ATM 10 Severe and Unusual Weather

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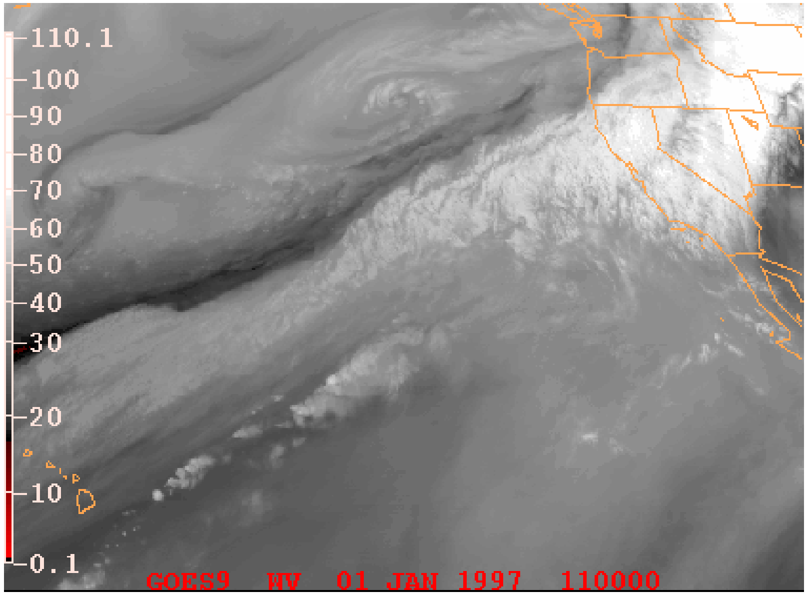
http://atm.ucdavis.edu/~grotjahn/course/atm10/index.html

Lecture topics:

- Relations between T, P, and wind
  - Hydrostatic law
  - “Sea level” station pressure
  - Relation between T and the slope of a P surface
  - Pressure gradient driving a motion
- Forces (general)
- Circulations driven by T differences
- Rotation and wind: Coriolis Force

T, P, & Wind

- Why do clouds move like this?



Hydrostatic Law – general (pt 1)

- Recall: pressure = force / area. Where, the force = "weight" of air molecules above.
- Recall: The amount of air molecules above = the density times the depth of the column.
- Hydrostatic law similar, except breaks the column into layers.
- Layer thickness depends on T and P change from bottom to top of the layer.

Hydrostatic Law – general (pt 2)

- P = force / area (upward)
- Downward force in a layer of thickness Δz and area 1 square meter is the weight:
  $\text{force} = \text{mass} * g = \rho * \Delta z * g * 1\text{m}^2$
- Hydrostatic law says downward force by weight of air balances the upward force by air pressure difference across the layer = ΔP
- Hydrostatic law:

