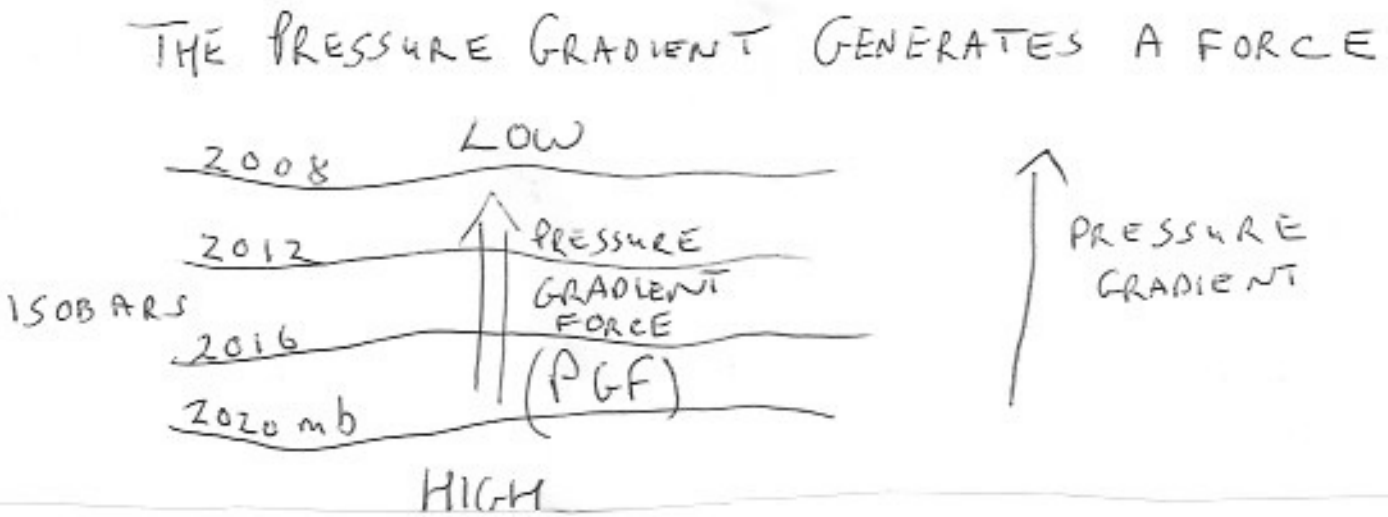
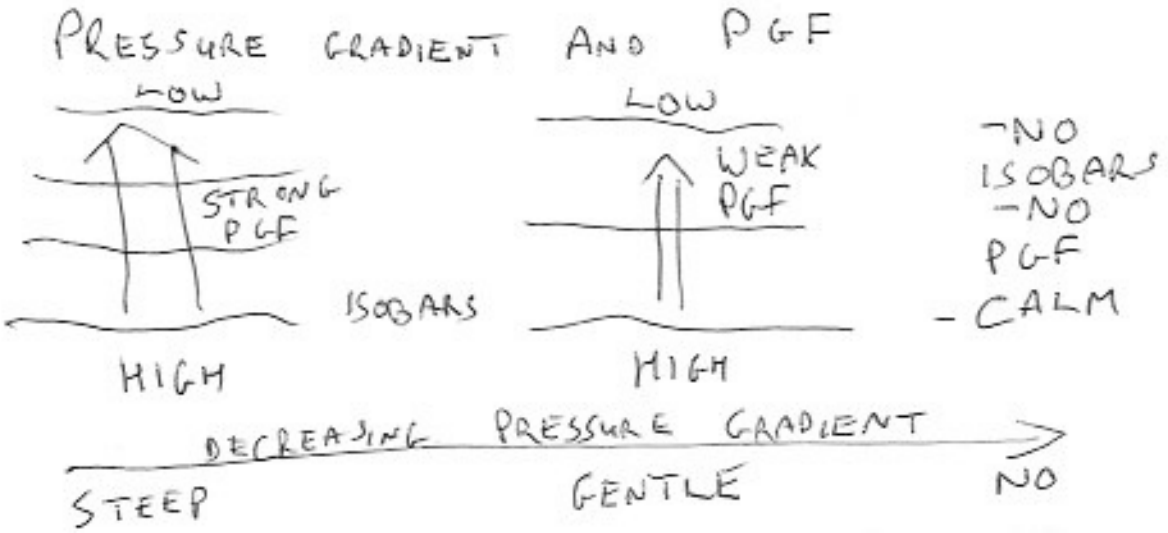
THE GENERAL CIRCULATION

