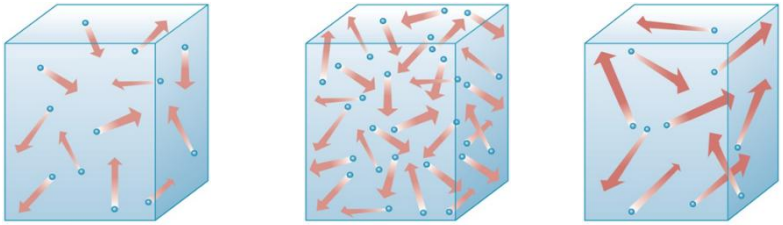
Chapter 4
Pressure and wind

Atmospheric Pressure
General Characteristics

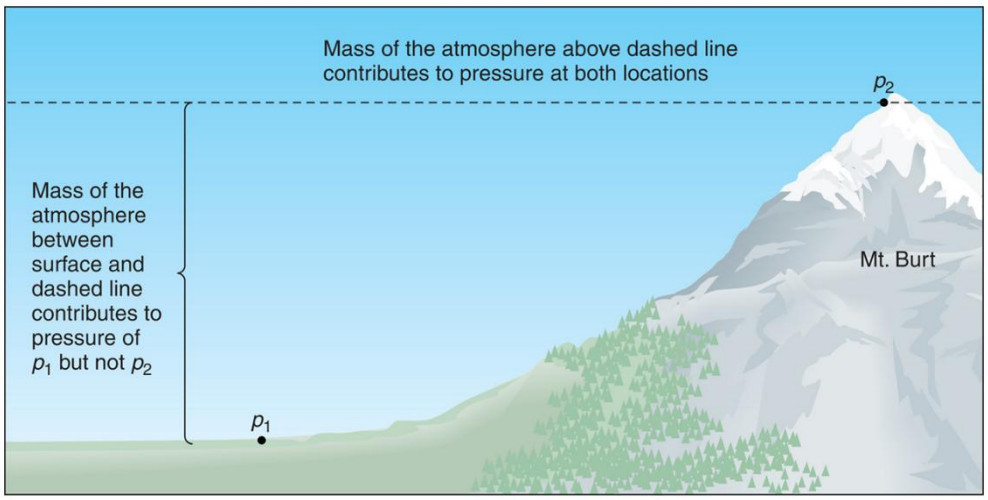
- Pressure is defined as force per unit area
- Pressure comes in different units:
  - Pascals(Pa), milibars(mb), inches of mercury (in Hg),
- pounds per square inch (psi)
- Pressure exists due to molecular collision



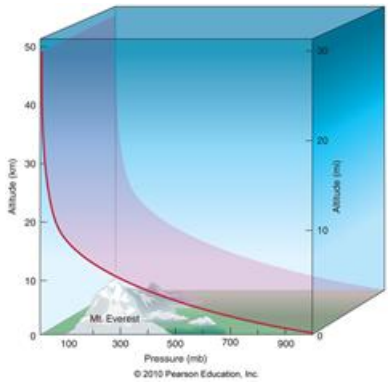
(1) (2)

Pressure increases with:
1) Higher density
2) Higher temperature

Pressure anywhere in the atmosphere is due to the weight of air above



- Pressure decreases faster near the surface, less so aloft (due to higher density near surface)
- Ultimately due to compressibility

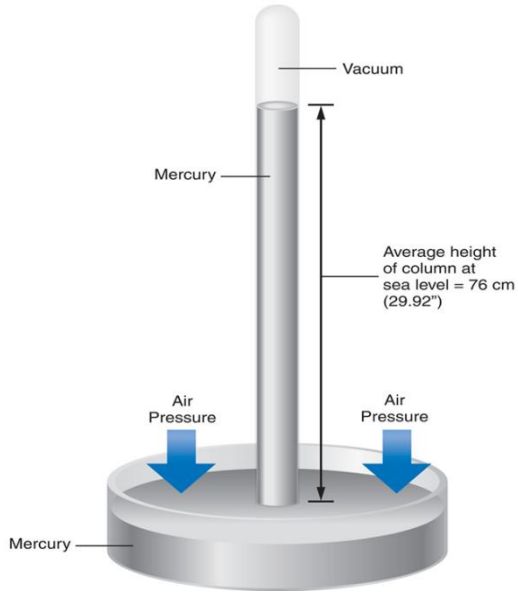


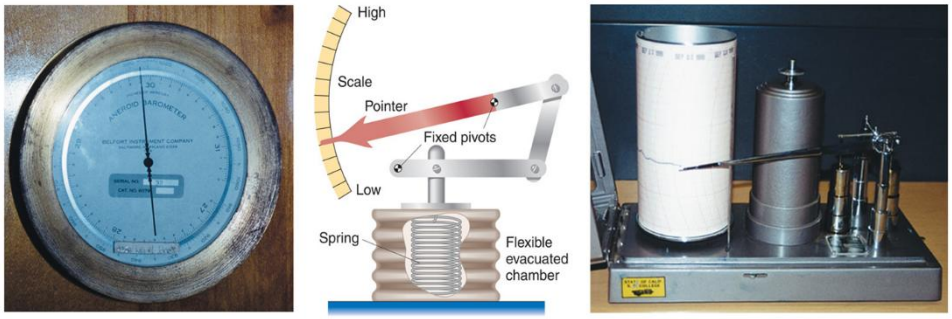
- The nature of atmospheric pressure explains much, including:
    1) My exploding bag of chips
    2) The gravity-defying upside-down cup of water (and the straw trick)