$$\Delta P + \rho * \Delta z * g = 0$$

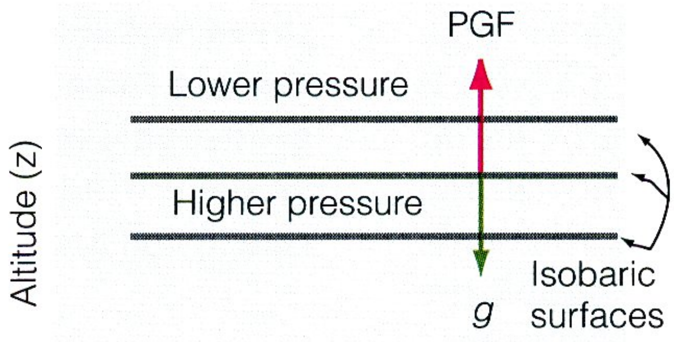


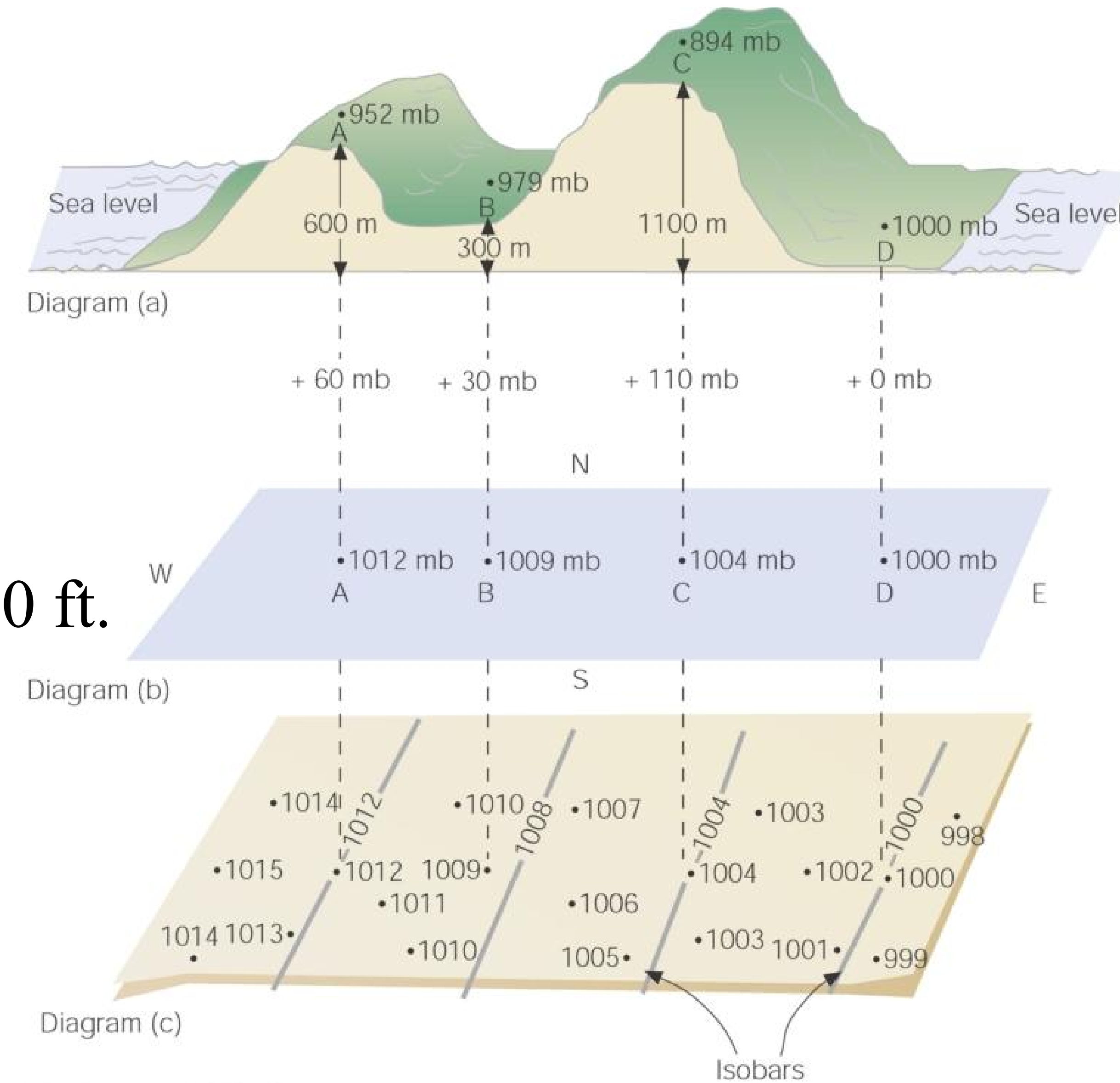
Figure 7
When the vertical pressure gradient force (PGF) is in balance with the force of gravity (g), the air is in hydrostatic equilibrium.

Hydrostatic Law – general (pt 3)

- Bringing the $\rho * \Delta z * g$ to the right side gives:
- Hydrostatic law: $\Delta P = - \rho * \Delta z * g$
- Note:
- Minus sign indicates opposite directions of the pressure (up) and gravitational weight (down) forces.
- The thicker the layer (Δz large) the more the pressure decreases by ΔP as one goes up.
- Example in book on page 243: let $g = 9.8\ m/s^2$, $\rho=1.1\ kg/m^3$, and $\Delta z = 1000\ m$; that makes $\Delta P = 10780\ Pa$ which $= 108\ mb$

Figure 9.8

Example 1 – Sea Level Pressure



Sea-Level Pressure Chart

- Lake Tahoe: ~6000 ft. actual P~840 mb.
- Sea level pressure ~1000 mb.

Example 2 – T versus Slope of P

- Recall: $P = \rho * R * T$
- Recall: $\Delta P = - \rho * \Delta z * g$
- Find Δz for ΔP=500 mb
- If ΔP is fixed, then a different Δz implies a compensating ρ
- Ideal gas law says ρ is related to T
- Where T is larger, ρ is smaller for a given P. If ρ is smaller, then Δz is larger for fixed ΔP.

