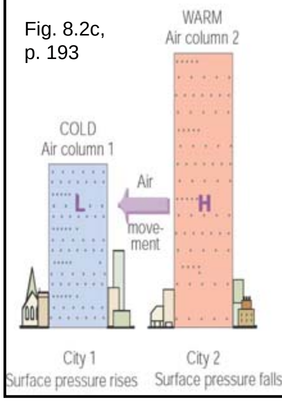
Chapter 8: Air pressure, Forces, and Winds

Cause of pressure and how it varies with height
Mercury and aneroid barometers
Surface pressure (i.e., station pressure)
Adjusting surface pressure readings to sea level
Surface and upper level weather maps
Newton's laws of motion
Pressure gradient force
Coriolis force. Example: Foucault pendulum
Geostrophic and curved winds
Flow near surface and effect of friction
Vertical motion

Atmospheric pressure (pp. 192-193)

Fig. 8.2c, p. 193



- Air pressure is due to the weight of the air above a point
- Pressure at upper levels depends on how warm the air is, because that determines how expanded the column is.
  - **Upper level low if column is cold**
  - **Upper level high if column is warm**

Example: Hurricane has upper-level high pressure due to warmth in eye wall

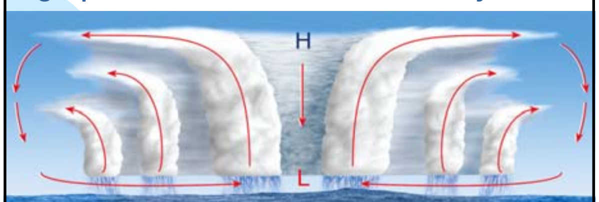
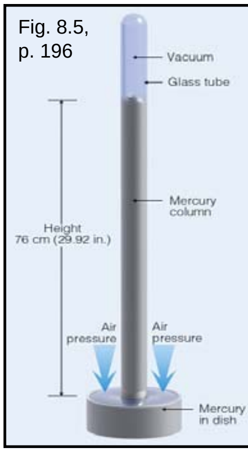


Fig. 15.8, p. 411: Latent heat release gives a hurricane a warm core. This is responsible for an upper level high, as in the previous figure. The upper level high pushes air out at the top, reducing the amount of air in the column, so the weight (& pressure) decreases at the surface.
H means high compared to same level, not higher than surface.

Mercury barometer (pp. 195-196)

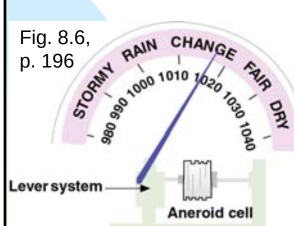
Fig. 8.5, p. 196



- Invented by Toricelli, student of Galileo, in 1643
- Air pressure pushes mercury up glass tube. Height of mercury is proportional to pressure
- Mercury used instead of water because it is so much denser. Height of mercury column: 30 in Height of water column: 30 ft
- Same principle for drinking straw: lower pressure in straw, so fluid pushed up tube
- Mercury barometer not so popular because mercury is a hazardous material.

Aneroid barometer (pp. 195-196)

Fig. 8.6, p. 196



- Aneroid barometer: sealed can ("aneroid" is from Greek "without liquid")
- Used in:
  - home barometers
  - weather balloons
  - automated weather stations

Examples of pressure at sea level (Fig. 8.4, p. 196)

- 1084 mb (hPa) (32.01 in): highest recorded sea level pressure (Siberia, December 1968)
- 1064 mb: highest recorded sea level pressure in US (Miles City, MT, December 1983)
- **1013 mb: AVERAGE SEA LEVEL PRESSURE**
- 980 mb: Deep mid-latitude low pressure system
- 926 mb: Lowest sea level pressure in Hurricane Andrew (Miami, August 1992)
- 882 mb: Lowest recorded sea level pressure over the Atlantic Ocean (Hurricane Wilma, October 2005)
- 870 mb: Lowest recorded sea level pressure anywhere (Typhoon Tip, October 1979)
- **Horizontally, pressure changes only a few %!**

Adjusting surface pressure readings to sea level (pp. 196-198)

- Pressure changes much more vertically than horizontally
- Near the surface, going up **100 meters** decreases pressure by 10 mb (1%). (Ears are an aneroid barometer. Your ears are uncomfortable in elevator or plane takeoff.)
- Horizontally, a pressure difference of 10 mb may occur over **1000 km (600 miles)**
- Difference in surface pressure between 2 cities is mainly due to difference in elevation.
- To see **horizontal** pressure differences, pressure readings are adjusted to common altitude: sea level.

Adjusting surface pressure readings to sea level (pp. 196-198)

- Surface pressure readings are adjusted mathematically to estimate pressure at sea level, as if the barometer were placed in a mine shaft that extended down to sea level.
- Removing altitude effect leaves weather effects on air pressure
- Air pressure reported on radio or TV is always "reduced to sea level."