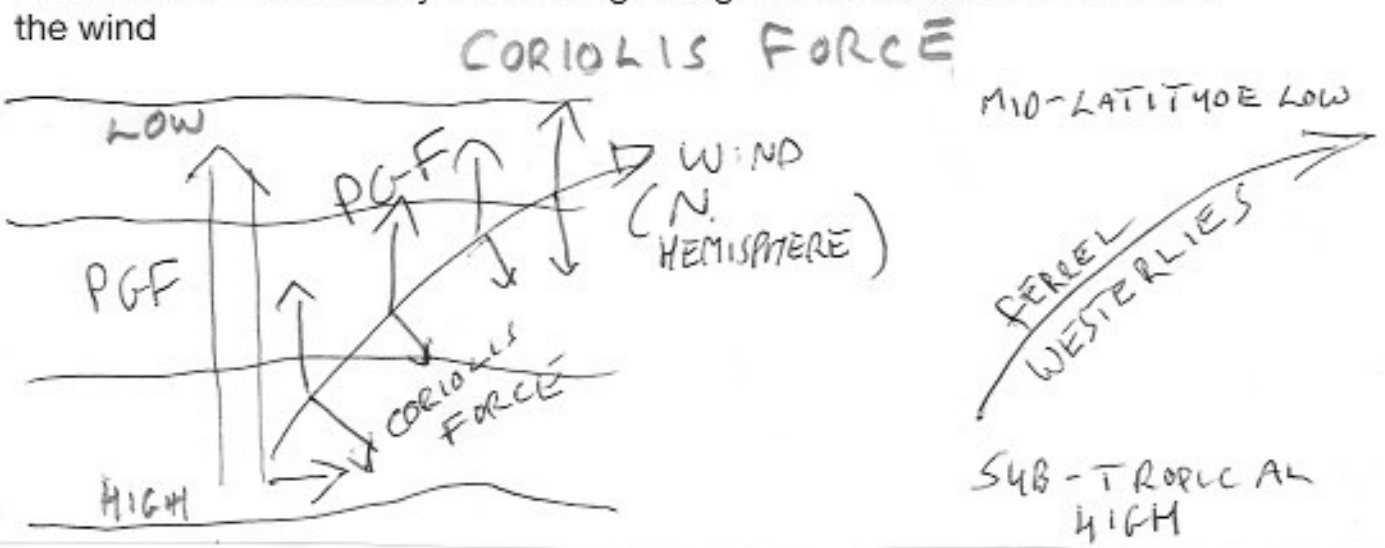
- The organised pattern of winds across the earth
- Not just surface winds, also a vertical/3D element up to the Tropopause (upper limit of the Troposphere, approximately 8-15 km) and the lower Stratosphere
- Energy for the system of circulation is from the sun in the form of solar radiation
- This sets up a pattern of high and low pressure zones that are either thermally induced by temperature differences or dynamically induced by vertical air movements
- The wind directions are generated by pressure differences and the pressure gradient between permanent and semi-permanent high and low pressure systems



