Today
- Cover temperature, pressure, and density.
- Discuss the relationship between these quantities.
- Vertical structure of temperature in the atmosphere/atmospheric layers
- Sensible heat; latent heat.
- Heat transfer.
- We will focus more on pressure when we discuss wind systems.

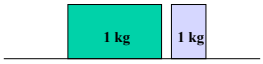
Next week:
- Composition and Radiation

What is Atmospheric Pressure?

- Atmospheric Pressure is the force per unit area of a column of air above you (extending all the way to the top of the atmosphere)
- In other words, pressure is the weight of the column of air above you - a measure of how hard this column of air is pushing down
- More fundamentally - atmospheric pressure arises from gravity acting on a column of air

Pressure

- Molecules bumping into an object create a force on that object
- Pressure is the force applied per unit area
  - P = F/A
  - Which box below is exerting the greatest pressure upon the ground?



Force = m*g

Why Pressure?

- Pressure is one of the most fundamental forces which produces weather and makes our atmosphere move - i.e. WIND
- Pressure defines many of our most definitive weather patterns: midlatitide cyclones, hurricanes, anticyclones

How do we measure pressure?

Sea Level Value (average)	Units of Pressure:
1	atmosphere
760	mm. of mercury
29.92	in. of mercury
33.9	ft. of water
1013.25	millibars

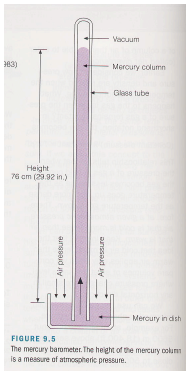


FIGURE 9.5
The mercury barometer. The height of the mercury column is a measure of atmospheric pressure.

Pressure vs Height

Sea Level Value (average)	Units of Pressure:
1	atmosphere
14.7	lbs./sq.in.
760	mm. of mercury
29.92	in. of mercury
33.9	ft. of water
1013.25	millibars

Why does pressure decrease with altitude?

Remember:

Pressure = mass*gravity/unit area

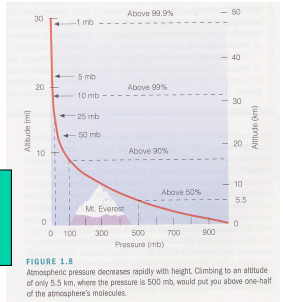
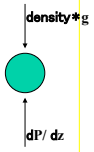


FIGURE 1.8
Atmospheric pressure decreases rapidly with height. Climbing to an altitude of only 5.5 km, where the pressure is 500 mb, would put you above one-half of the atmosphere's molecules.

Hydrostatic balance

What keeps air from always moving downwards due to gravity?

A balance between gravity and the pressure gradient force.



What is the pressure gradient force?

Pushes from high to low pressure.

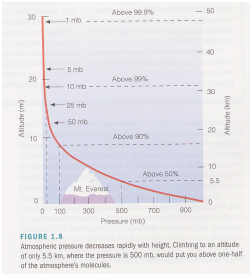


FIGURE 1.8
Atmospheric pressure decreases rapidly with height. Climbing to an altitude of only 5.5 km, where the pressure is 500 mb, would put you above one-half of the atmosphere's molecules.

What is Air Temperature?

- Temperature is a measure of the kinetic (motion) energy of air molecules
  - K.E. = ½ mv^2 m = mass, v = velocity
  - So…temperature is a measure of air molecule speed
- The sensation of warmth is created by air molecules striking and bouncing off your skin surface
  - The warmer it is, the faster molecules move in a random fashion and the more collisions with your skin per unit time
  - Could you feel cold in a place where the temperature is high?

How do we measure Temperature?

- Conventional thermometry
  - *Liquid in glass.*
- Electronic thermometers
  - *Measures resistance in a metal such as nickel.*
- Remote sensing using radiation emitted by the air and surface (particularly, though not exclusively, from satellites).
- Units of temperature: Celsius, Kelvin

What is the coldest possible temperature? Why?

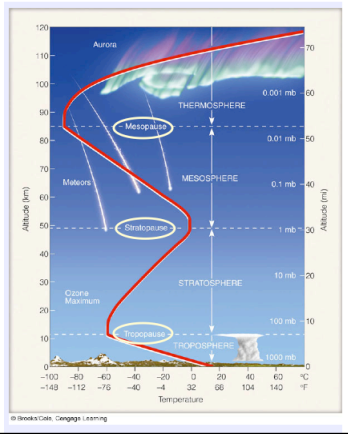
The atmosphere is layered according to its temperature structure

In some layers the temperature increases with height

In others it decreases with height or is constant

. . .pause is a level

. . . sphere is a layer



Density of air=mass/volume

Density can be determined via its relationship to pressure and temperature:

Equation of State (Ideal Gas Law:

P = ρ R T (Pressure equals the product of the density, Universal gas constant and absolute temperature)

$$\rho = \frac{P}{RT} = \frac{\text{mass}}{\text{volume}} = [gm/cm^3]$$

- **Direct relationship between Density and Pressure (pressure goes up; density goes up if T constant)**
- **Inverse relationship between Density and temperature (temperature goes up; density goes down if P constant)**
- **Direct relationship between temperature and pressure (temperature goes up; pressure goes up if density constant)**

Atmospheric density

- Decreases with height
  - compressible atmosphere
- Density is not directly measured. We calculate it from temperature and pressure measurements

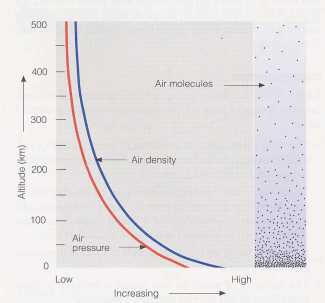


FIGURE 1.7
Both air pressure and air density decrease with increasing altitude.

Why do we care about density?

Changes in density drive vertical motion in the atmosphere *and* ocean.

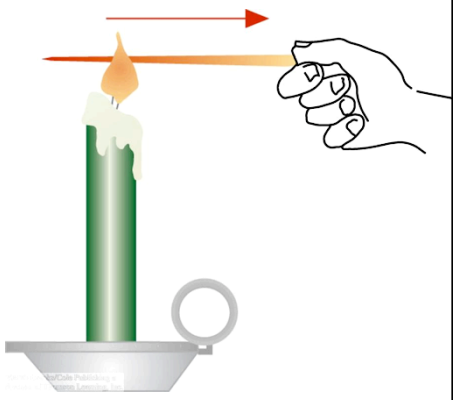
- Lower density air rises when it is surrounded by denser air.

  -Think of a hollow plastic ball submerged under water. What happens when you release it?

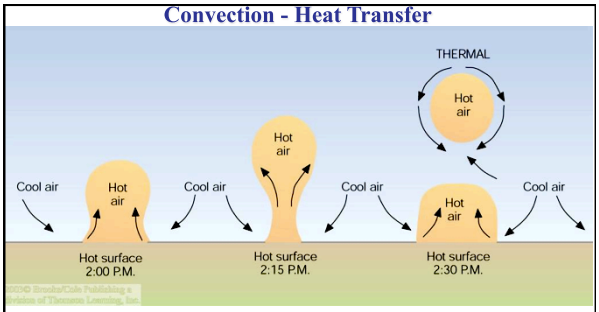
Heat transfer processes

- *Conduction* - Where molecules transfer energy by coming into contact with one another.
- *Convection* - Where a fluid moves from one place to another, carrying it's heat energy with it.
  - In atmospheric science, convection is usually associated with vertical movement of the fluid (air or water).
  - Advection is the horizontal component of the classical meaning of convection.
- *Radiation* - The transfer of heat by radiation does not require contact between the bodies exchanging heat, nor does it require a fluid between them.

Conduction - Heat Transfer



Convection - Heat Transfer



Important thermodynamic concepts

Adiabatic temperature change

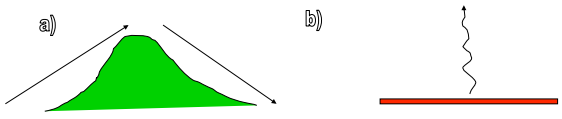
•*Adiabatic process:*

When a material changes its physical state, such as its temperature, without any heat being added to it or subtracted from it.

•*Example*:

a) Rising air cools; sinking air warms

(not to be confused with: *b)* convection).



Other important thermodynamic concepts

Heat capacity:

amount of heat added to a substance
change in temperature

(e.g., water has a higher heat capacity than air)

Sensible heat:

The heat that can be measured by a thermometer.

Latent heat:

Heat required to change a substance from one state to another.

(e.g., heat can be added/removed from a substance without its temperature changing)

Water phase changes

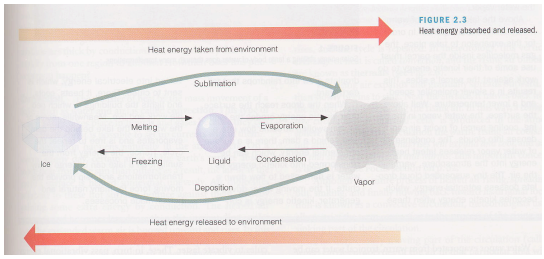


FIGURE 2.3
Heat energy absorbed and released.