Measuring Pressure

Barometer – an instrument that measures pressure

1) Mercury barometer
2) Aneroid barometer



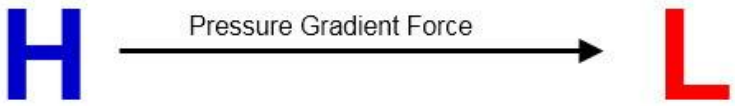


Horizontal Pressure Distribution

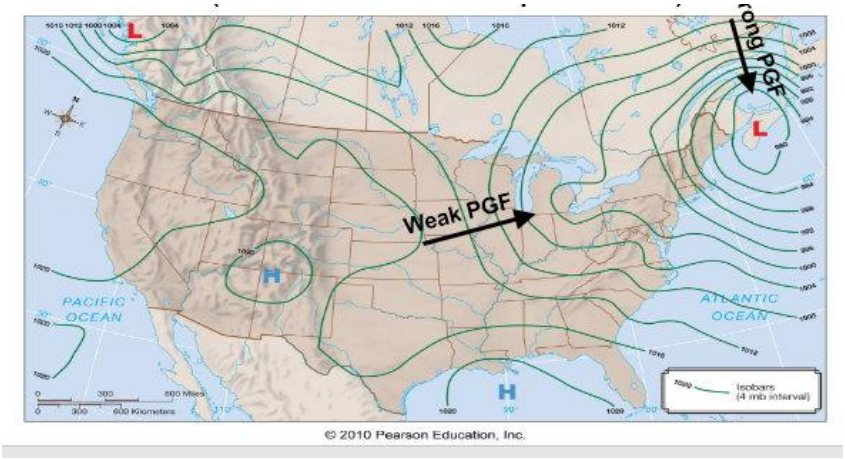
- Pressure gradients (change in pressure with distance) cause air to move
    ➔ Wind!!!
- This wind is a direct application of how force equals mass times acceleration (F=m*a)
- In the case of wind, the force (F) is the pressure gradient force

Pressure Gradient Force

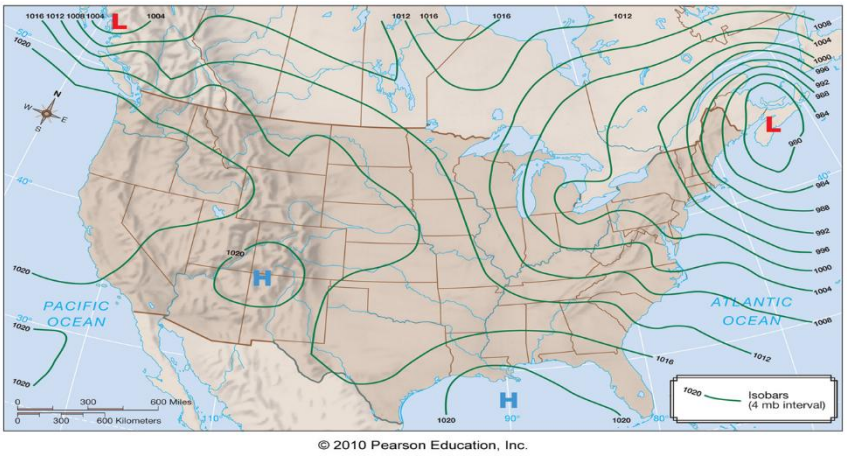
- The pressure gradient force always points from HIGH pressure toward LOW pressure!!!



- Pressure is viewed horizontally using **isobars** (lines of constant pressure)

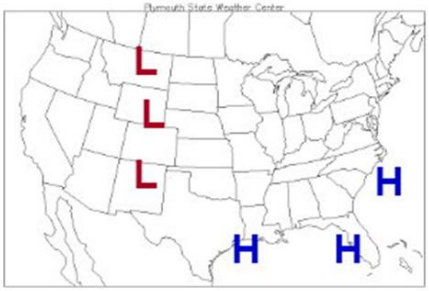


- Sea level pressure maps are a good weather analysis tool*, but wait a second…*



If Station Pressures Were Used

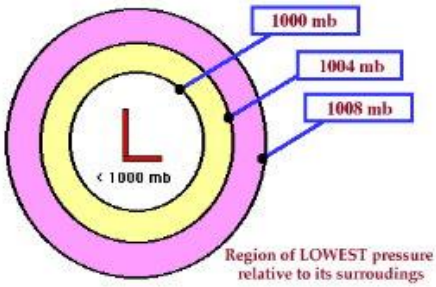
- Lower pressure in mountain areas
- Higher pressure in coastal areas
- Not a true picture of atmospheric effects