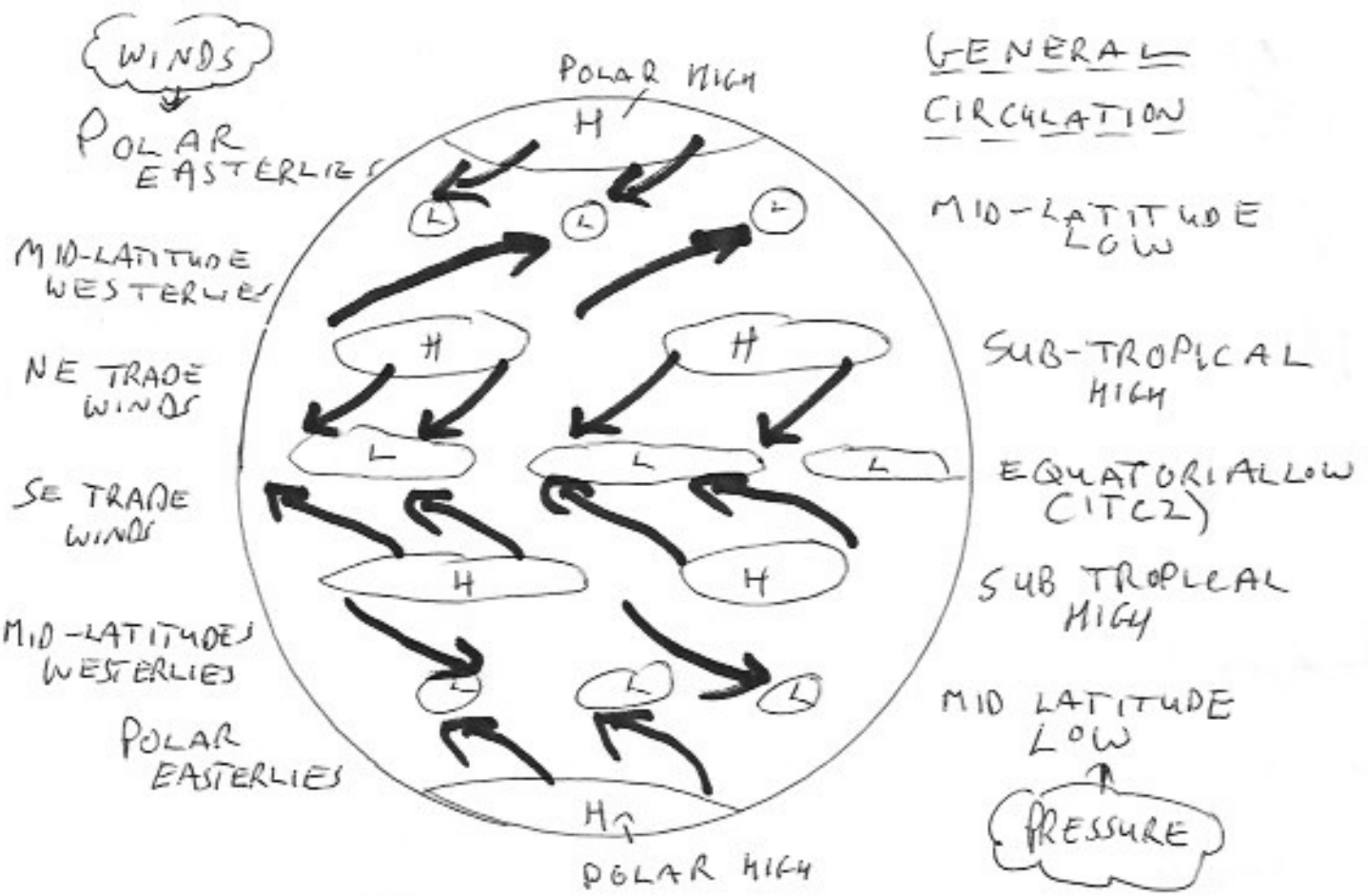
- The Coriolis 'Force' has an important impact on the general circulation of winds. Caused by the earths rotation this 'force' bends winds to the right in the northern hemisphere and to the left in the southern hemisphere
- The pressure gradient generates a force from high to low pressure, the Pressure Gradient Force (PGF). The strength of the PGF is determined by the steepness of the pressure gradient. A steep pressure gradient produces a strong PGF, a gentle pressure gradient produces a weak PGF and if there is no pressure gradient the PGF is zero



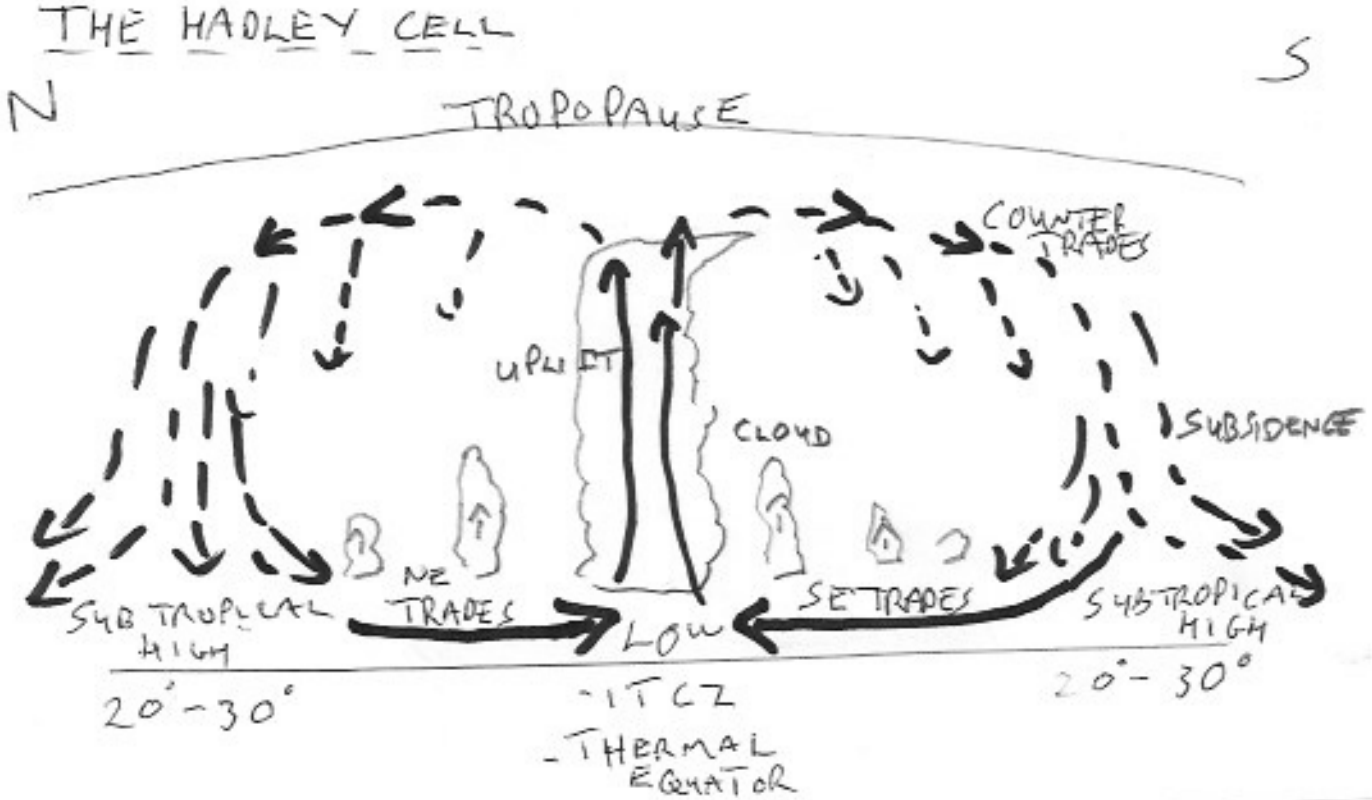
- The global pressure systems are fairly constant in position and strength which causes the global pattern of winds (the general circulation) to be fairly constant and reliable on a global or regional scale
- More local pressure patterns and winds may not, however, follow the general circulation. The UK, for example is in a westerly wind belt in terms of the general circulation, meaning that the prevailing wind direction is from the west, but over any short term period winds may be from any direction
- The PGF always acts 'down' the pressure gradient from high to low and the Coriolis 'Force' always acts at right angles to the direction of flow of the wind



