Chapter 4 – Atmospheric Pressure and Wind

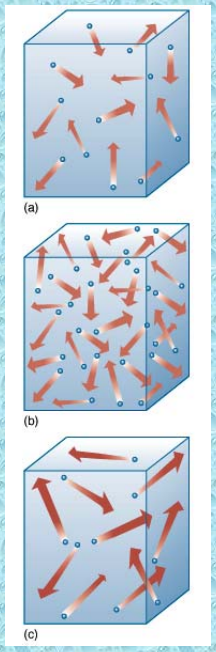
Understanding Weather and Climate
Aguado and Burt

Pressure

- Pressure – amount of force exerted per unit of surface area.
  - Pressure <u>always</u> decreases vertically with height
  - Air pressure is exerted equally in all directions

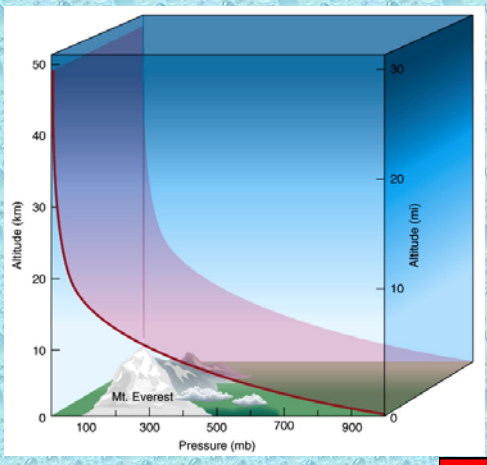
Pressure

- Pressure of the air is proportional to the rate of collisions between the molecules and the wall
- Increased pressure can result from
  - Increased density
  - Increased temperature
- Air constantly moves from high to low pressure



Vertical and Horizontal Changes in Pressure

- Vertical
  - Pressure decreases with height
  - A small elevation change at low levels, results in a large pressure change
- Horizontal
  - Changes are small relative to vertical changes



Surface Pressure vs. Sea Level Pressure

- Sea Level Pressure – the pressure that would exist if the observation point were at sea level.
- Surface Pressure – the pressure observed at a particular location

Equation of State

- Ideal gas law $p = \rho RT$
  - P = pressure (Pa)
  - ρ = density (kg/m^3)
  - T = temperature (K)
  - R = gas constant (287 J/kg k)

Pressure Measurement

- Barometer – an instrument that measures pressure
  - Mercury barometer
    - Corrections include: elevation, expansion, acceleration of gravity
  - Aneroid barometer
    - No corrections

Pressure Gradients

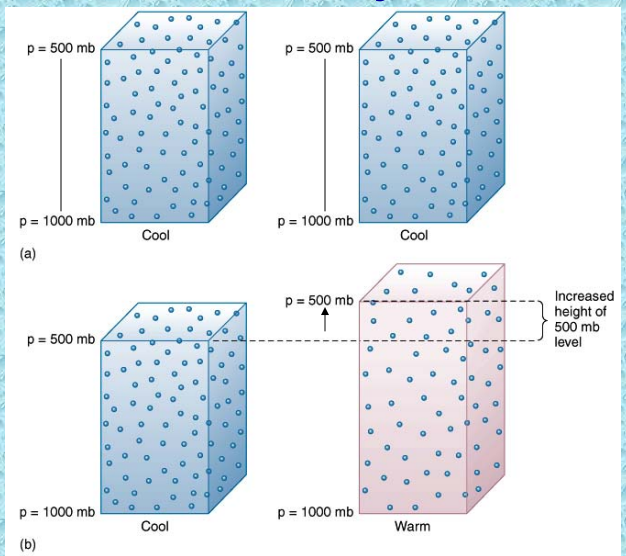
- Pressure gradient – rate of change in pressure with distance
- Isobar – line connecting points with exactly the same sea level pressure
  - Closely spaced isobars indicate a stronger pressure gradient and increased wind speeds
  - Horizontal pressure gradients are small relative to vertical ones.

Hydrostatic Equilibrium

- Hydrostatic Equation $\frac{\Delta p}{\Delta z} = -\rho g$

- Gravity offsets the pressure gradient force which would accelerate the air upwards yielding hydrostatic equilibrium.