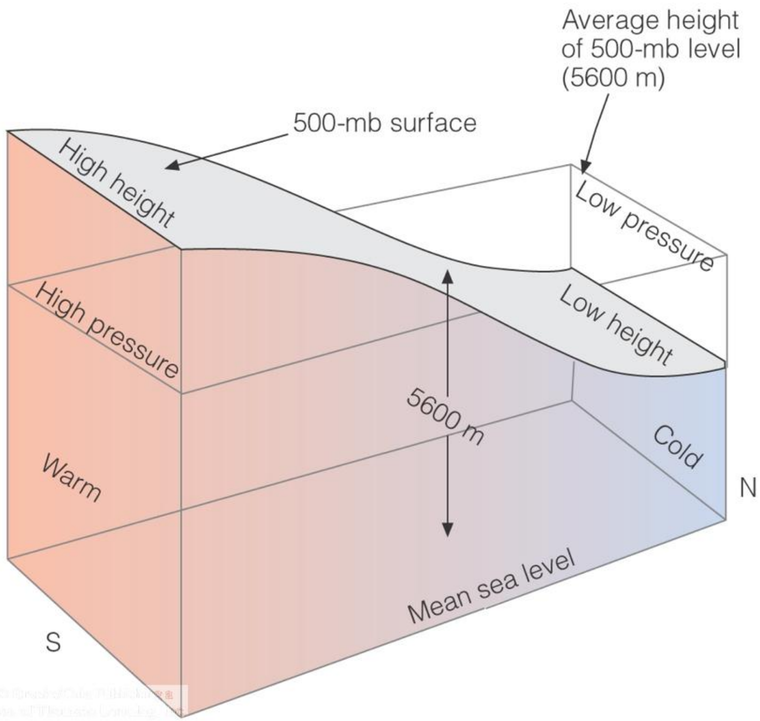
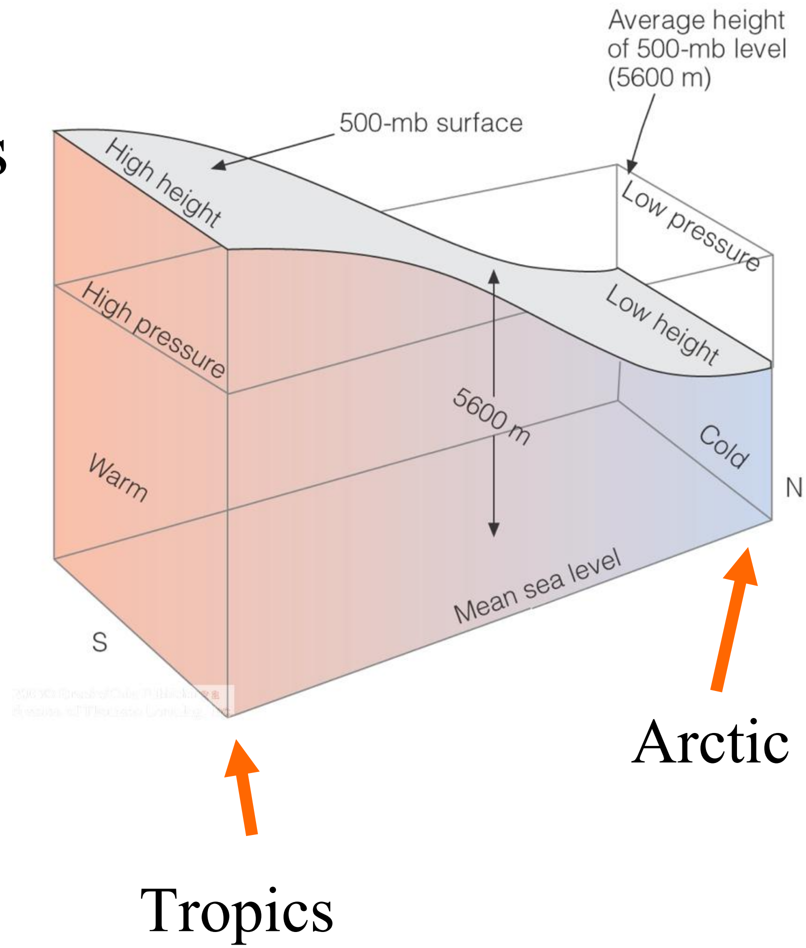