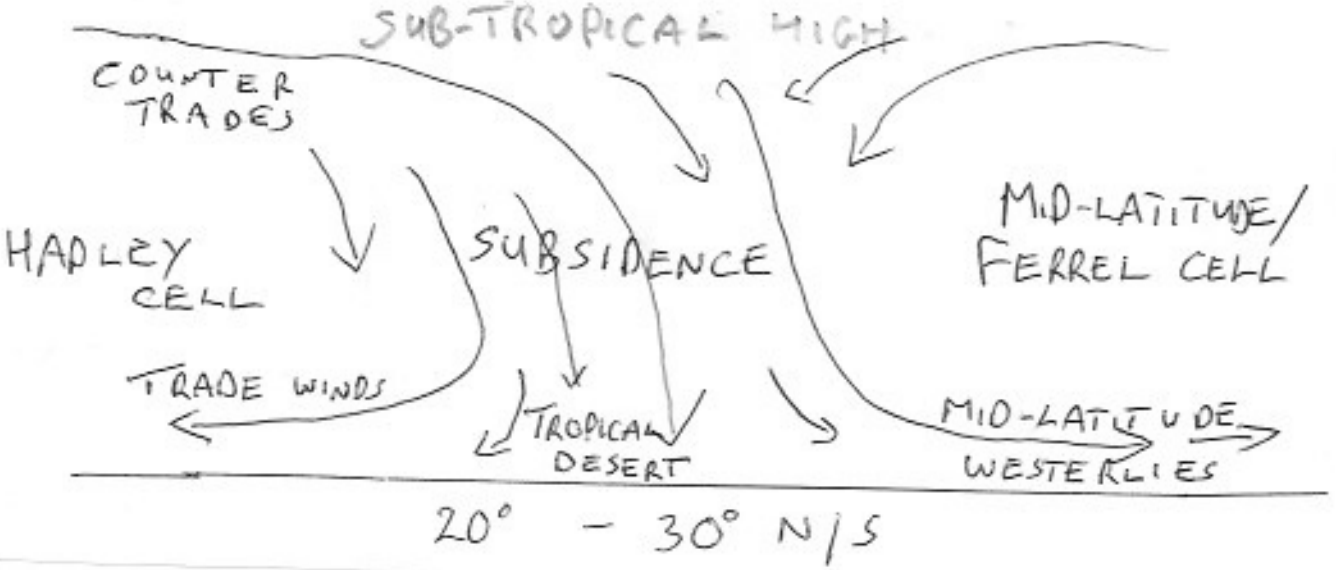
- The strength of the Coriolis 'Force' is affected by latitude. At the Equator (0 latitude) the force is zero and it increases with increasing latitude
- The general circulation has 3 Cells determined by the the position of global high and low pressure systems



