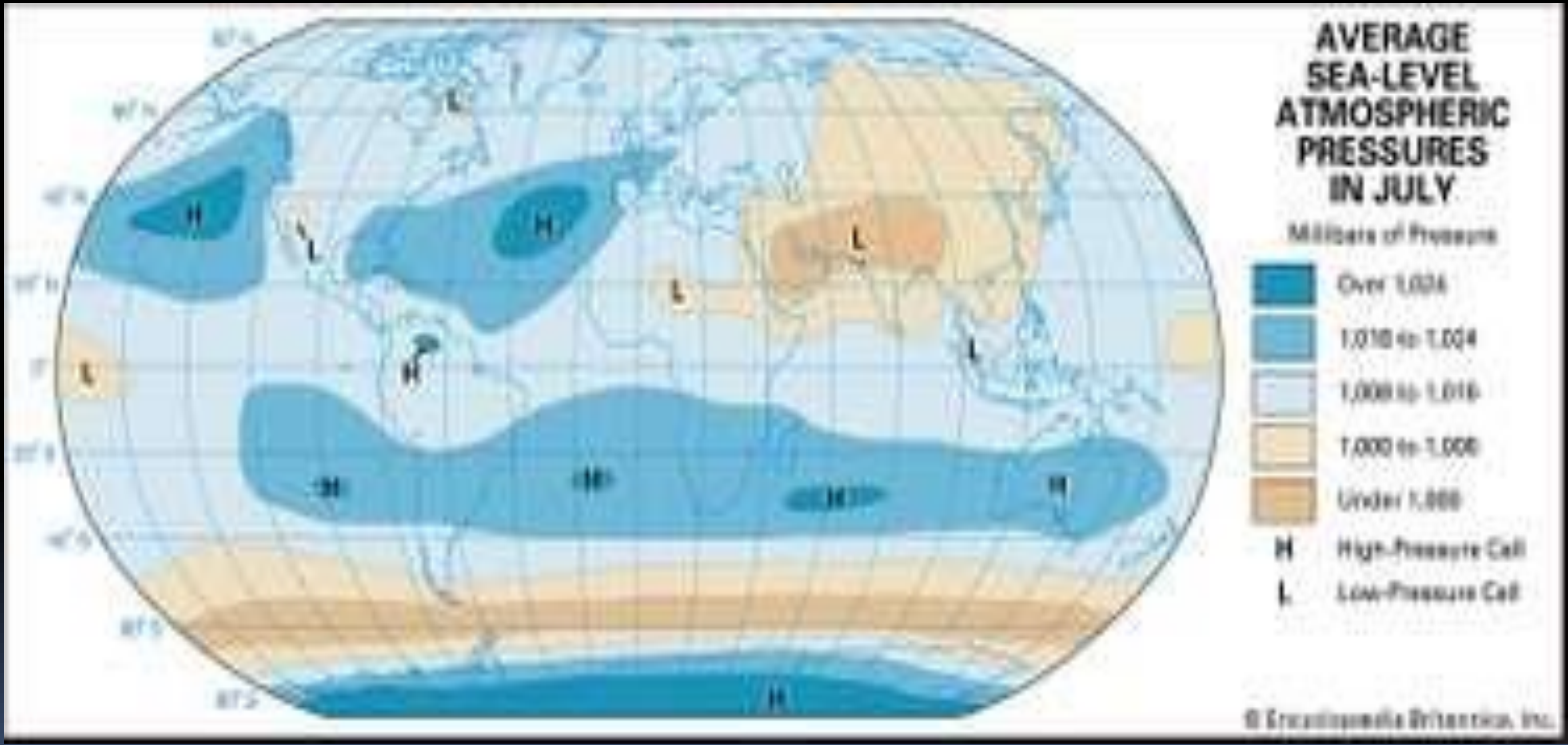
- Thus it can be observed that:
- There is trough of low pressure in the vicinity of the equator which is to a certain extent is zonal in character.
- The subtropical region in either hemisphere are dominated by a number if discontinuous high pressure cells called the subtropical highs.
- In the northern hemisphere the subpolar low consists of individual cells of low pressure over the oceans.
- There is a continuous belt of low pressure at about the latitude of Antarctic circle.