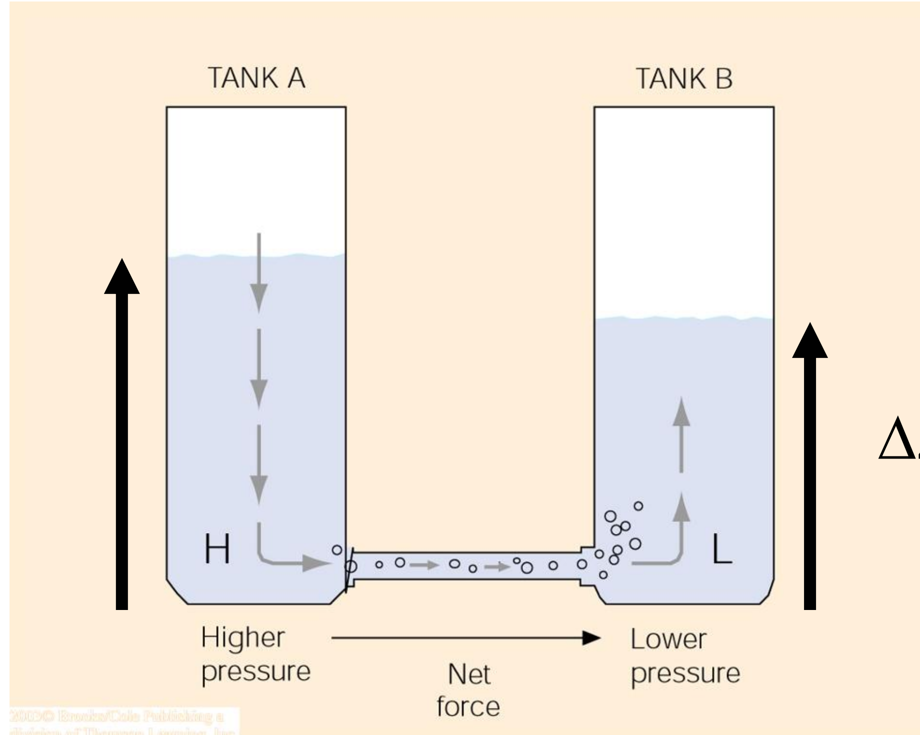
Fig. 9.12

Example 2 – T versus Slope of P

- Where T is larger, ρ is smaller for a given P. If ρ is smaller, then Δz is larger for fixed ΔP.
- Vice-versa where it is cold.
- Warm in tropics → larger Δz for fixed ΔP → higher elevation of P=500 mb.
- Lower elevation for polar regions because the air is cold.



Example 3 – pressure force



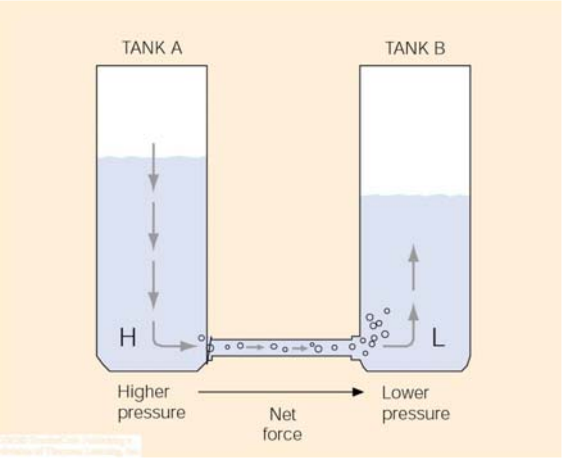
$$\Delta P = - \rho * \Delta z * g$$

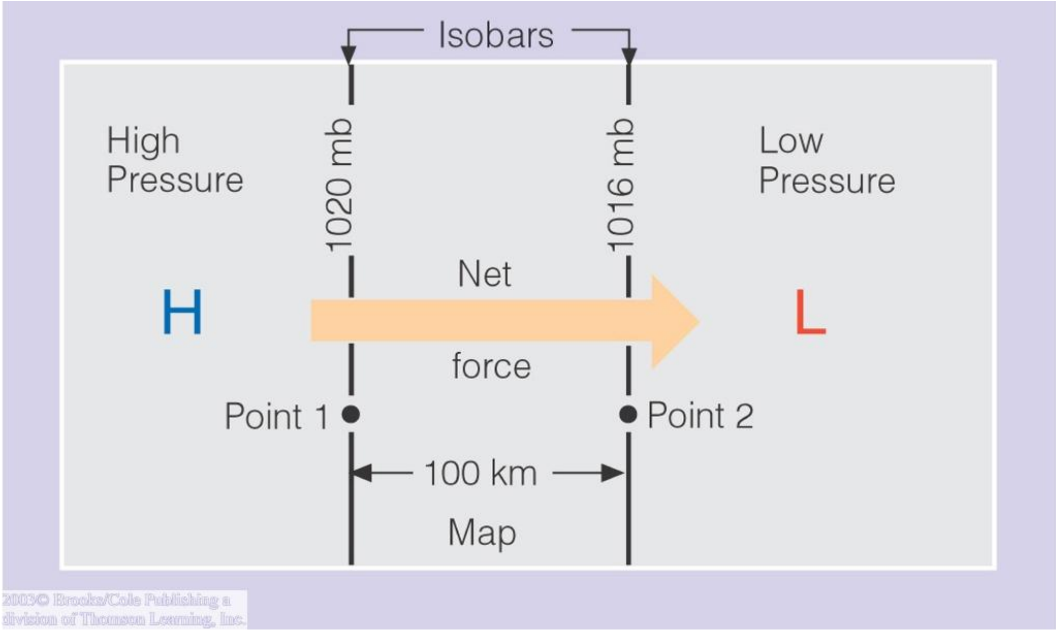
- Open tanks containing different depths of water
- Hydrostatic law gives pressure at bottom of each tank
- Greater depth ($\Delta Za > \Delta Zb$) means ΔP at bottom of tank A is greater than ΔP at bottom of tank B. => net force

Forces

- 4 forces:
  - Pressure,
  - Coriolis,
  - Centripetal,
  - Friction
- Most motions a combination of these 4

Newton's Laws

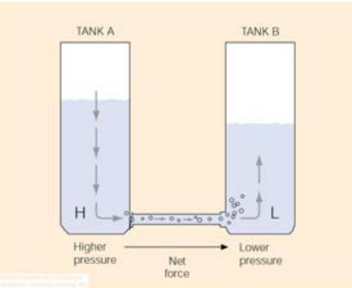




1. A body in motion will stay in motion unless acted upon by an external force
2. Force = mass times acceleration (of that mass)

