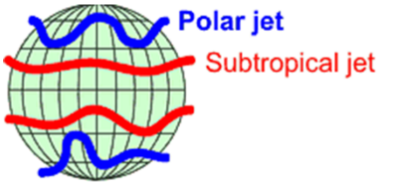
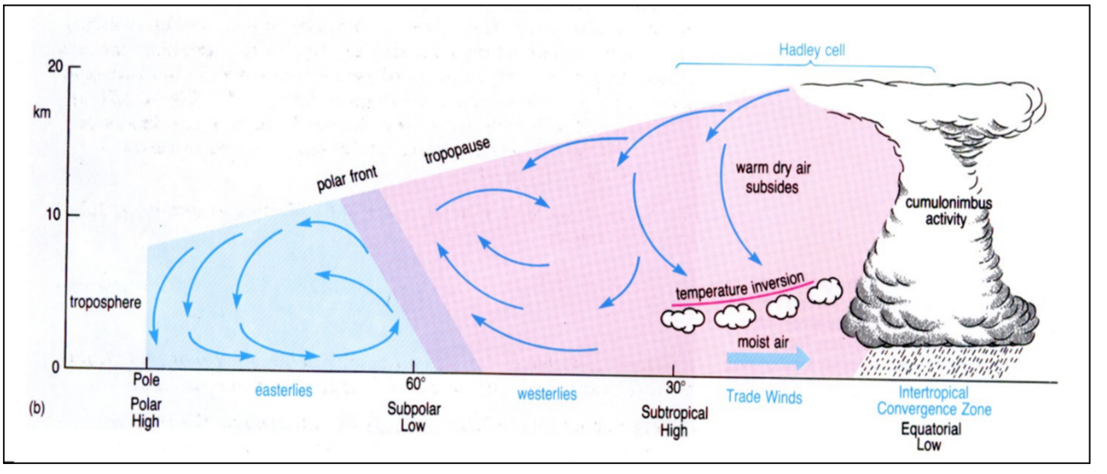
13. Polar Highs (90°N,S)

- cold air sinks - Polar easterlies



14. Subpolar lows (60° N,S)

- warm air rises in between ferrel cell and polar cell.
- Polar jet can be observed near the tropopause



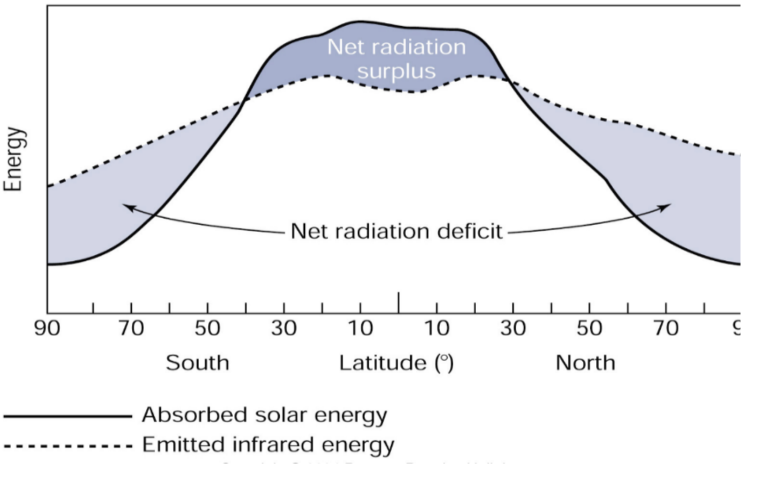
Global Heat Imbalance:

Primary energy input-> solar radiation

(Results: Hot at equator, cold at poles)

-> Zone of <u>Low pressure</u> at **Tropics** and <u>High pressure</u> at **Poles.**

➔ Approximately **50%** of the heat is transported by the <u>atmosphere</u> and **50%** by the <u>ocean</u>.



15. Monsoon winds

- Weak monsoon at the transition season (April to May)
- Similar to the sea/land breeze system but on a seasonal time scale
- Northern hemisphere **winter**: high pressure in northern India: **North-east Monsoon**
  - No monsoon in the atlantic and pacific, pacific has no land in north and south
  - <u>High pressure systems</u> move to the **East**
  - Onshore wind in Aus
  - ITCZ at the south
- Northern hemisphere **summer**: low pressure in northern India: **South-west Monsoon**
  - <u>High pressure systems</u> move to the **West**
  - ITCZ at the north
  - Hadley and Ferrel cell converge at AUS
  - Offshore wind in Aus, WA is open to the Ferrel cell and experienced the westerlies.