Observed Distribution of Pressure and Winds

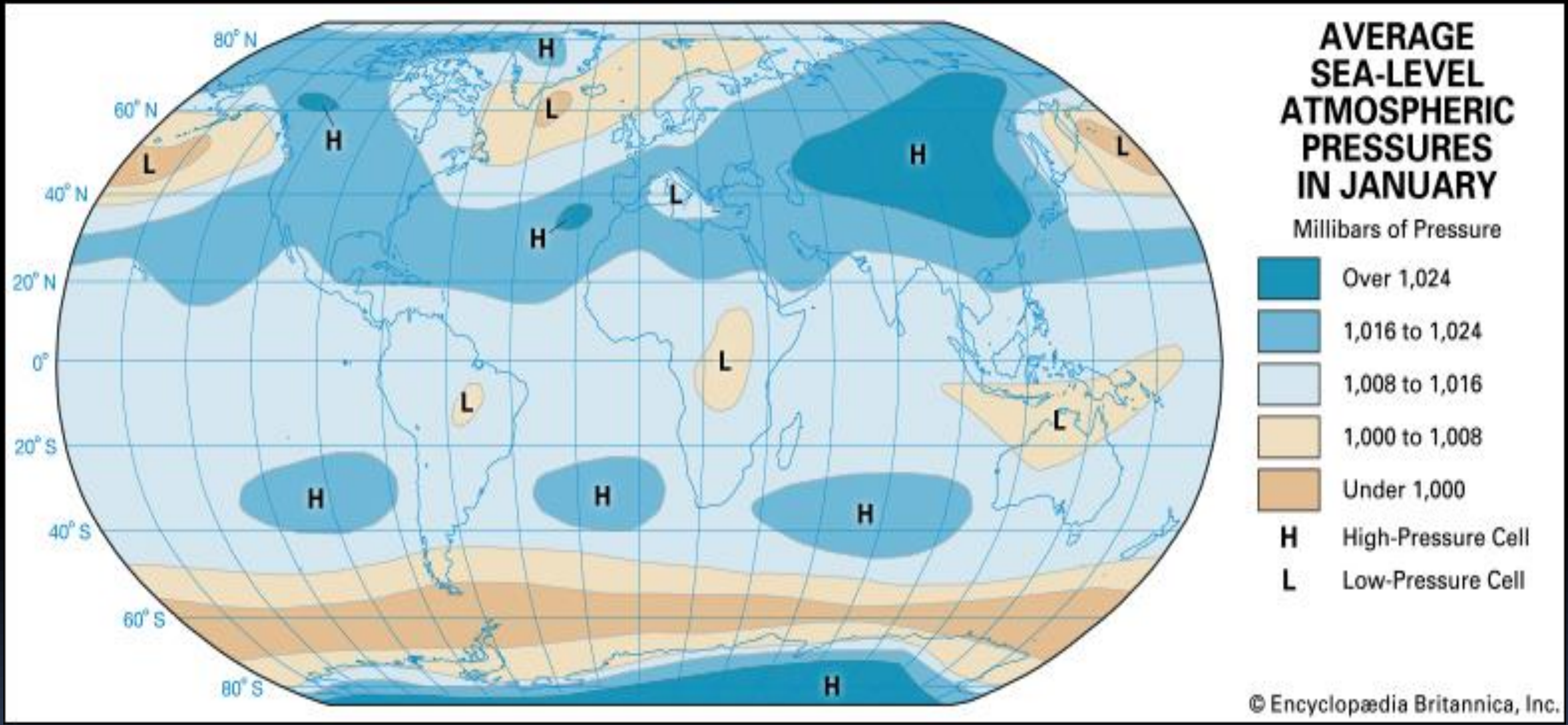


(a) An imaginary uniform Earth with idealized zonal (continuous) pressure belts

Pressure distribution in July



Pressure distribution in January



Equatorial trough of low pressure

- 5degree north to 5 degree south
- Extends more to the north than to the south of the equator
- Width of the trough is not uniform
- Pressure is less than 1013 millibar, but in the eastern hemisphere it is generally less than 1009 millibar
- Convectional currents set up and warm air rises upward
- The air is warm and moist
- The zone of convergence of trade winds
- Within this belt the winds are light and variable with frequent calms, so the belt is called doldrums
- in the pressure distribution map of July this belt is highly irregular and indistinct, but belt is quit distinct for January
- Shifts with the apparent movement of sun
- During July extends up to 20 degree north in Northern part of Africa and beyond the tropic of cancer in the vast continent of Asia
- In January it extends to latitude to 10-20 degree south

Subtropical High Pressure Belt

- Located between 25-35 degree latitudes
- It is broken into a number of high pressure centres or cells
- These cells are dynamically produced
- Areas of sinking and settling air from higher altitudes
- In the upper atmosphere over this belt upper level westerlies and antitrades converge and set up descending currents in the atmosphere
- These area have no prevailing winds
- The winds are light and variable. There are occasional calms
- Sometimes these belts are invaded by extatropical or tropical cylones

Subtropical High Pressure Belt

- Due to subsidence of air the weather remains fair and dry for most part of the year
- The deserts are located in this zone
- Are called horse latitudes
- The cells of high pressure persists throughout the year over the oceans with slight seasonal change in their position
- In the southern hemisphere there is almost continuous belt of high pressure
- The subtropical high pressure record higher pressure in the northern hemisphere during the warmer part of the year
- The highs extends to about 9600 metres above the mean sea level

Sub polar low pressure belt

- 60-70 degree latitude
- Uninterrupted belt of low pressure over the oceans
- In the northern hemisphere pressure over the landmasses are high due to coldness
- Thus the continuity is broken
- The centres of low pressure lie in the vicinity of the Aleutian island in the Pacific and between Greenland and Iceland in the Atlantic
- During winter there is a great contrast of temperature between the continents and oceans. This helps reinforcing the Aleutian low and Icelandic low

