CLASS 14: PROPERTIES OF WATER AND SEA WATER
Why is water such a remarkable substance?
Structure of the H_2O molecule
States of H_2O, and energy transfer during changes of state
Density, and effects of temperature
Sea water -- the effect of dissolved salts

IMPORTANCE OF H_2O: The most important driver of Earth Surface processes
- Most common substance at surface; rare on other planets
- Essential for life
- Unusual properties
  - Excellent solvent
  - Absorbs (and releases) large amounts of energy
- Regulates climate

STRUCTURE OF THE H_2O MOLECULE

Non-linear ==> electrically "polar" = + and - charged ends
"Hydrogen-bonding" = attraction between + end of one H_2O molecule and - end of another
Strong solvent for ions (charged atoms or groups of atoms)
Charges attracted and nicely balanced (in many cases) by the charges on the ends of the water molecules

STATES (PHASES) OF H_2O

Ice -- H_2O molecules H-bonded in an orderly crystal structure- perfect rows
Liquid Water -- H_2O molecules about as close as in ice, but...
- There are free molecules and ice-like clusters
- not rigidly held in rows
- free to move somewhat

Vapor -- Free molecules only

ENERGY ABSORBED OR RELEASED IN H_2O PHASE CHANGES

Ice <==> Water -- 80 calories/gram
... required (absorbed) to melt ice
... liberated (extracted) when ice freezes

Water<-->Vapor -- nearly 600 calories/gram...
...is required (absorbed) to evaporate liquid water
**Example: a wet towel becomes cool because of evaporation. Why? Because heat is transferred from the towel to the molecules of the water vapor that is produced by evaporation
... liberated when water vapor is condensed.

** This is harder to envision. When a warm, moist air mass meets a cold air mass, rain or snow forms. During the process of condensing rain or snow from the water vapor in the air, the "latent heat" in the water vapor is released and the air is warmed.

Why so much energy?
* evap., or melting --> energy required (must be added) to break H-bonds
* condensation, freezing --> energy must be taken away to make H-bonds form

The bottom line: Water vapor is an efficient way to move heat around (think of steam heat at UIUC).

VERY IMPORTANT .....
On Earth:
Evap. of sea water puts water vapor in atm.
Cools the ocean: Heat transferred to make water vapor
Water vapor that gets moved to high latitude carries this latent heat with it
Formation of rain (or snow) at high latitude converts the latent heat to actual heat and warms the air there
This is the principal mechanism for warming the atmosphere, and transferring heat from low latitude to high latitude.

HEAT CAPACITY (or specific heat)
How much energy is needed to heat a substance OR...
How efficiently heat is stored in a substance
Definition = "Energy required to raise temp. of one gram of substance by 1°C."

Water has a large heat capacity: 1.00 calorie / g - °C
Heat capacity of rocks and soils only about 0.2 cal. / g - °C.
Consequences of difference:
Bodies of water gain/lose much heat with little T change.
They can thus moderate the air temperature- e.g., Lake Michigan
Land heats and cools much more easily

DENSITY -- mass per unit volume, grams/cm3
Pure water (at 4°C) = 1.000 g/cm3
Ice = 0.92 g/cm3 . . . The solid is LESS dense than the liquid- **unusual behavior**!
(for most substances, the solid form is denser)
**The crystal structure of ice, with its perfect rows, is actually more "open" or "expanded" than the more random structure of water
Sea water density = 1.021 - 1.028 g/cm3

STRATIFICATION
Large water bodies tend to be stratified according to density
Top layers -- least dense
Bottom layers -- most dense

DENSITY OF FRESH WATER (NOT sea water)
As water cools, it becomes denser- normal behavior except below 4°C
Maximum density at 4°C
Higher T --> density decreases (normal behavior)
Lower T (4°C to 0°C) -- density also decreases!
Ice clusters start to form - leads to greater avg. volume per molecule

Fresh Water Lakes during winter cooling
Surface freezes in cold weather
Water just below the layer of ice is at 0°C this is less dense than the water below and thus stays on top
Bottom stays at 4°C (that's the densest water) and does not freeze – allows fish to live through the winter.
Consider what would happen if ice sank to the bottom...