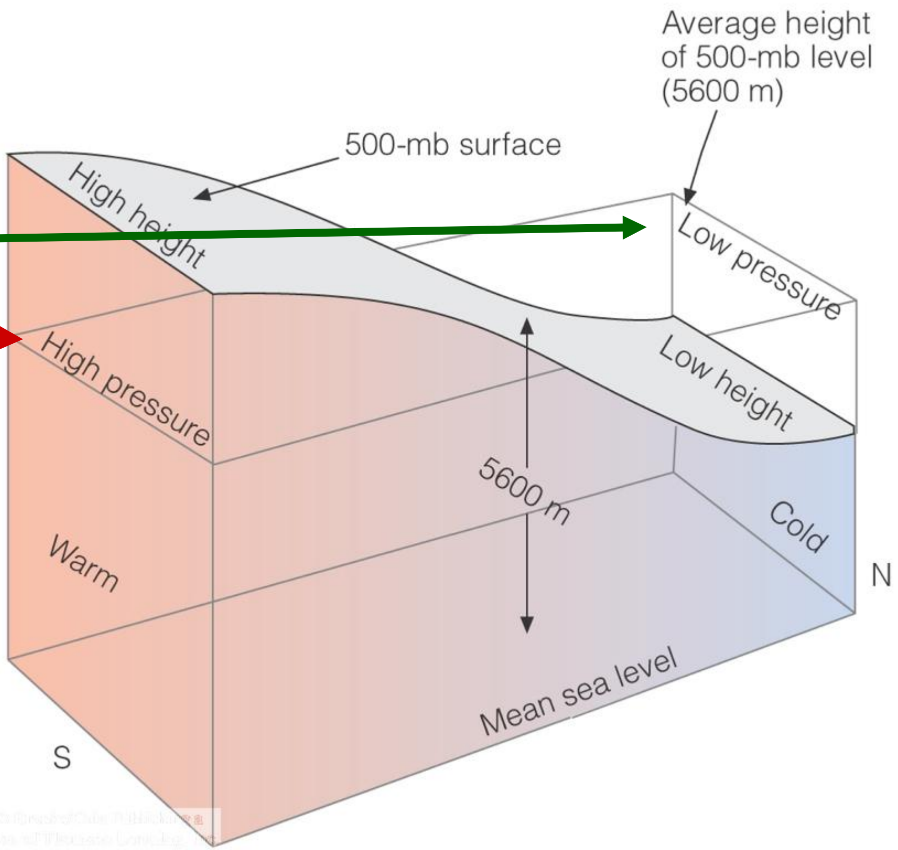
- In third example, water accelerated from tank A to B because pressure was different. That pressure exerted a net force upon the water. The force pushes the water from higher pressure (tank A) to lower pressure (tank B)

Circulations Driven by T Differences – part 1

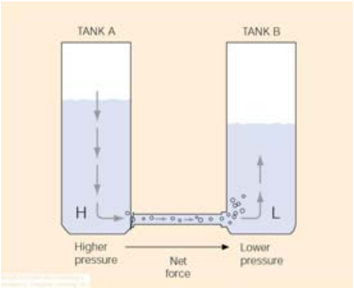


- At 5600 m elevation the pressure is:
  - lower in Arctic
  - higher in tropics

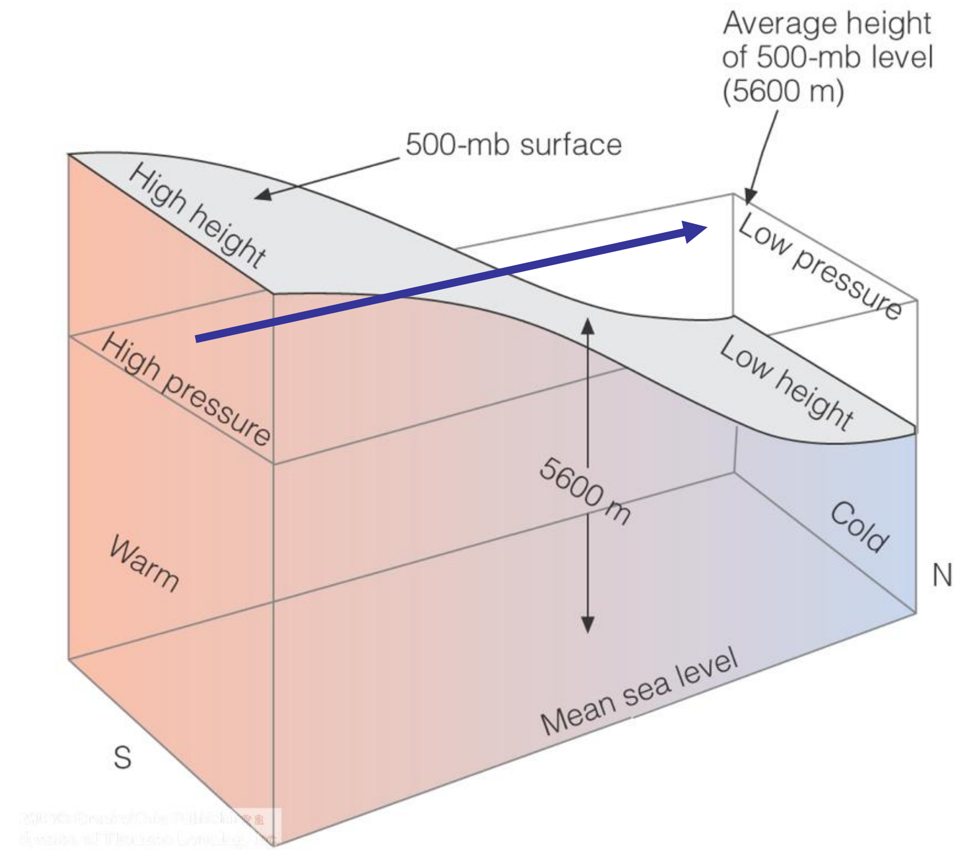
- When 500mb surface is above 5600m that means P>500mb at 5600 m