Surface weather map (p. 198)

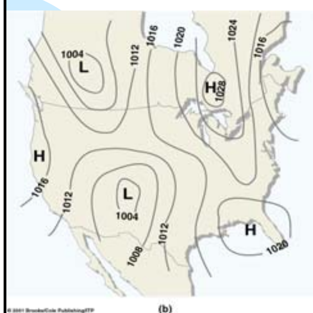


Fig. 8.9b, p. 198

- All surface pressures are "reduced to sea level" before plotting
- Isobars (lines of constant pressure, iso = same, bar = pressure) are drawn every 4 mb.
- Trough or ridge: elongated region of low or high pressure
- Identify a ridge and 2 troughs in this figure.

Upper-level charts (The material below replaces pp. 199-200)

- Needed as most weather is above the surface
- Get info mainly from weather balloons, satellites, & commercial aircraft carrying automated equipment.
- Weather maps drawn for levels throughout troposphere
- Fastest wind (jet stream) is in upper troposphere (maximum at 30,000-40,000 feet, 300-200 mb)
- Middle troposphere: 18,000 feet, 500 mb
- Most moisture is moved in lower troposphere (maximum at 5000 - 10,000 feet, 850-700 mb)
- Water vapor satellite image shown on TV depicts UPPER tropospheric moisture. Also helps show how air is moving in cloud-free areas.

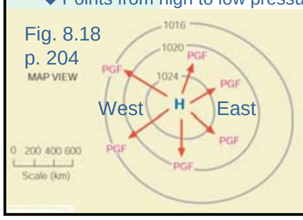
Newton's Laws of Motion (pp. 202-203)

- 1st law: Object at rest will stay at rest and an object in motion will stay in motion as long as no force is exerted on object
- 2nd law: Force exerted on object will produce an acceleration given by $a = F/m$, where a=acceleration, F=force, and m=mass of object.
- Acceleration involves change of speed and or direction
- Let's explore the forces responsible for the wind

Pressure Gradient Force (p. 203-204)

- Pressure gradient = (pressure difference) / distance
- Isobar = line of constant pressure.
  On maps of sea level pressure, isobars are drawn every 4mb.
- Pressure gradient large where isobars are close
- Pressure gradient force pushes on air, causing wind to blow.
  - Proportional to pressure gradient
  - Points from high to low pressure

Fig. 8.18
p. 204

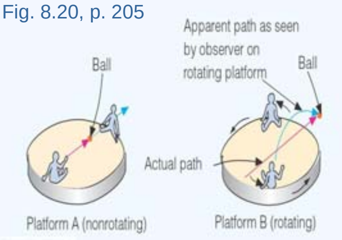


On west side of high, pressure gradient = 4mb/200 km = 2mb/100km
On east side of high, pressure gradient = 4mb/400km = 1mb/100km
Thus, twice the force on air on the west side versus east side.

Coriolis Force (pp. 204-206)

- Coriolis force: apparent force ("pseudo-force") we observe because we are riding on a rotating Earth.
- Appears to push an object to the side without changing its speed
- Ball moves straight on a non-rotating platform. Ball appears to curve to side on rotating platform, even though actual path is straight.

Fig. 8.20, p. 205



Coriolis Force (continued)

- As we ride with rotating Earth, Coriolis force appears to push wind toward right of direction of motion in Northern Hemisphere, toward left in Southern Hemisphere.
- The push sideways is greater:
  - the faster the object moves
  - the closer to the North or South Pole the object is
- Coriolis force due to Earth's rotation is very weak. Only important when all other forces are weak.
- Two slides ago, we looked at a 4 mb pressure difference across 200-400 km horizontally. That is a weak force, so Coriolis force matters.

Coriolis Force (continued)

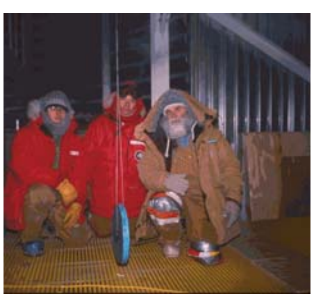
- Coriolis force is too weak to matter in day-to-day life.
- Very fast pitcher can throw baseball at 100 mph (45 m/s) for distance of 60.5 feet (18.4 m) from pitcher's mound to home plate. This takes 0.4 seconds. The ball is deflected to right only about 0.4 mm by Coriolis force.
- Puzzle: If you are locked below deck in a ship that sails throughout ocean, how can you tell what hemisphere you are in? Supposed answer of seeing whether water spirals down drain in clockwise or counterclockwise direction is WRONG. Coriolis force is about 10,000 times too weak to account for acceleration of water rotating around a drain.

