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)

- 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)

- 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)

- 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)

- 1064 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.

Surface weather map (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.

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 4 mb.
- 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.

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.
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 non-rotating platform. Ball appears to curve to side on rotating platform, even though actual path is straight.

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 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 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:

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 (anticyclone).

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.

Winds 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.

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

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