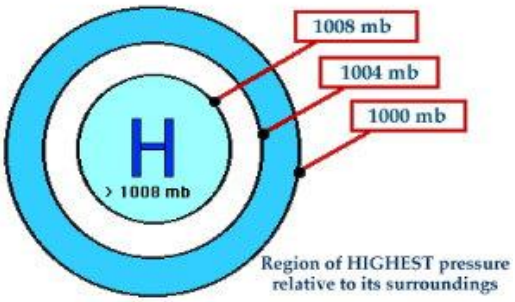
- Surface pressure observations are "reduced" to sea level (10 mb/100 meters is typical in lower atmosphere)
- These sea level pressure values are the numbers on sea level pressure maps

- The effects of elevation are removed, revealing a more useful horizontal pressure distribution

Lows and Highs



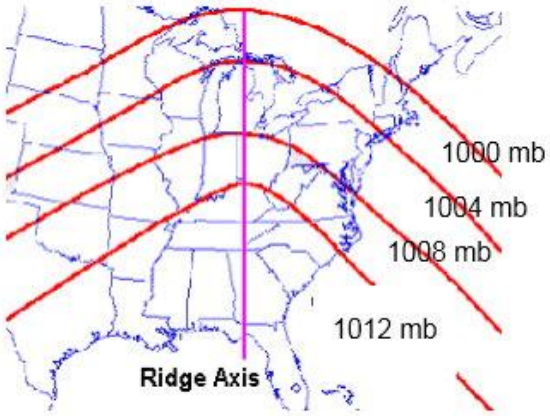
Cyclone



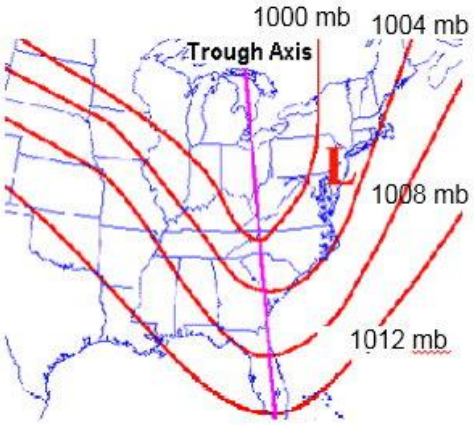
Anticyclone

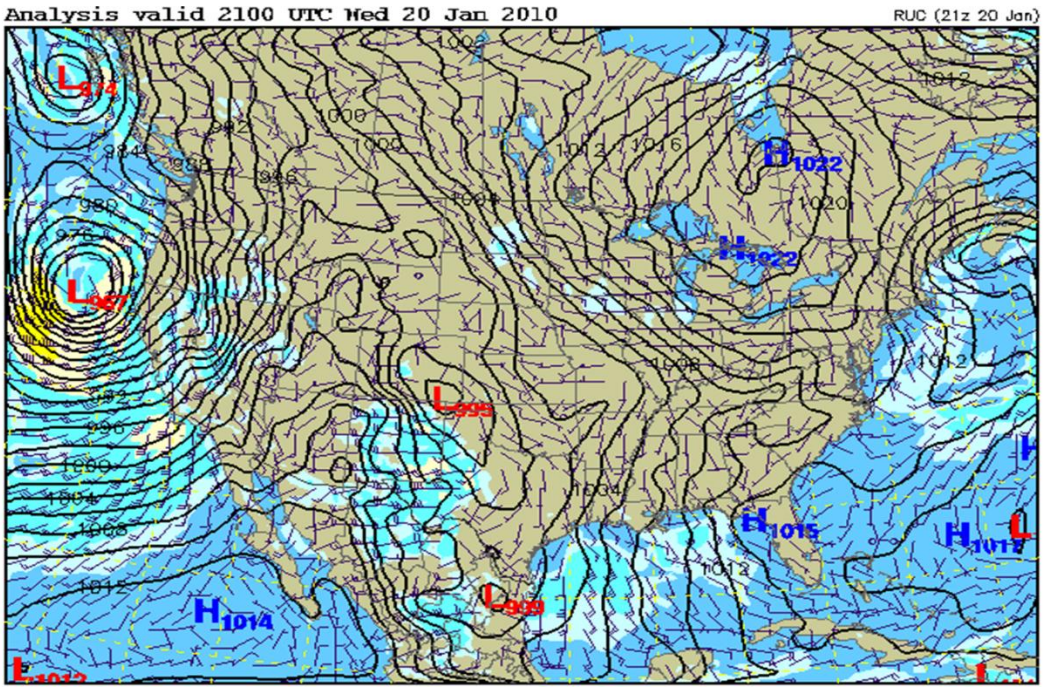
Ridges and Troughs

Ridge – a bow in isobars indicating a line of high pressure