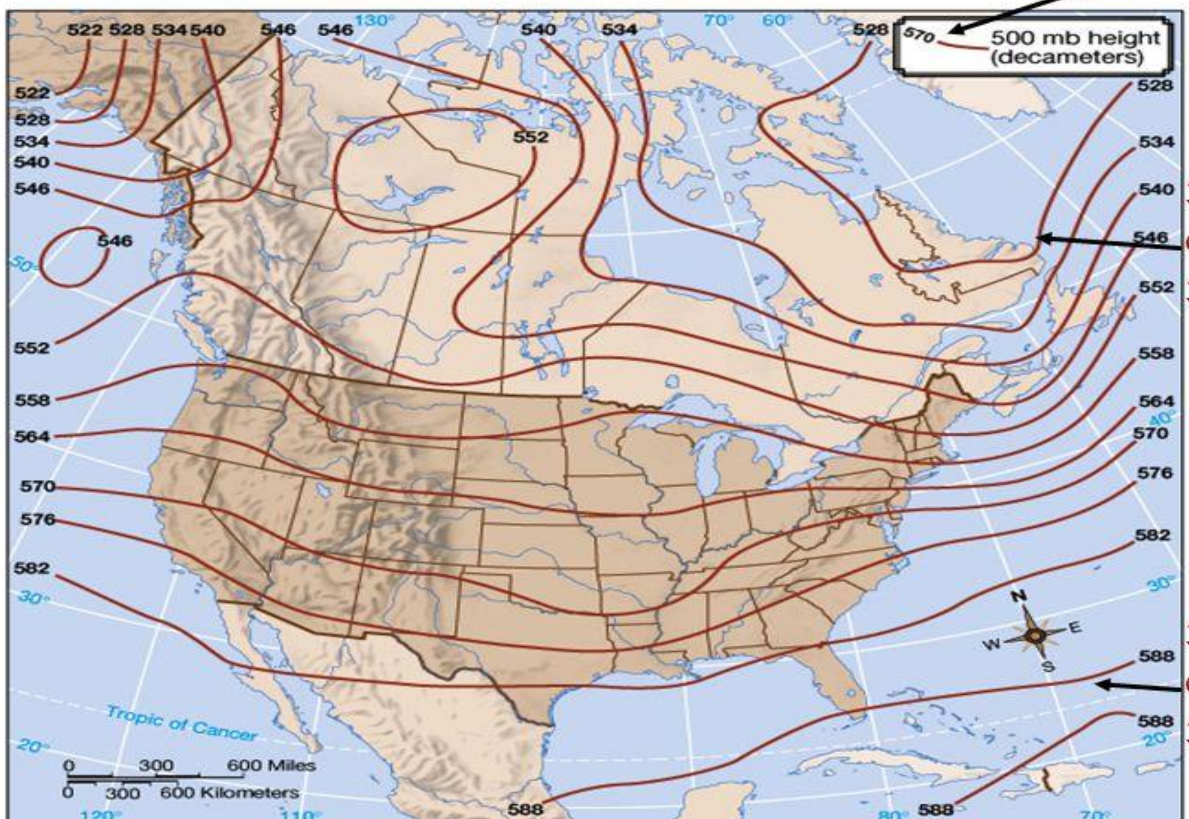
Polar High

- Pressure at the poles are consistently high.
- In northern hemisphere it is not centred at the pole.
- Extends from northern Greenland westward across the islands situated in the northern part of Canada
- The existence of relatively higher pressure near the south pole is confirmed
- Thermal factor is more important

Atmospheric pressure at 500mb level

500 mb height contours for May 3, 1995

Upper air pressure maps depict the height to the specific air pressure level (such as the height to the 500 mb air pressure level)