Air-Sea fluxes of heat and water

$$\boxed{c_P \frac{dT}{dt} = Q_{IN} - Q_{OUT}}$$

- ➔ Sea surface temperature and salinity are controlled by air-sea interaction.
- ➔ Sea Surface Temperature (SST) is warm, Sea Surface Salinity (SSS) is low, excess precipitation can be seen along the ITCZ.
- ➔ Sea Surface Temperature (SST) is warm, Sea Surface Salinity (SSS) is high, excess evaporation can be seen along the Subtropics.

Heat Budget:

Incoming short-wave radiant energy from the sun at the top of the atmosphere is balanced by outgoing long-wave radiation. (Incoming = Outgoing)

<u>Air – Sea heat fluxes</u>

Incoming shortwave radiation (Q_{SW}) =

Outgoing longwave radiation (Q_{LW}) + Sensible heat flux (Q_S) + Latent heat flux (Q_L)

<u>Factors controlling the fluxes:</u>

Q_{SW} – latitude and cloud cover (albedo) *in the atmosphere*. = Q_s

Q_{LW} – Temperature, water vapour, cloud cover. = Q_b

Q_S – Boundary layer turbulence, heat lost by conduction (carried by wind). = Q_h

Q_L – Evaporation. = Q_e

➔ $Q_T = Q_{SW} - Q_{LW} - Q_S - Q_L$

Q_{SW} – Low heat flux at the equator due to the abundance of cloud cover over the sea surface;

Q_{LW} - high humidity at the equator will reduce the heat;

Q_L – wind speed and relative humidity affect the rate of evaporation;

Q_S – driven by surface wind speed and air-sea temperature difference.

Oblique Rays – Sum directly overhead in tropics. Rays strikes Earth surface at increasingly oblique angles.

Reflection by Earth – Different surfaces have different Albedoes. (Snow/Ice reflects 70-95% of energy received; water/forest reflects 3-10% of energy)

Summer Solstice – length of the day is the longest, the amount of heat receives is different as compared to winter solstice.

Lengths of day and night vary more between the seasons at higher latitudes. This makes climate more seasonal at the poles than the equator.

Inertial motion: circular path due to centrifugal acceleration = $\frac{U^2}{r}$

Centrifugal force always operates away from the center.

Centrifugal force – outside; Coriolis Force – inside

ROTATION: Northern H. – **Clockwise**; Southern H. – **anti-clockwise**

Cyclostrophic Balance: occurs where flow is on a small enough scale where the Coriolis force becomes negligible.

Rossby Number: The importance of the Coriolis force is defines through the use of the Rossby Number (R_o):

$$R_o = \frac{Centrifugal.Force}{Coriolis.Force} = \frac{\frac{v^2}{R}}{fv} = \frac{v}{fR}$$

Small values of Rossby Number (R_o ~0.01) – Coriolis Force is important (Geostrophic balance)

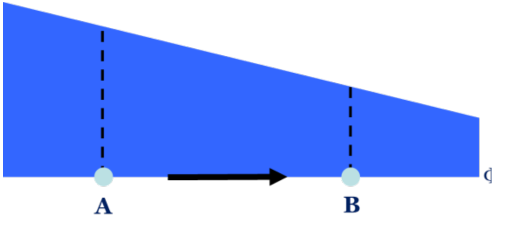
Large values of Rossby Number (Ro > 100) – Coriolis Force is **NOT** important (Cyclostrophic balance)

Geostrophic Balance: If the pressure gradient term is known then can estimate the velocity. (Refer to Geostrophic flow in the later section).

- The only external force is gravity. (Friction is negligible)
- Assume no acceleration, steady state, vertical velocity << horizontal velocity (x and y direction).

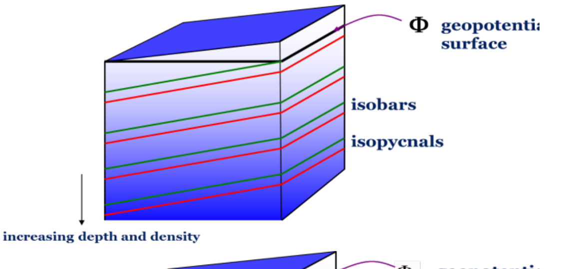
18. Geopotential surface

- A geopotential surface is a horizontal surface i.e. gravity acts perpendicular to a geopotential surface. Usually denoted by Φ.
- Velocity = 0 at the horizontal surface.