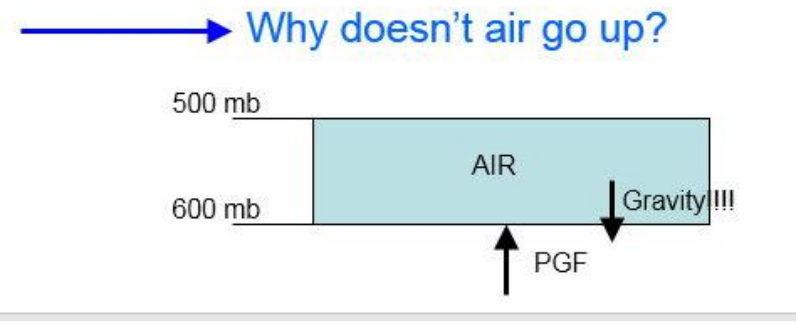
Trough – a bow in isobars indicating a line of low pressure





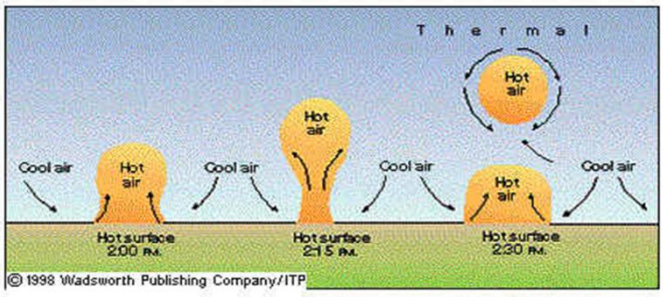
Vertical Pressure Distribution

- Pressure always decreases with height
  - Fastest near the surface
  - Vertical pressure gradients many times greater than horizontal pressure gradients



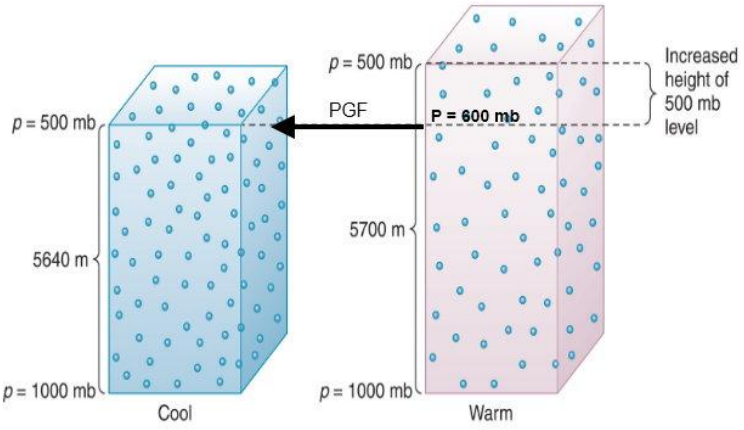
Hydrostatic Balance

- Hydrostatic balance (or equilibrium) is the balance between the pressure gradient and gravity forces in the vertical
  - Exists almost always in the atmosphere
  - Exception is convection and thunderstorms