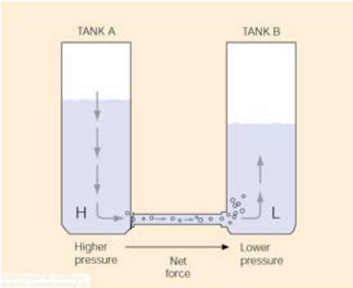
Circulations Driven by T Differences – part 2



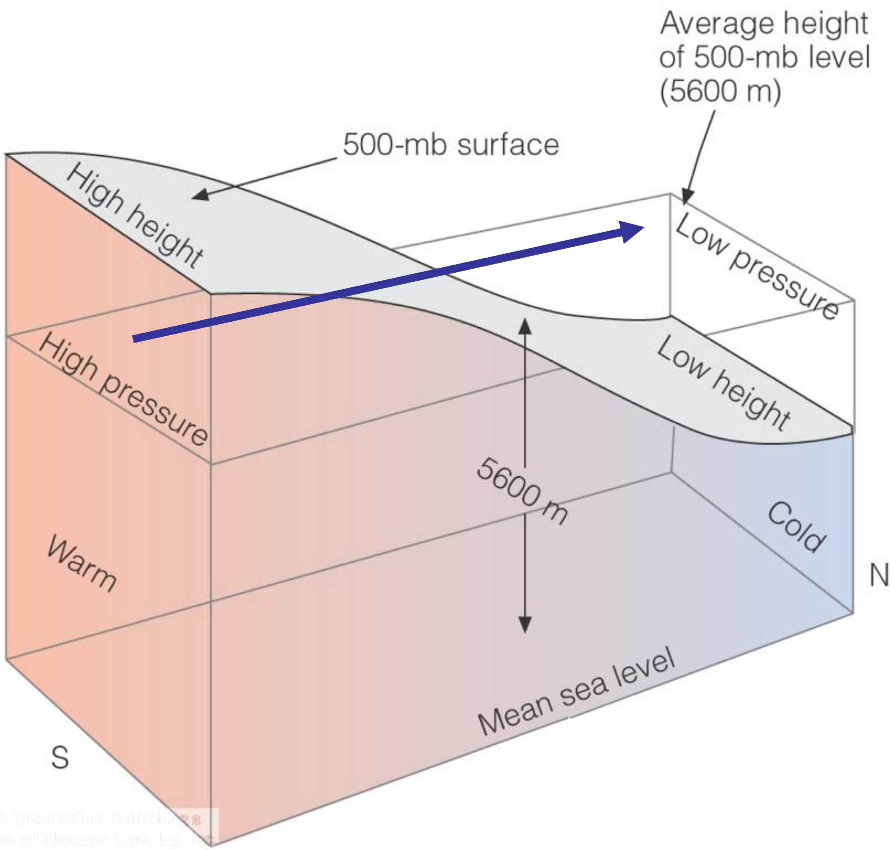
- pressure gradient at 5600m elevation
- that gradient is slope of 500 mb surface.
- Like the water tanks, pressure gradient drives the air from higher to lower P. (blue arrow = air motion)



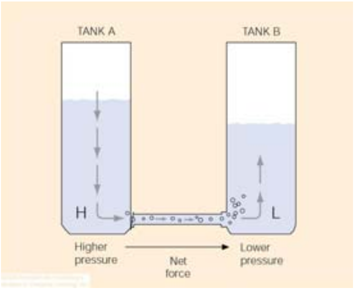
Circulations Driven by T Differences – part 3