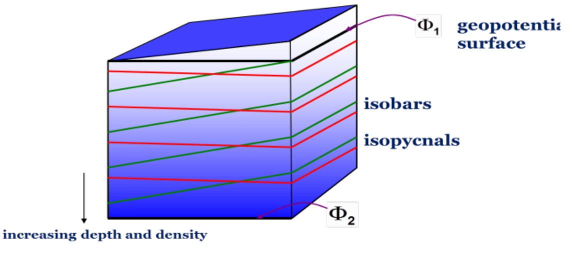
19. Barotropic flow (well mixed ocean)

- When isopycnals (lines of equal density) are parallel to isobars.
- If Φ is parallel to isobars then there is no motion.
- No density change.



20. Baroclinic flow (Stratified ocean)

- Wind moves the water without changing its density.
- Paratrophic force (wind & tides)
- Density flow, density changes with depth and space.
- Heating/cooling will change the temperature of the system in turns changing the density of the system (Baroclinic force).



Rossby Radius of Deformation (R_0) is the distance that a particle or wave travels before being significantly affected by the earth's rotation. It defines the effect of **Coriolis force**.

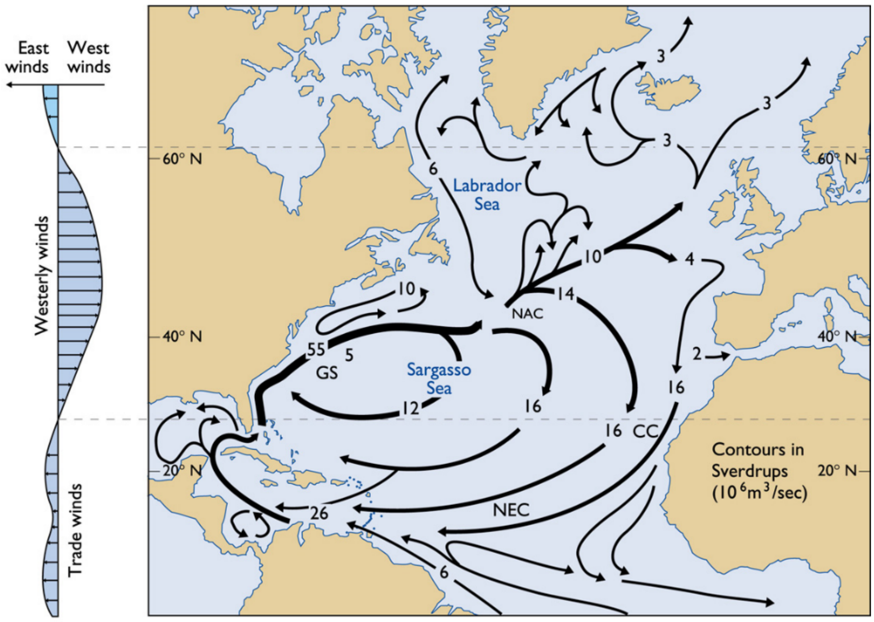
$$R_0 = \frac{\sqrt{gh}}{f}$$

h is the water depth.

- L decreases with latitude (increasing f) so that a wave (or current for that matter) at high latitude need only travel a short distance before being affected by Coriolis Force.

32b. North Atlantic Subtropical Gyre (Sargasso Sea)

- Surrounded by Gulf Stream, North Atlantic Current, Canary Current, and North Equatorial Current.



(a) FLOW RATES IN THE NORTH ATLANTIC OCEAN

33. Canary Current
- A wind-driven surface current that is part of the North Atlantic Subtropical Gyre. This **eastern boundary current** branches south from the North Atlantic Current and later joins the Atlantic North Equatorial Current.

34. Benguela Current
- A northward flowing ocean current that forms the **eastern portion** of the
- South Atlantic Ocean Gyre. A branch of the West Wind Drift of the Southern H.

35. California Current
- A Pacific Ocean current that moves equatorward (southward) along the western coast of North America. This **eastern boundary current** is part of the North Pacific Subtropical Gyre.

36. Humbolt Current (Peru Current)
- A cold, low salinity ocean current that flows equatorward (northward) along the west coast of South America. An **eastern boundary current**.

<u>Major coastal upwelling ecosystems</u>

37. Upwelling/Downwelling in the Ocean
- Coastal Upwelling (divergence) and Downwelling (convergence, due to gravity pulling water downwards).
- The movements of water mass in the ocean are essential in stirring the ocean, delivering oxygen to depth, disturbing heat, and bringing nutrients to the surface.
- **Downwelling**: water goes vertically downwards. (occurs at horse latitude~30°N/S)