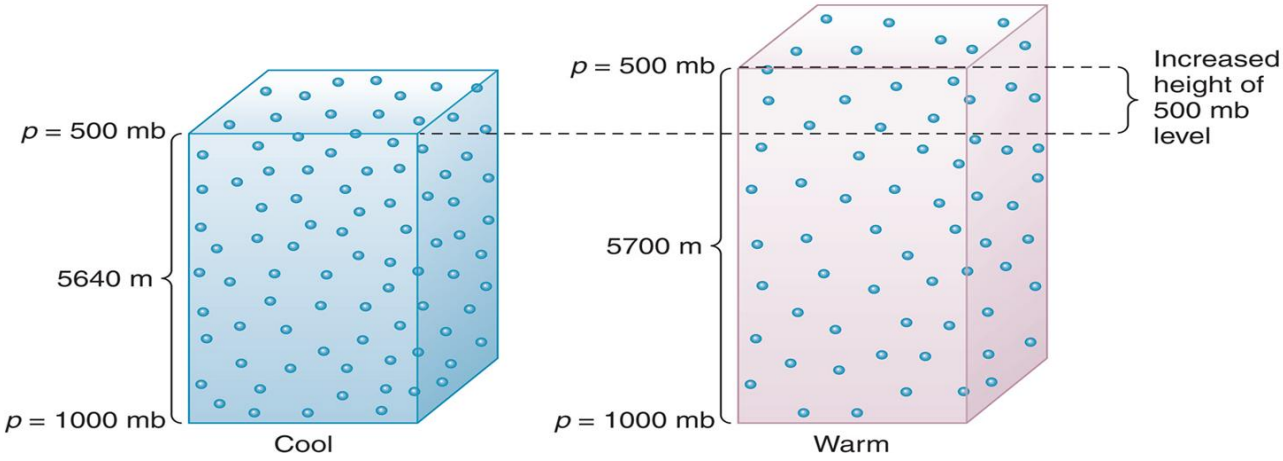


Horizontal Pressure Maps Aloft

- The height of a pressure level depends on temperature

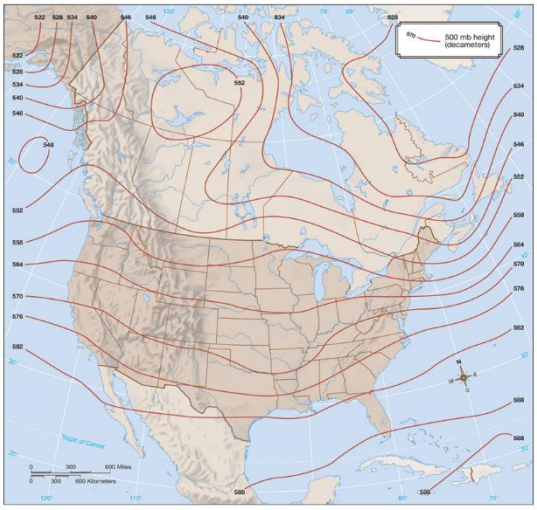


- Stronger temperature difference = stronger pressure gradients
- Higher heights mean higher pressure



The 500 mb Map

- Closer lines = larger slopes = stronger PGF
- Higher heights to the south (warmer)
- Ridges and troughs (Important – they make the weather!)
- Lines of constant height = isohypse (isoheight)



Other Standard Pressure Levels

- In addition to 500mb, other standard levels are:

  850mb - 1500m
  700mb - 3000m (10000')
  300mb - 10000m (33000')

Forces Affecting the Wind

- Pressure gradient force (PGF, directed from high pressure to low pressure)
- **The Coriolis Force**
  1) Due to earth's rotation
  2) Known as an apparent force
  3) Conservation of angular momentum (N-S)
  4) Centrifugal force (E-W)
- An apparent force because of different frames of reference

- In the N-S direction, conservation of angular momentum produces the Coriolis Force

  angular momentum = $R2 * \Omega$

  R = radius

  Ω = rate of rotation

  - deflects right as one moves equator to North Pole (and vice-versa)
  - deflects left as one moves equator to South Pole (and vice-versa)
- In the E-W direction, changing the centrifugal force produces the Coriolis Force

  <u>Northern Hemisphere</u>
  - deflects right as one moves east
  - deflects right as one moves west

  <u>Southern Hemisphere</u>
  - deflects left as one moves east
  - deflects left as one moves west
- Main points to remember:
  1) Coriolis Force deflects moving things right (NH) or left (SH)
  2) There is no Coriolis Force at the equator, and it is maximum at the poles
  3) The Coriolis Force is proportional to speed

4) The Coriolis Forces changes only direction, not speed
5) Coriolis force is slow to act (noticeable only after a few hours)

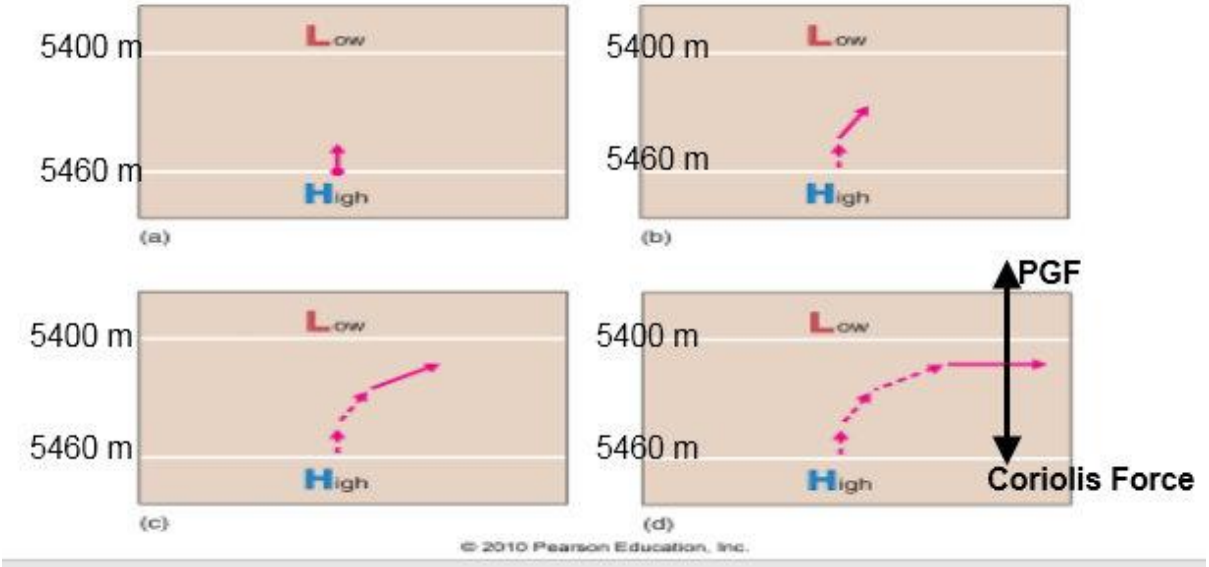
Forces Affecting the Wind –Summary

- Pressure gradient force (PGF, directed from high pressure to low pressure)