Coriolis example: Foucault pendulum

- Foucault pendulum, seen at science museums. Long pendulum swings back and forth from high ceiling. Earth rotates, but pendulum's plane of swing does not. Because we're on the rotating Earth, it is seems to us that we are stationary and that the plane of the pendulum's swing is rotating slowly.
- Foucault pendulum knocks down dominos or little bowling pins placed in circle around pendulum.
- For more information, do a Web search on "Foucault pendulum" For example, see: http://www.calacademy.org/products/pendulum/index.html

Coriolis example: Foucault pendulum

- Coriolis force greatest at poles, so for the fun of it, Foucault pendulum was set up at South Pole in winter 2001. See: http://www.phys-astro.sonoma.edu/people/students/baker/SouthPoleFoucault.html
- Conditions for experiment: -90°F, 11,000 ft elevation, p=660mb



Geostrophic wind (pp. 206-208)

- Geostrophic wind: Wind in which Coriolis force is equal and opposite to pressure gradient force. Geostrophic wind blows straight and is PARALLEL to isobars.
- More than a few 100 m above surface, the actual wind is nearly geostrophic. (Near surface, there is also friction.)
- **In Northern Hemisphere, low pressure to left of wind.** Application: Look at moving clouds. At cloud level, low pressure lies to left of cloud motion.

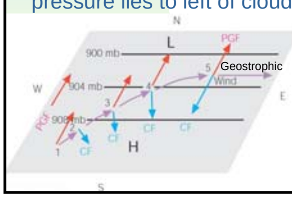


Fig. 8.23, p. 207: Air pushed from high toward low pressure (red arrows). Coriolis force pushes air to right (blue arrows). Ultimately, wind (purple) blows parallel to isobars, low pressure to left: geostrophic wind.

Curved winds (pp. 208-210)

- If pressure gradient force (push toward low pressure) and Coriolis force (push toward right) are not quite in balance, air is pushed to the side of the greater force and air flow moves in curved path.
- Wind is parallel to isobars with low pressure to left in Northern Hemisphere. Thus, CCW flow around low (cyclone), CW around high (anti-cyclone).

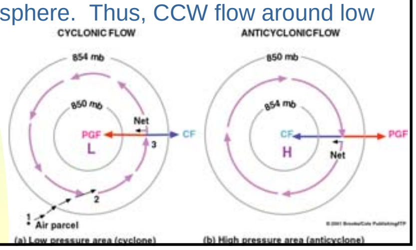


Fig. 8.26, p. 210

Winds Near Surface (pp. 212-214)

- Friction strongest near surface, gets weaker with height. Typically negligible above 1000 m.
- Friction slows wind, so Coriolis force (proportional to wind speed) is reduced and does not match pressure gradient force's push toward low pressure.
- Because of friction, surface wind blows across isobars at an angle from high toward low pressure.

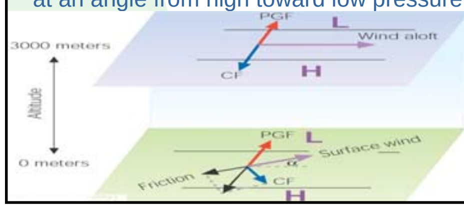


Fig. 8.29a, p. 213

Wind Summary (p. 213)

- Upper level winds blow parallel to isobars.
- Surface winds spiral into lows, out of highs.
- In Northern Hemisphere, low pressure lies to left.

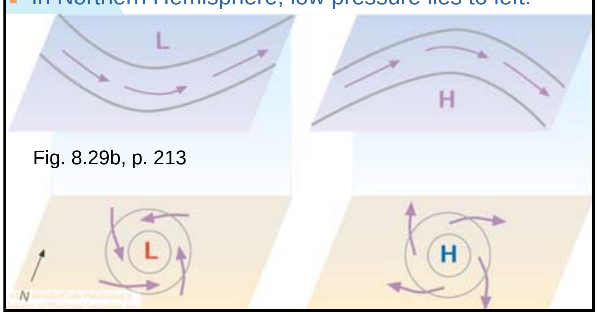
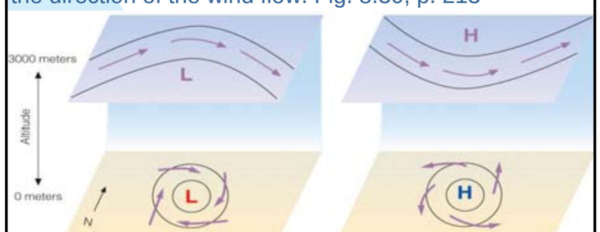


Fig. 8.29b, p. 213

Winds in Southern Hemisphere (p. 213)

In Southern Hemisphere, upper level flow is still parallel to isobars, but winds have low pressure to the RIGHT of the direction of the wind flow. Fig. 8.30, p. 213



As in Northern Hemisphere, winds spiral clockwise INTO low and spiral counterclockwise OUT OF high.

Vertical Motion (pp. 215-216)

- Convergence: air coming together
  Divergence: air spreading out
- Generally, there is convergence into surface low with rising air above & divergence out of surface high with sinking air above

Fig. 8.33 p. 243