- The Hadley cell forms the Tropical element of the general circulation. This is driven by two pressure systems, the equatorial low at or near the thermal equator (zone of highest temperatures and therefore lowest pressures); and the sub-tropical high pressure cells around 20-30 degrees north and south of the equator. The sub-tropical highs are dynamically induced by descending air currents.
- The air flows equator-wards from the sub-tropical highs towards the equatorial low. Diverted by the Coriolis effect these airflows become the North East and South East Trade winds. Since the patterns of high and low pressure systems in the tropics is consistent in strength and position the resulting trade winds are equally consistent in strength and direction and during the age of sailing ships were important for world 'Trade'
- The convergence of air at or near the equator produces the Inter-Tropical Convergence Zone (ITCZ), here converging and rising air flows produce a girdle of cloud, often cumulonimbus, and heavy rainfall around the earth at or near the equator
- Pressure gradients are small at the equatorial low causing light and variable winds in the area known as the Doldrums
- At the sub-tropical highs the air drawn aloft at the ITCZ and moved polewards as the Counter Trades descends producing the high pressure (dynamically induced)

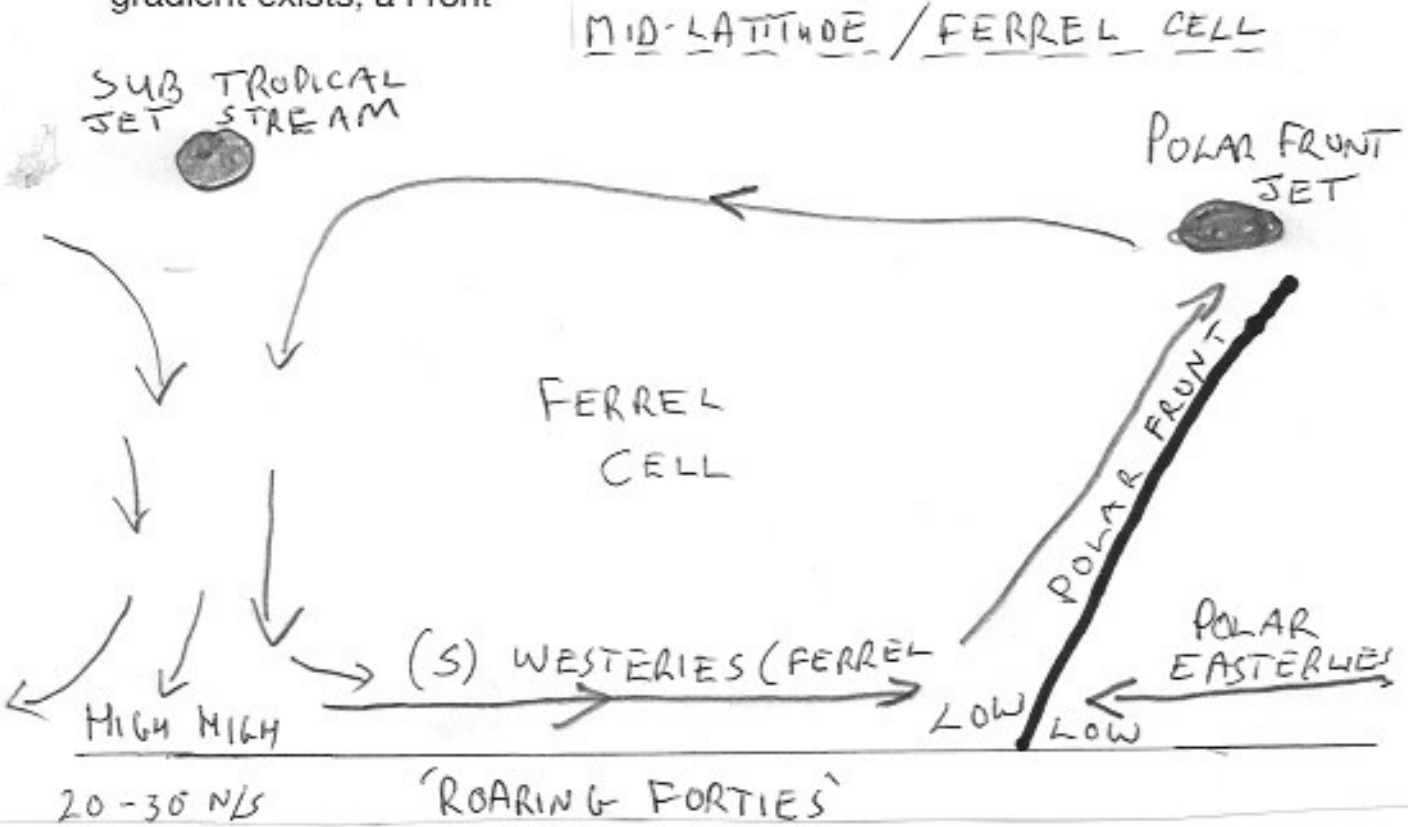


- This air warms as it descends producing a mid-troposphere inversion that limits up-currents of air, stops cloud formation and greatly limits the chance of rainfall. As such these high pressure systems overlay the Tropical deserts