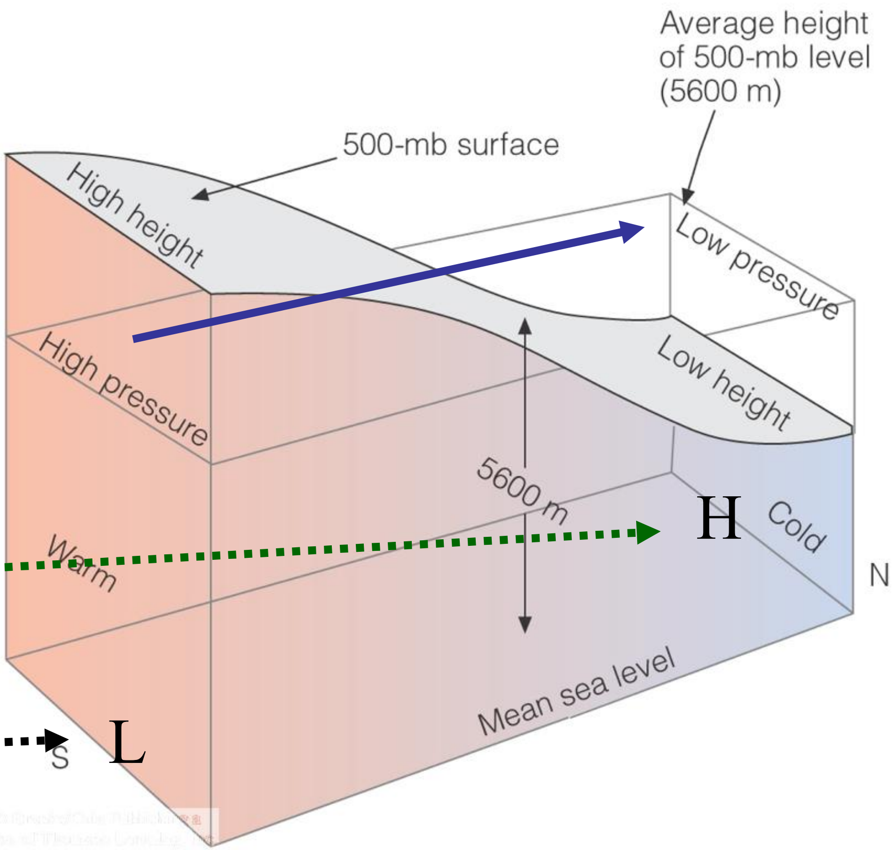
- Larger gradient means steeper slope.
- P gradient is the change in pressure over a distance d (= ΔP) divided by that distance (d)
- The pressure gradient force drives the air from higher to lower P
- Pressure gradient force is the pressure gradient divided by density: PGF = ΔP/d * 1./ρ



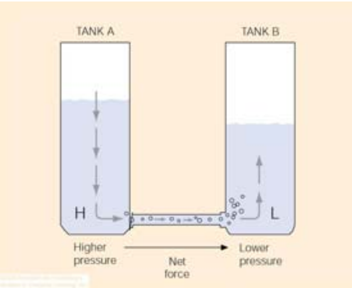
Circulations Driven by T Differences – part 4



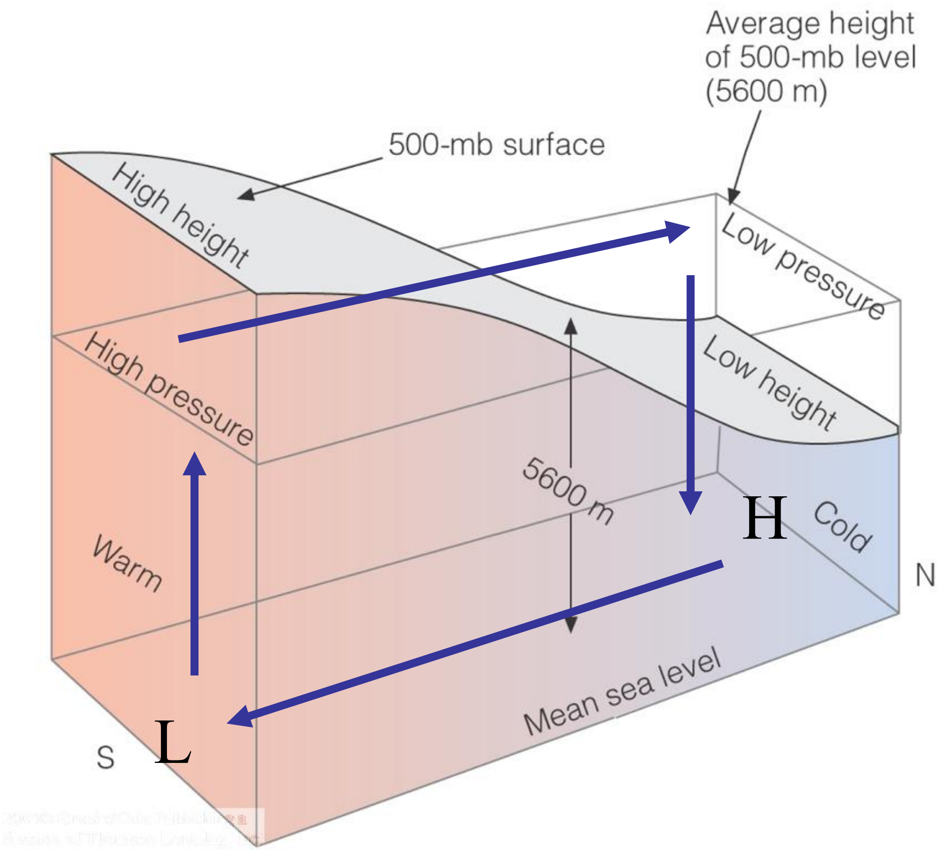
- PGF drives air from tropics to Arctic at high elevation
- Molecules move from tropics towards Arctic
  - Arctic surface P is increased (H)
  - Tropical surface P is reduced (L)
- Surface PGF created



