Paper CC5
Unit 2 Topic 5

General Circulation of the Atmosphere

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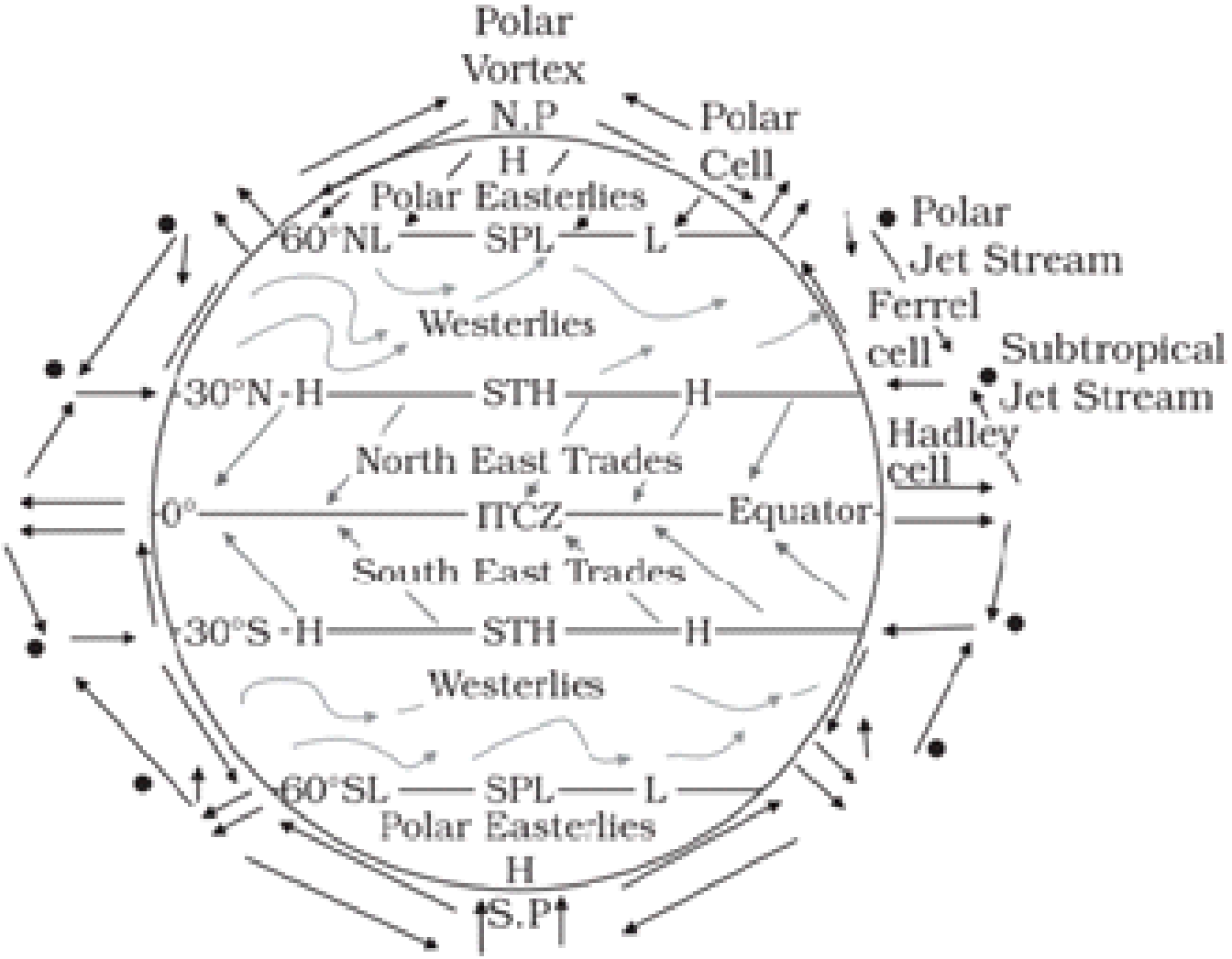
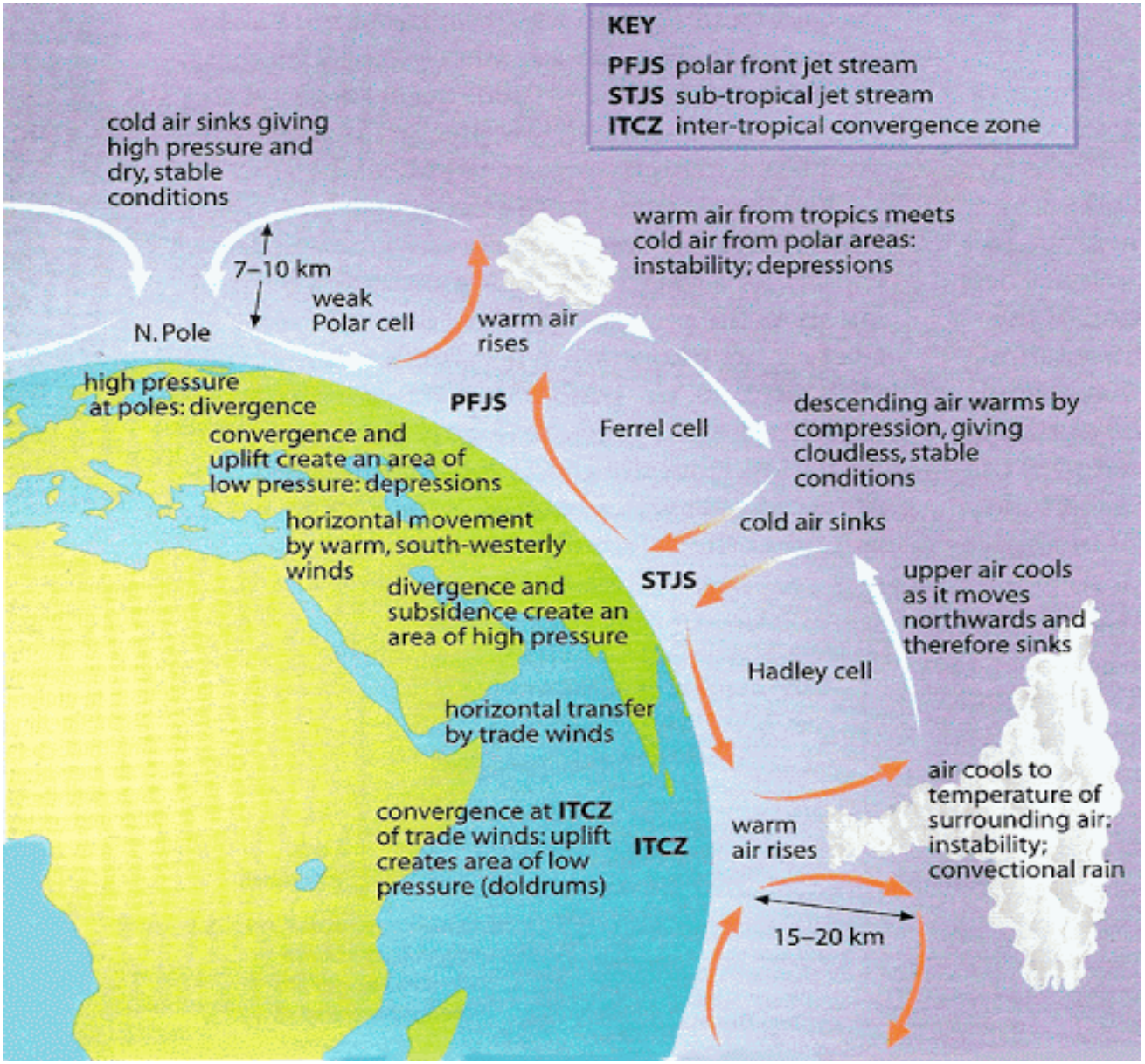