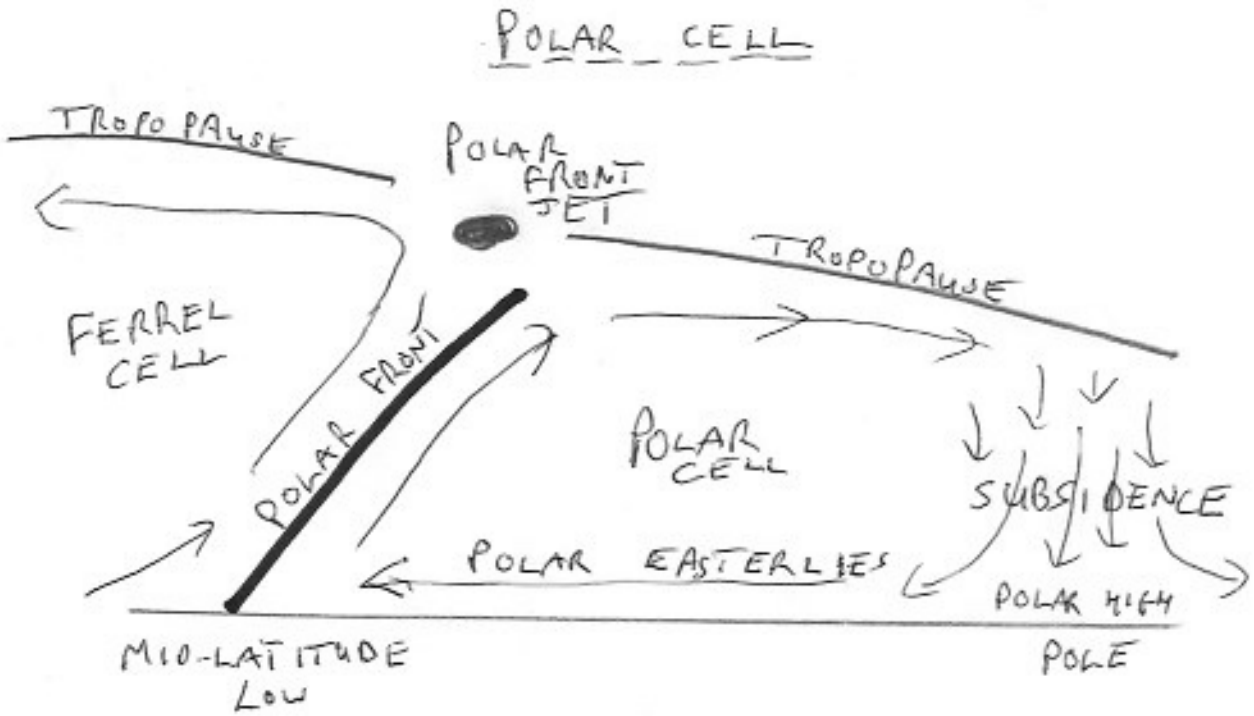
- The pressure gradients in the sub-tropics are usually very gentle giving light winds and a general outflow of air both equator-wards and polewards
- The ITCZ/Thermal Equator will move with the 'movement' of the sun and the seasons and is generally north of the equator in the northern hemisphere summer (June) and south of the equator in the southern hemisphere summer (Dec). The ITCZ will, however, lag behind the sun reaching only 10 or so degrees N or S of the equator, not reaching the respective tropics, Cancer and Capricorn (231/2 degrees N or S)
- It is also influenced by the disposition of land and sea, since land surfaces reach higher temperatures than sea surfaces and the equatorial low/ITCZ will follow land masses where possible
- This has a marked impact in West Africa, where the ITCZ stays north of the equator in the southern summer and the SE Trades cross the equator to become the SW Monsoon winds before they converge on the ITCZ in West Africa itself

- The mid-latitude or Ferrel Cell makes up the second element of the general circulation. Some of the descending and diverging air at the sub-tropical highs spreads polewards. As the air moves away from the equator it is deflected by the Coriolis effect to form Westerlies, south-westerlies in the northern hemisphere and north-westerlies in the south
- In the southern hemisphere the large expanse of ocean and lack of friction allows these winds to be extremely strong, the so called Roaring Forties, named after their approximate latitudes
- At about 50-60 degrees North and South a marked boundary forms between these mid-latitude westerlies and the Polar Easterlies
- This semi-permanent boundary forms the Polar Front running more or less east-west. In the northern hemisphere this front is a distinct boundary between the warmer tropical air to the south and colder polar air to the north
- Here the two airstreams do not mix significantly and a sharp temperature gradient exists, a Front