Circulations Driven by T Differences – part 5

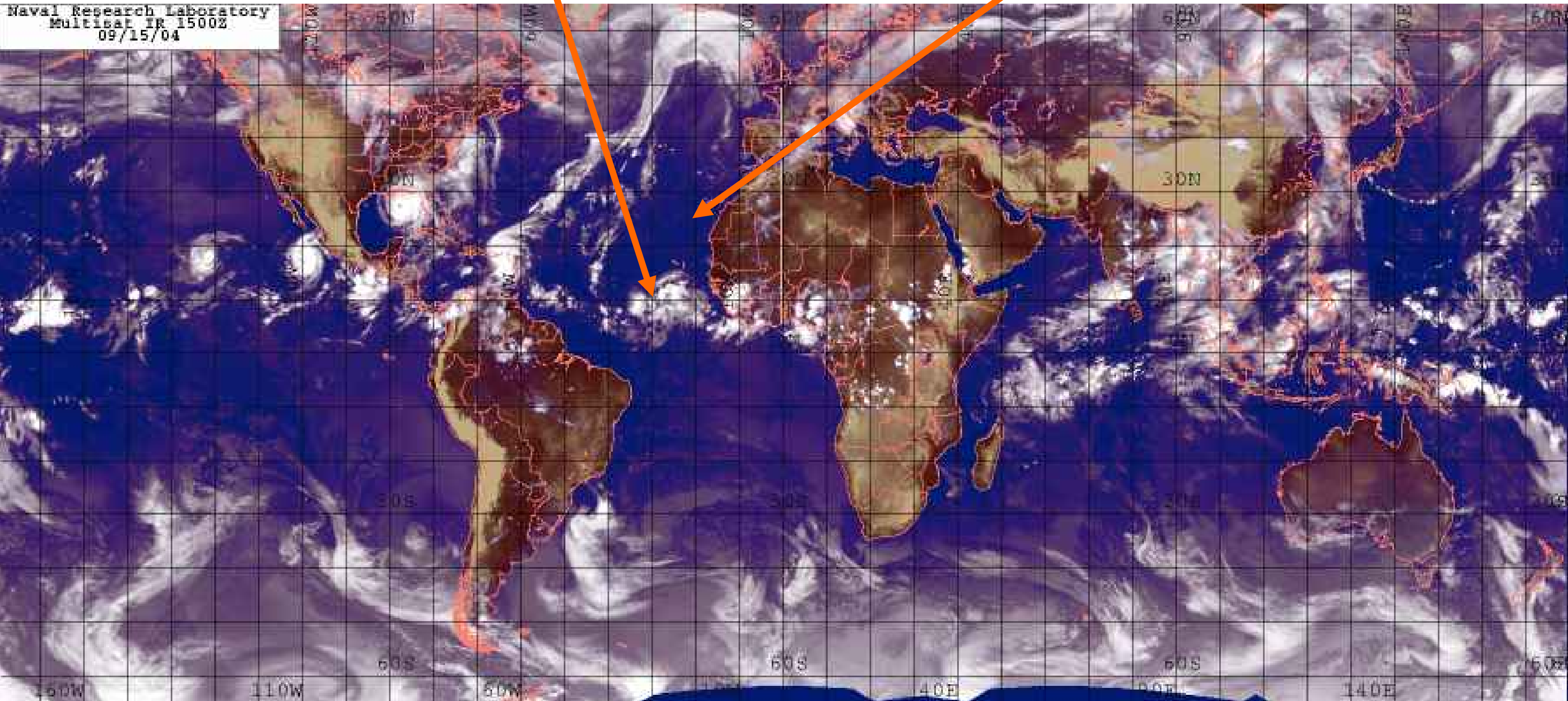


- PGF drives air from tropics to Arctic at high elevation
- Surface PGF drives air from Arctic to tropics
- Rising in tropics & sinking in Arctic completes circulation
- Rising hot air, sinking cold air



Thermally driven circulation example 1

- Intertropical convergence zone
- Convection enhanced Convection suppressed



Thermally driven circulation example 2

- Sea breeze off India
- Convection enhanced
- Convection suppressed

End of lecture 7