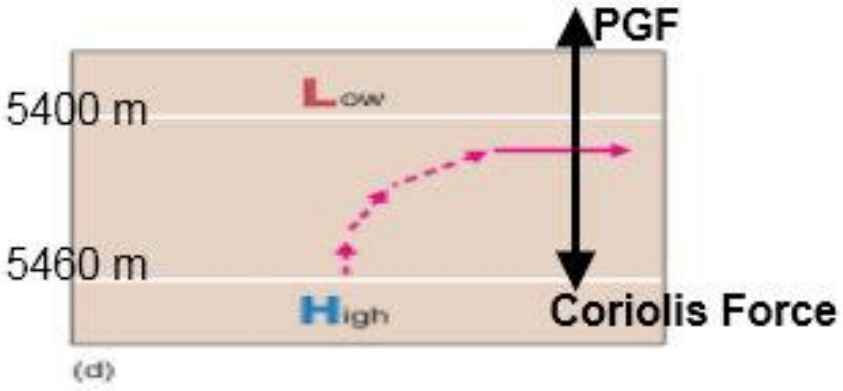
- The Coriolis Force
    1) Due to earth's rotation
    2) Known as an apparent force
    3) Conservation of angular momentum (N-S)
    4) Centrifugal force (E-W)
- Friction (from the ground, within the planetary boundary layer)

How the Wind Blows (The Upper Atmosphere Version)

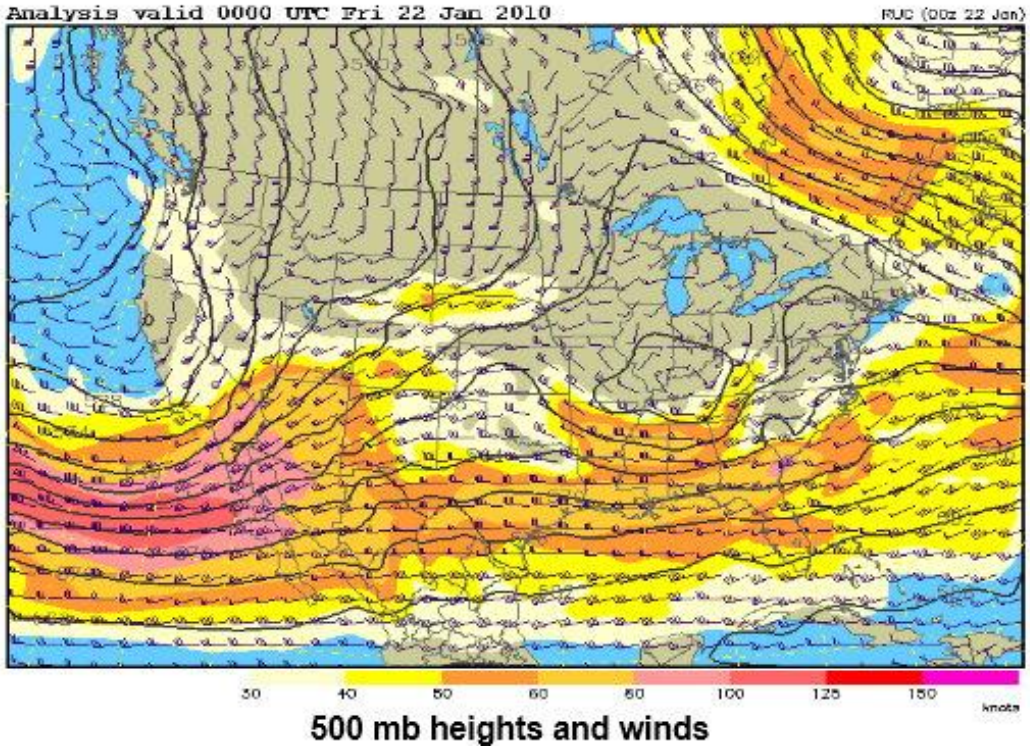
- Forces acting on air above the boundary layer are the PGF and the Coriolis Force