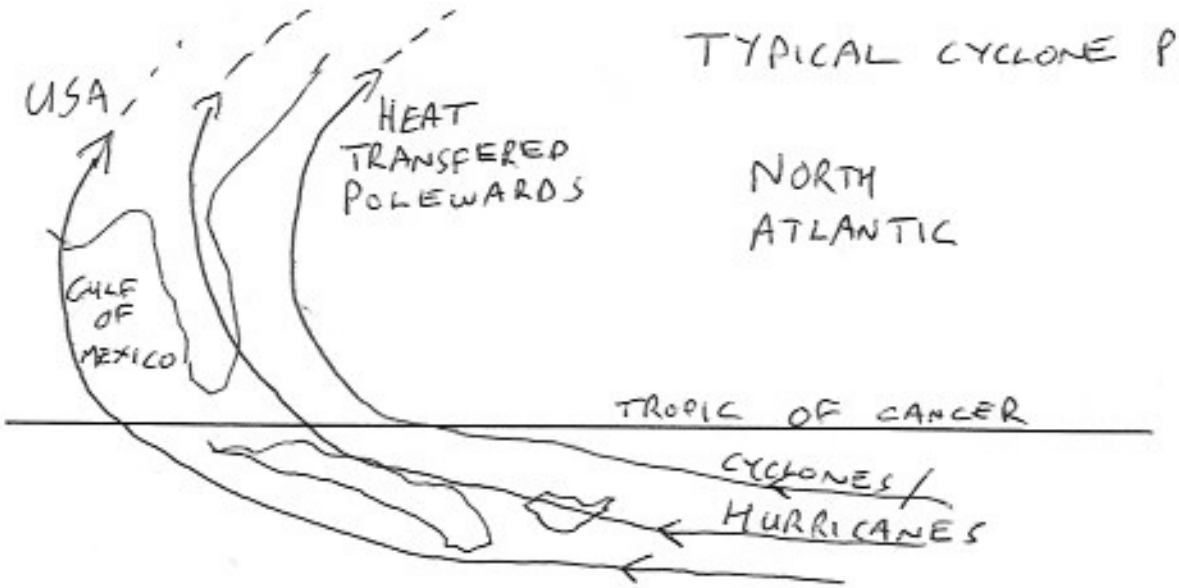
- At the Polar Front the warm tropical air rises over and is undercut by the colder, heavier polar air mass.This forms a distinct cloud zone as the warm air rises and condenses, and a region of 'frontal' precipitation is found
- As this rising air reaches the Tropopause it reverses direction and moves equator-wards aloft to descend again at the sub-tropical high pressure belts
- The third and final cell in each hemisphere of the General Circulation is the Polar cell. Sitting above each polar region is a high pressure zone caused by the cold, heavy air found there. This cold, heavy air descends and flows equator-wards away from the poles

- The Coriolis effect defects these winds to produce Polar easterlies, north easterlies in the northern hemisphere and south easterlies in the southern
- This cold polar air spreads away from the poles to confront the warmer tropical air at the respective Polar Fronts. Although the depth of the troposphere is less nearer the poles than at the equator due to the lower temperature of the air it is thought that a 3 dimensional cell does exist with air returning aloft to the poles to descend at the polar highs



- The motivational force behind the general circulation is the need to transfer heat from the tropics towards the poles. Tropical areas receive more energy from the sun than they lose and high latitude lose more heat than they gain; a major purpose of the general circulation is to equalise this imbalance to prevent tropical areas continuing to heat up
- In the Tropics the poleward transfer of heat is produced by the counter Trades that move warm air away from the equator. Descending at the sub-tropical highs, some of the heat is transferred polewards as the air spreads away from these high pressure systems
- Disturbances within the Trade wind belt may also be responsible for some poleward transfer of heat. Tropical storms forming initially as Easterly Waves in the eastern ends of oceans may eventually reach Cyclone/ Hurricane/Typhoon status, and as they move westwards, in the Northern Hemisphere, may veer northwards, dissipate and become part of the mid-latitude circulation
- These Hurricanes are fuelled by the heat of the Tropical oceans. Both sensible heat and latent heat are taken up into the air from the surface layers of the ocean water. Latent heat may be particularly important, as tropical ocean water evaporates and the condenses to form the clouds of a

cyclone the heat is transferred to the atmosphere. In the Atlantic Ocean, as these storms move west they often veer northwards across Florida or into the Gulf of Mexico, eventually transferring their energy into the mid-latitude airstreams



- In mid-latitudes the poleward transfer of heat is aided by the formation of travelling frontal depression systems along the polar front. At this boundary between the warm tropical air and colder polar air disturbances form as frontal depressions and as the occlude and eventually dissipate a parcel of warm air is transferred across the polar front towards the poles.