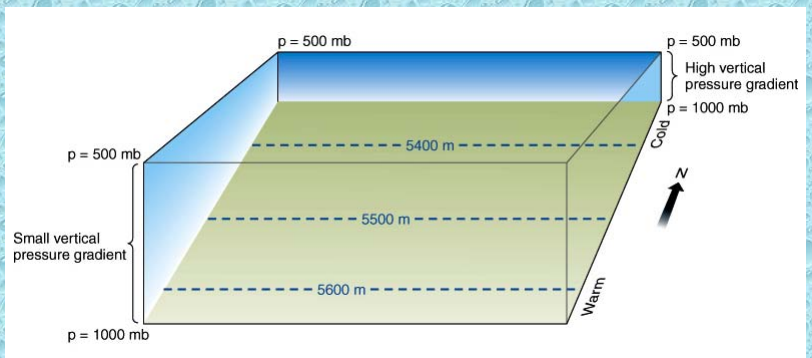
The Role of Density on Pressure



Horizontal Pressure Gradients in the Upper Atmosphere

- Cold columns of air yield lower pressures at a given elevation and produce a horizontal pressure gradient.
- A given pressure (example: 500 mb) level occurs at a lower elevation (height) for colder columns of air.

Horizontal Pressure Gradients in the Upper Atmosphere



Forces Affecting Wind Speed and Direction

- Pressure Gradient Force
- Planetary Rotation (Coriolis Force)
- Friction
- Gravity (affects vertical motion)

Coriolis Force

- Our ‘frame of reference’ is the surface.
- The rotation of the Earth exerts a real impact on flying objects, causing an apparent deflection in their flight.

- Equator – Motion is translational
- Poles – Motion is rotational

Coriolis Force

- Coriolis force deflects all moving objects regardless of their translational direction.
- Coriolis force is zero at the equator and maximum at the pole.
- Coriolis force increases with an object's speed.
- Coriolis force changes only the direction of the moving object.

Coriolis Force

$$F_c = 2\Omega v \sin\phi$$

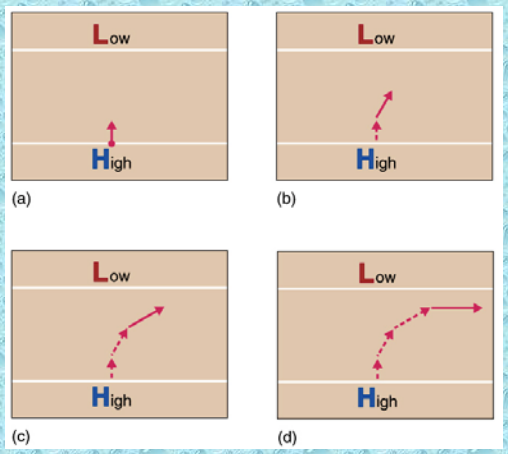
- F_c = Coriolis Force
- Ω = Earth rotation
- v = Wind Speed
- ϕ = Latitude

Friction

- Air in contact with the surface experiences frictional drag, effectively slowing the wind speeds.
- Planetary Boundary Layer (BL) – the lowest ~1.5 km of the atmosphere which experiences friction.
- Free Atmosphere – the remaining atmosphere above the BL which is free from frictional effects.

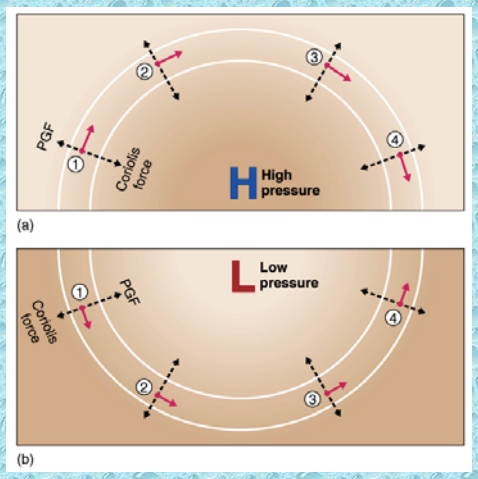
Winds in the Upper Atmosphere

- Geostrophic wind – balance between pressure gradient and Coriolis forces.



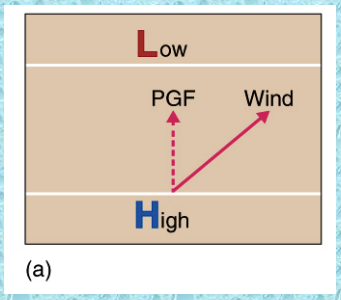
Winds in the Upper Atmosphere

- Supergeostrophic – Coriolis force exceeds the pressure gradient force
- Subgeostrophic – Pressure gradient force exceeds the Coriolis force



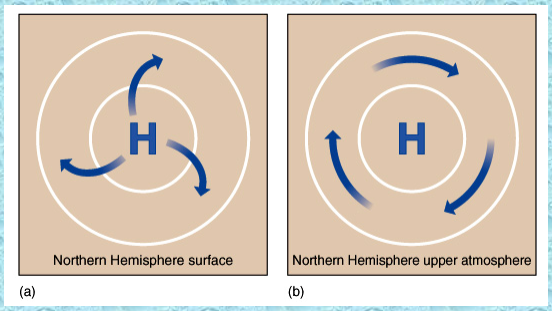
Winds Near the Surface

- Wind is slowed by friction
- Coriolis force is reduced
- Pressure gradient force exceeds Coriolis force and caused the wind to flow at an angle to the right of the pressure gradient force.