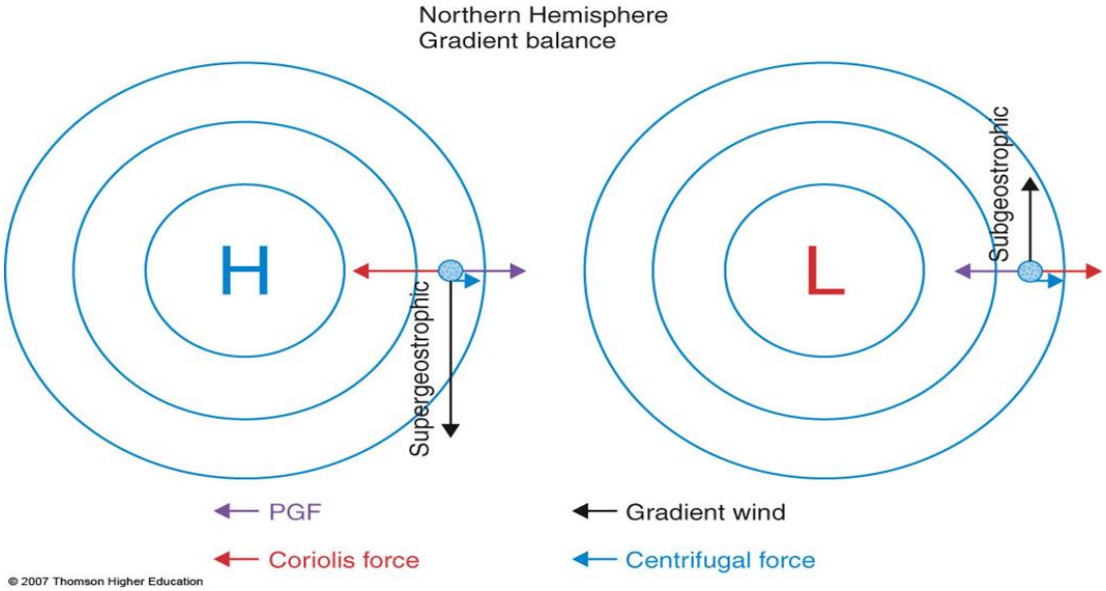
- The balance between the PGF and the Coriolis Force is called geostrophic balance (wind is geostrophic wind)



Geostrophic Balance



In curved flow, another force comes into play – centrifugal force (results in gradient wind balance)

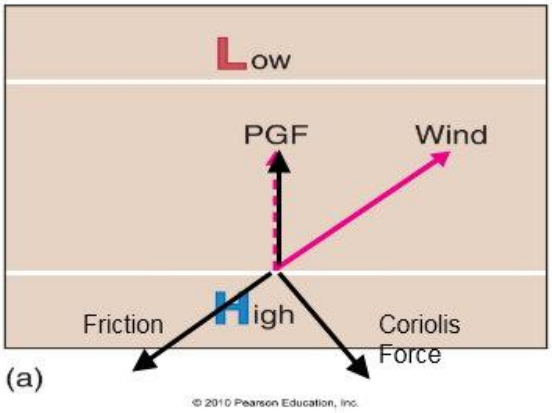


- **Subgeostrophic** flow occurs around Lows
- **Supergeostrophic** flow occurs around Highs

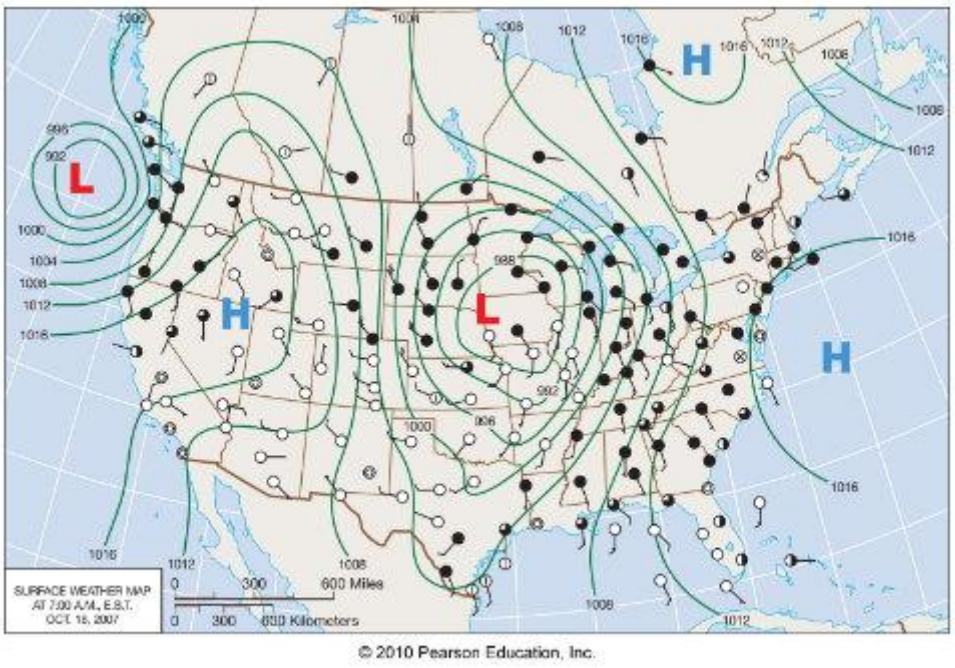
key: wind speed is proportional to the Coriolis Force