Simplified general circulation of the atmosphere

Tricellular Meridional Circulation



Concept

- According to the old concept of the mechanism of general circulation of the atmosphere the movement of air is temperature dependent.
- In other words, temperature gradient causes air circulation on the earth's surface.
- According to the advocates of thermal school of the mechanism of general circulation of the atmosphere the tropical areas receive maximum amount of solar energy which substantially decreases poleward.

- Thus, there is latitudinal imbalance of solar radiation from lower to higher latitudes.
- Consequently, there is transfer of heat through horizontal air circulation from the areas of high solar radiation (low latitudes) to the areas of low solar radiation (high latitudes) in order to balance the heat energy so that there does not exist too much heat energy in the low latitudes and too low heat energy in the high latitudes.

- This old school considers only the horizontal component of the atmospheric circulation and does not consider the potential energy generated by unequal heating of the earth and its atmosphere and its continuous transformation into kinetic energy.
- It may be pointed out that the potential heat energy is continuously transformed into kinetic energy by the upward movement (ascent) and downward movement (descent) of heated and cold air respectively.

- It may be remembered that the kinetic energy is also dissipated due to friction and small-scale atmospheric disturbances upward.
- Thus, it is necessary that there must exist balance between the rate of generation of kinetic energy and the rate of its dissipation due to friction.
- The modern concept of the mechanism of general circulation of the atmosphere, thus, includes both, the horizontal and vertical components of atmospheric circulation.