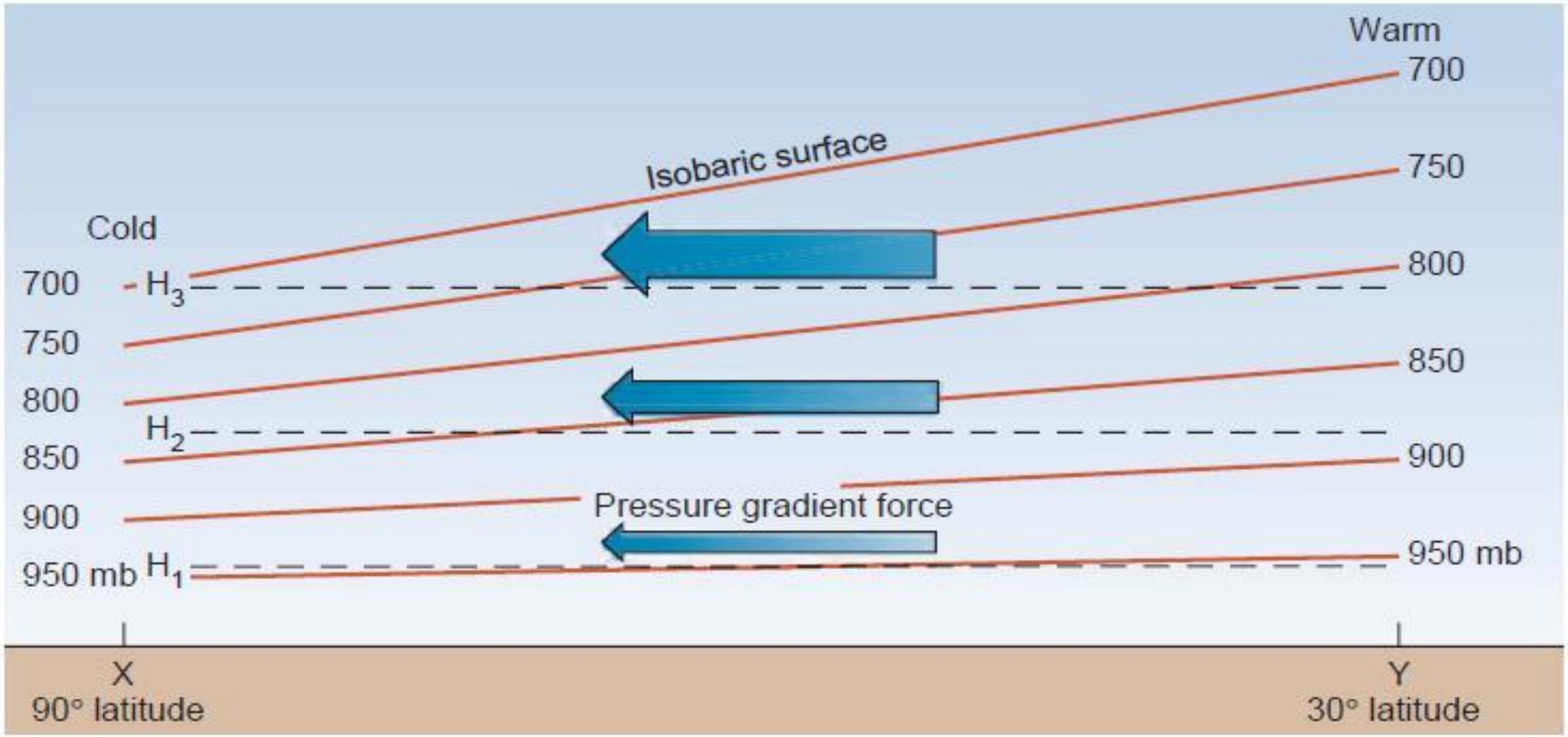


Lines of equal elevation

500 mb elevation 5280 m

500 mb elevation 5880 m

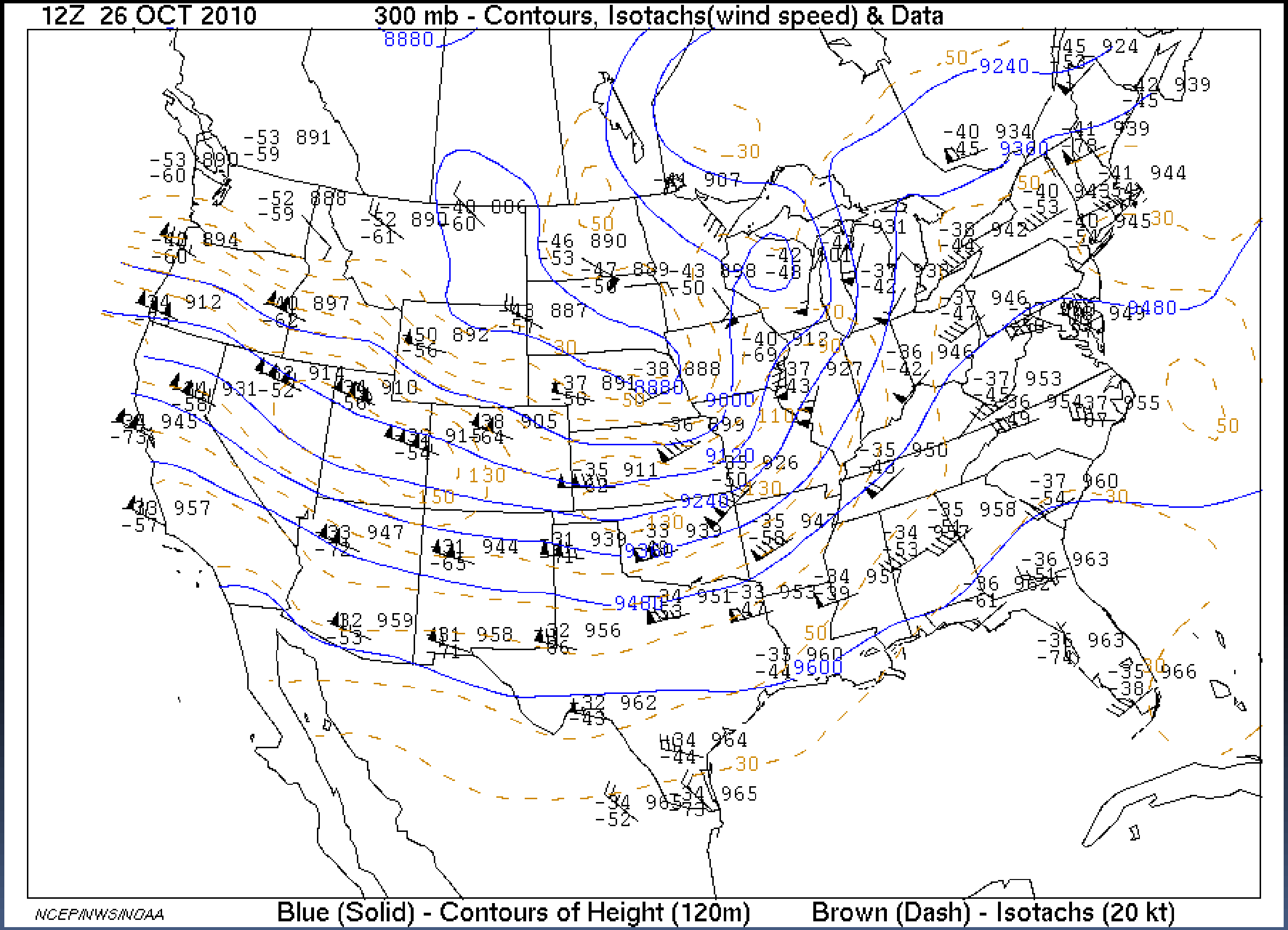
Upper- air pressure gradient



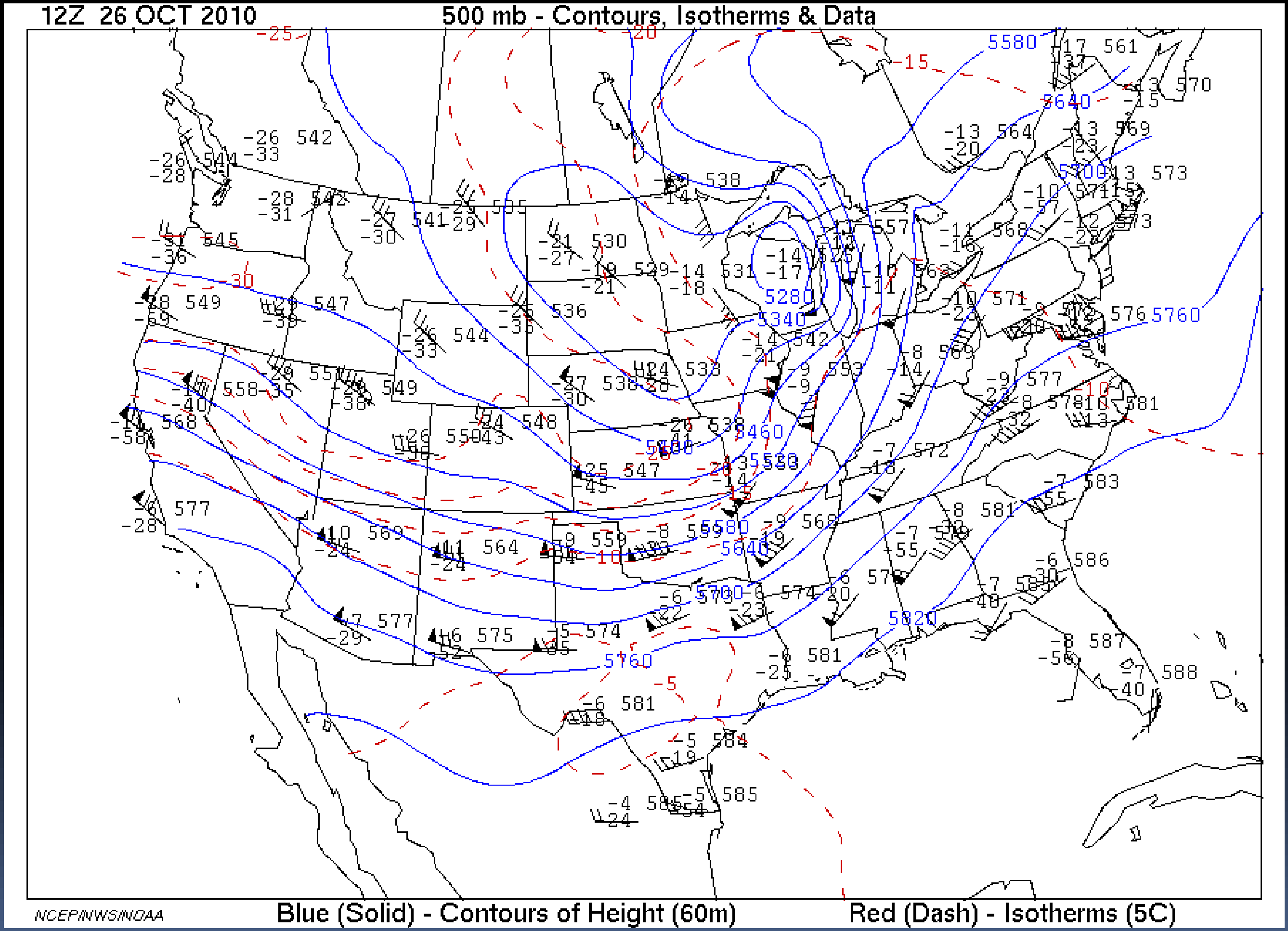
5.20 Upper-air pressure gradient

The isobaric surfaces in this upper-air pressure gradient map slope downward from the low latitudes to the pole, creating a pressure gradient force. Because the atmosphere is warmer near the Equator than at the poles, a pressure gradient force pushes air poleward. The pressure gradient force increases with altitude, bringing strong winds at high altitudes.

Atmospheric pressure at 500mb level



Atmospheric pressure at 500mb level



Atmospheric pressure at 800mb level

- There is a great variation in pressure distribution pattern aloft and at sea level
- The cellular pattern of pressure distribution disappears with increasing elevation.
- In the middle of the troposphere at 700 mb level the pressure cells grow much weaker
- In the northern hemisphere in January the pressure is characterized by a gradual decrease from the equator to pole at an elevation of about 3000 meters
- the pressure gradient is maximum in the middle latitude zones
- The pressure distribution pattern at the same level in July is different from that of January
- The pressure gradient is relatively less steep than that of January
- In July there is an extensive area of high pressure in the low latitudes
- Between latitudes of 20 to30 degree north and south there is a slight increase in air pressure at the same level

Atmospheric pressure at 500mb level

- The patterns of pressure and wind is less complicated in the middle troposphere than at the surface due to diminished effects of the land masses.
- In the middle troposphere of the southern hemisphere there is a vast circumpolar cyclonic vortex pole ward of latitude of 30 degree south in summer and winter
- The vortex is more or less symmetrical about the pole although low centre is towards the Ross sea sector
- There is an extensive cyclonic vortex in the northern hemisphere also with a primary center of low over the eastern Canadian arctic and a secondary one over eastern Siberia

- References:
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- D.S.Lal: Climatology, Sharda Pustak Bhawan, Allahabad