How the Wind Blows (The Lower Atmosphere Version)

- Now we have PGF, the Coriolis Force, and friction:

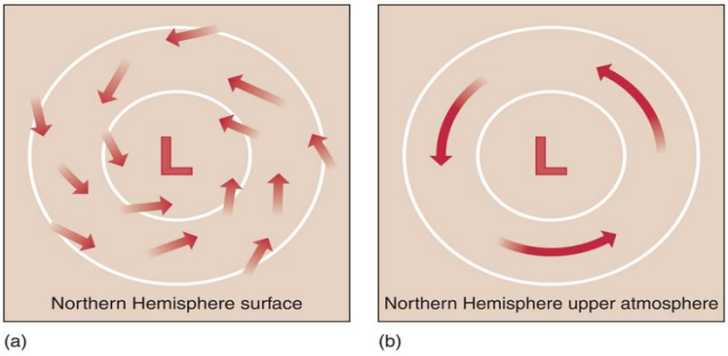


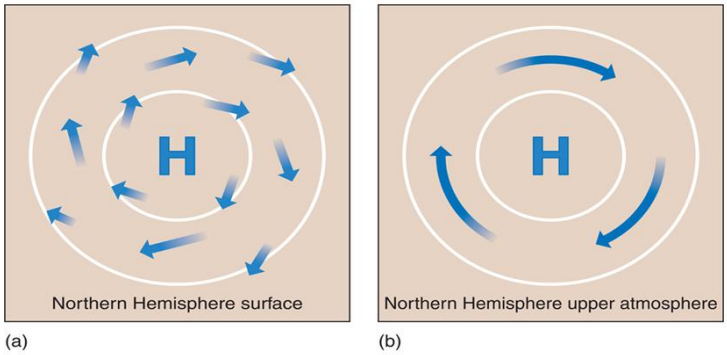
- Wind blows across isobars toward lower pressure



Surface SLP and winds

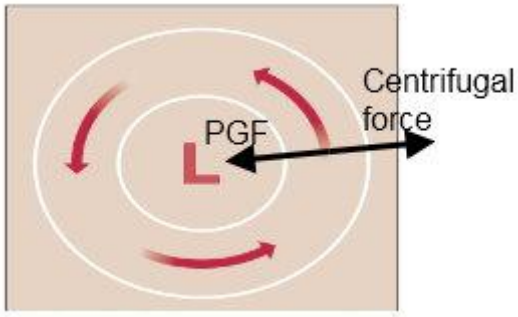
Upper vs. Lower Atmospheric Winds





Cyclostrophic Balance

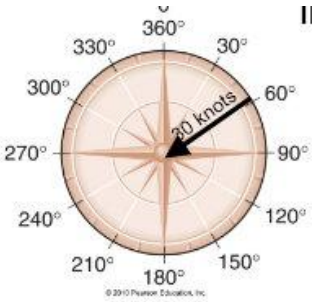
- Wind field achieves a balance between the centrifugal force and the PGF
- This occurs on short time scales (tornadoes) before the Coriolis Force can act (think draining bathtub drains…)



Measuring Wind

- Both wind speed and direction are measured
  direction: measured as the direction where the wind blows **from** in degrees clockwise from **North**

wind is 30 knots at
60º
1 kmph = 1.85 * knots (30 knots = 55.5 kmph)



Wind vane – measures wind direction only

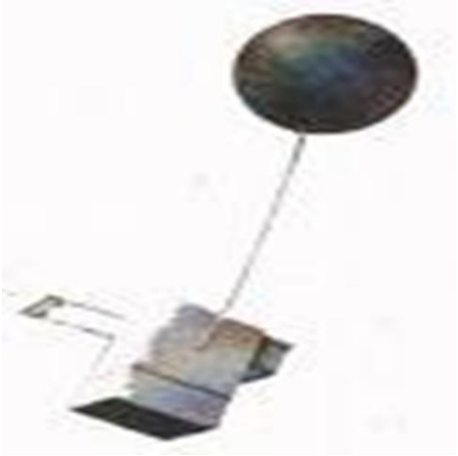
Anemometer – measures wind speed only

Aerovane – measures wind speed and direction

The Observational Network

Upper-air observations

Radiosondes – a package of instruments launched twice daily on weather balloons from stations around the globe



- Launched globally at 0000 UTC and 1200 UTC

  UTC – Universal Time Coordiante – same time everywhere on earth (as opposed to local time)

  Local Baghdad time = UTC time + 3 hours

Surface observations

- Automated Surface Observing System (ASOS) – the primary U.S. surface observing network, observation stations located at airports
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