- The modern school envisages a three-cell model of meridional circulation of the atmosphere, popularly known as tri-cellular meridional circulation of the atmosphere, wherein it is believed that there is cellular circulation of air at each meridian (longitude).
- Surface winds blow from high pressure areas to low pressure areas but in the upper atmosphere the general direction of air circulation is opposite to the direction of surface winds.

Cells of Tri-Cellular Meridional Circulation

Each meridian has three cells of air circulation in the northern hemisphere e.g.:

(1) Tropical cell or Hadley cell,

(2) Polar front cell or mid-latitude cell or Ferrel cell, and

(3) Polar or subpolar cell

Tropical or Hadley Cell

- Tropical cell is also called as Hadley cell because G. Hadley first identified this thermally induced cell in both the hemispheres in the year 1735.
- The winds after being heated due to very high temperature at the equator ascend upward.
- These ascending warm and moist winds release latent heat after condensation which causes further ascent of the winds which after reaching the height of 8 to 12 kilometers in the troposphere over the equator diverge northward and southward or say poleward.

- The surface winds in the name of trade winds blow from subtropical high pressure belts to equatorial low pressure belt in order to replace the ascending air at the equator.
- The upper air moving in opposite direction to surface winds (trade winds) is called antitrade.
- These upper air antitrades descend near 30°-35° latitudes to cause subtropical high pressure belt.

- These antitrades after descending near 30°-35° latitudes again blow towards the equator where they are again heated and ascend.
- Thus, one complete meridional cell of air circulation is formed.
- This is called tropical meridional cell which is located between the equator and 30° latitudes.
- It may be pointed out that the regularity and continuity of the antitrade wind systems in the upper air has been refuted by a host of meteorologists on the basis of more upper air data being available during and after Second World War.

Polar Front Cell or Mid-Latitude Cell

- According to old concept surface winds, known as westerlies, blow from the subtropical high pressure belt to subpolar low pressure belt (60°-65°).
- The winds ascend near 60°-65° latitudes because of the rotation of the earth and after reaching the upper troposphere diverge in opposite directions (poleward and equatorward).
- These winds (which diverge equatorward) again descend near horse latitudes (30°-35° latitudes) to reinforce subtropical high pressure belt.
- After descending these winds again blow poleward as surface westerlies and thus a complete cell is formed.

- According to new concept of air circulation the pattern between 30°-60° latitudes consists of surface westerlies.
- In fact, winds blow from subtropical high pressure belt to subpolar low pressure belt but the winds become almost westerly due to Coriolis force.
- It may be mentioned that the regularity and continuity of westerlies are frequently disturbed by temperate cyclones, migratory extra-tropical cyclones and anticy-clones.

- Contrary to the existing view of upper air tropospheric easterly winds in the zones extending between 30°-60° latitudes Rossby observed the existence of upper air westerlies in the middle latitudes due to poleward decrease of air temperature.
- According to G.T. Trewartha the middle and upper tropospheric westerlies are associated with long waves and jet streams.
- Warm air ascends along the polar front which is more regular and continuous in the middle troposphere.
- It may be pointed out that this new concept does not explain the cellular meridional circulation in the middle latitudes.

Polar Cell

- Polar cell involves the atmospheric circulation prevailing between 60° and poles.
- Cold winds, known as polar easterlies, blow from polar high pressure areas to sub-polar or mid- latitude low pressure belt.
- The general direction of surface polar winds becomes easterly (east to west) due to coriolis force.

- These polar cold winds converge with warm westerlies near 60°-65° latitudes and form polar front or mid- latitude front which becomes the centre for the origin of temperate cyclones.
- The winds ascend upward due to the rotation of the earth at the subpolar low pressure belt and after reaching middle troposphere they turn poleward and equatorward.
- The poleward upper air descends at the poles and reinforce the polar high pressure.
- Thus, a complete polar cell is formed.

Objections

- The temperature gradient should not be taken as the only basis for the origin and maintenance of cellular meridional circulation because not all the high and low pressure belts are thermally induced.

- For example, the subtropical high pressure and sub-polar low pressure belts are dynamically induced due to subsidence and spreading of air caused by the rotation of the earth respectively.
- Upper air anti-trades are not uniformly found over all the meridians.
- If the trade winds are exclusively of thermal origin, then the thermal gradient must be present boldly throughout the tropics but this is not true.
- At the height of 500 to 1000m in the atmosphere the winds become almost parallel to the isobars which are generally parallel to the latitude.
- If this is so, the meridional cell of air circulation may not be possible.

Conclusion

- The pressure and winds in most parts of lower atmosphere are found in cellular form rather than in zonal pattern.
- These pressure and winds cells are elliptical, circular or semi-circular in shape.
- These evidences (cellular form of air circulation) no doubt contradict the old concept of general pattern of atmospheric circulation but the cellular meridional circulation has not been fully validated.