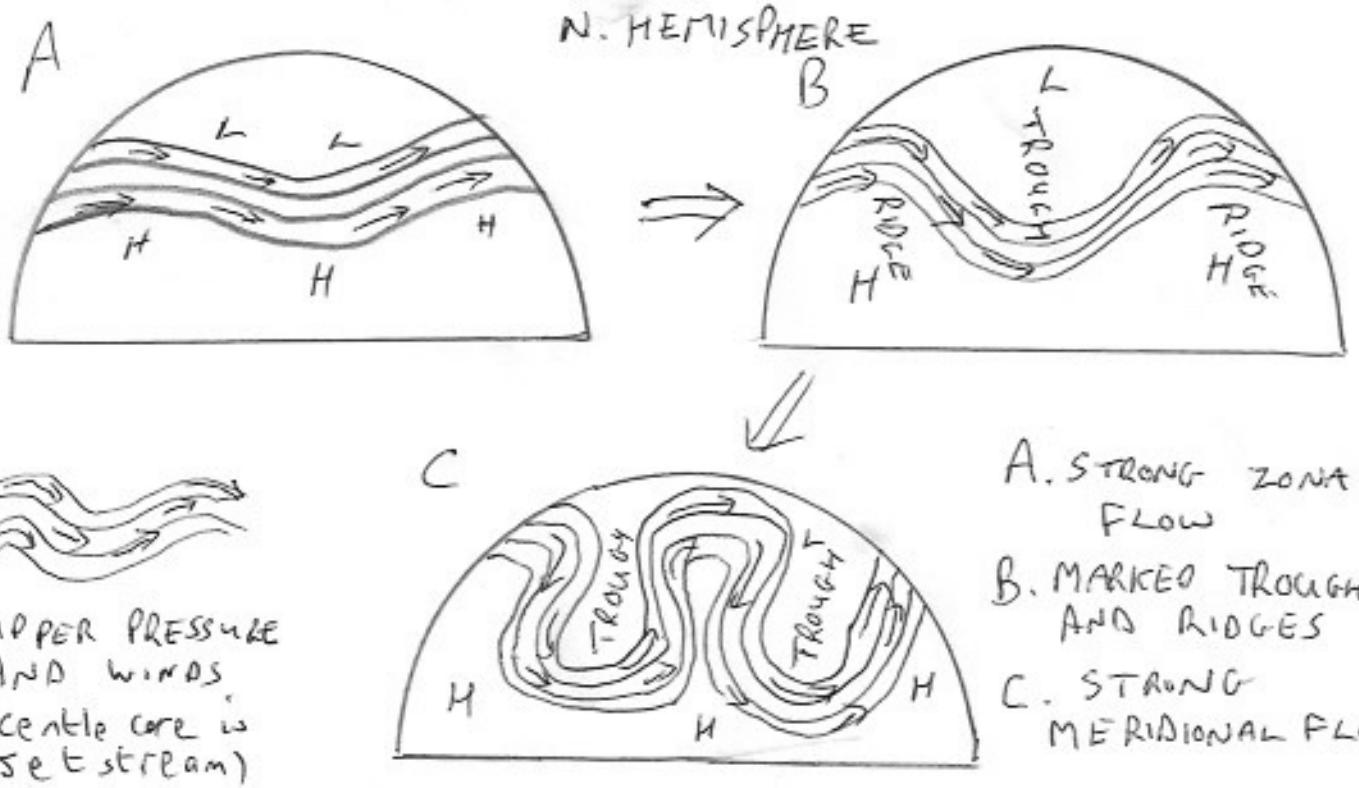
ROLE OF FRONTAL DEPRESSIONS IN HEAT TRANSFER

LIFE CYCLE OF DEPRESSION a-d

- This meridional transfer of air and energy is illustrated by the Index Cycle. The main body of the mid-latitude westerlies both low levels and upper levels as illustrated by the polar front Jet Stream undergo a cycle of changes. These changes are from strong zonal flow, where air flows from west to east to a more extreme part of the cycle where strong meridional air flows occur and air/energy is transferred to the poles.

ROSSBY LONG WAVES AND THE INDEX CYCLE

N. HEMISPHERE



UPPER PRESSURE AND WINDS (Centre core is jetstream)

A. STRONG ZONAL FLOW

B. MARKED TROUGHS AND RIDGES

C. STRONG MERIDIONAL FLOW