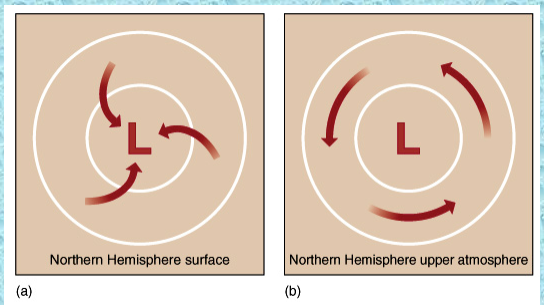
Anticyclones

- Enclosed areas of high pressure indicated by closed isobars or height contours

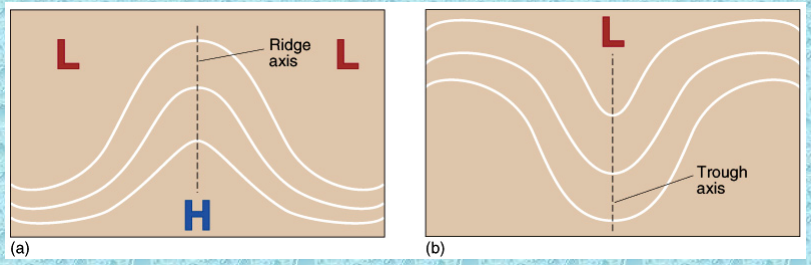


Cyclones

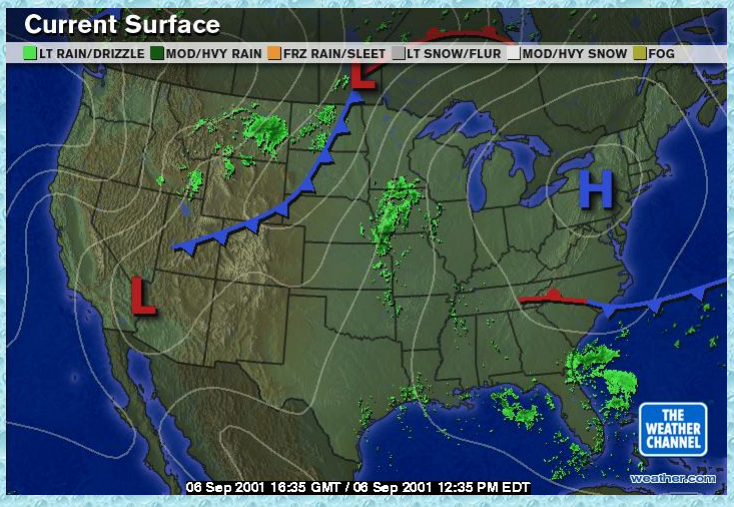
- Enclosed areas of low pressure indicated by closed isobars or height contours



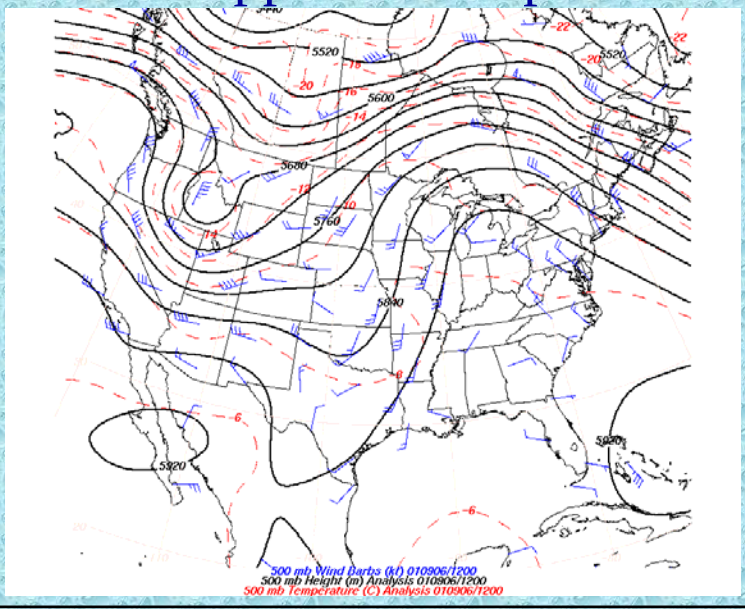
Troughs and Ridges



Surface Map



Upper Air Map



Measuring the Wind

- Anemometer – instrument to measure the wind.
  - 3-cup anemometer
  - Aerovane anemometer
  - Sonic anemometer
  - Hot-wire anemometer

Measuring the Wind

ATMO 1300

Wind Record