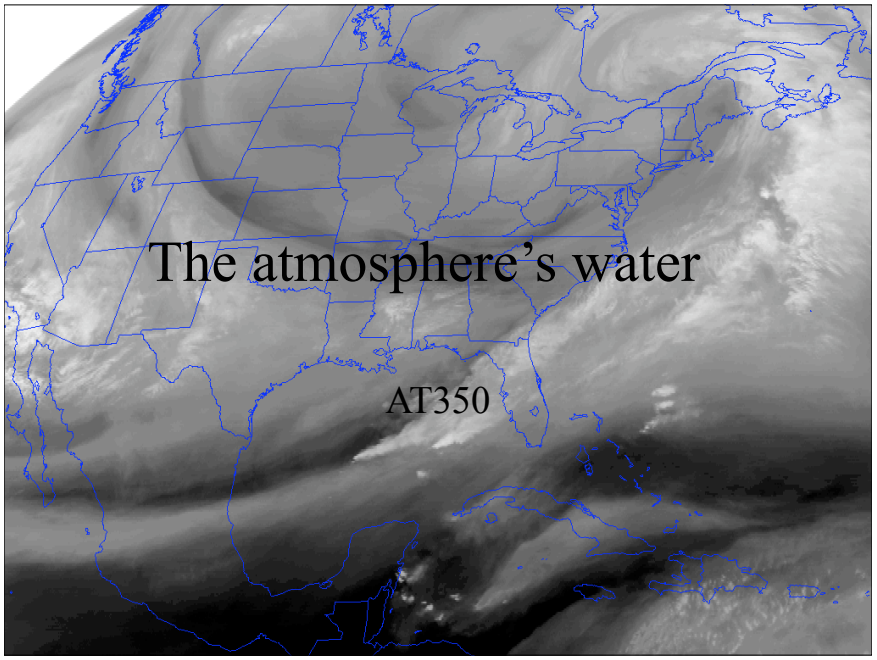


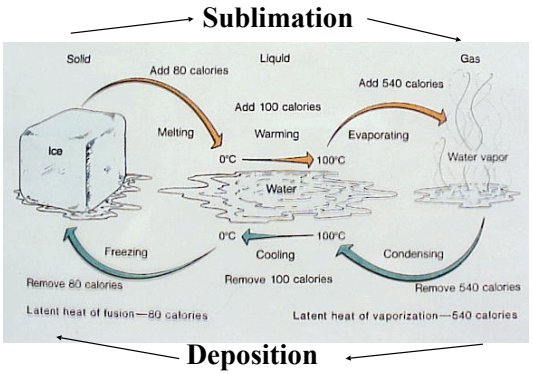
Properties of Water

- Physical States
  - only natural substance that occurs naturally in three states on the earth's surface
- Heat Capacity
  - Highest of all common solids and liquids
- Surface Tension
  - Highest of all common liquids
- Latent Heat of Fusion
  - Highest of all common substances
- Compressibility
  - Virtually incompressible as a liquid
- Density
  - Density of seawater is controlled by temperature, salinity and pressure
  - Liquid has maximum density at +4°C; solid phase has lower density!

Properties of Water (cont')

- Radiative Properties
  - transparent to visible wavelengths
  - virtually opaque to many infrared wavelengths
  - large range of albedo possible
    - water 10 % (daily average)
    - Ice 30 to 40%
    - Snow 20 to 95%
    - Cloud 30 to 90%

Energy associated with phase change



Why does it take so much energy to evaporate water?

- In the liquid state, adjacent water molecules attract one another
  - "-" charge on O attracted to "+" charge on H
  - we call this hydrogen bonding
- This same hydrogen bond accounts for surface tension on a free water surface
  - column of water

Sublimation - **evaporate ice directly to water vapor**

Take one gram of ice at zero degrees centigrade

Energy required to change the phase of one gram of ice to vapor:

Add 80 calories to melt the ice
Add 100 calories to raise the temperature to 100 degrees C
Add 540 calories to evaporate the liquid

Total Energy **ADDED** for sublimation of 1 gram of ice:

80 + 100 + 540 = 720 calories

Deposition - **convert vapor directly to ice**

Take one gram of water vapor at 100 degrees Centigrade

Release 540 calories to condense
Release 100 calories to cool temperature of liquid to ^{o}C
Release 80 calories to freeze water

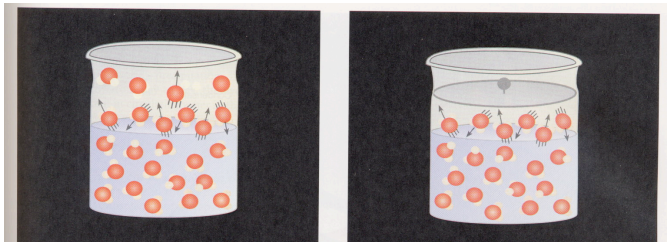
Total energy **RELEASED** for deposition of 1 gram of ice

540 + 100 + 80 = 720 calories

Water vapor pressure

- Molecules in an air parcel all contribute to parcel pressure
- Each subset of molecules (e.g., N_2, O_2, H_2O) exerts a partial pressure
- The VAPOR PRESSURE, e, is the pressure exerted by water vapor molecules in the air
  - similar to atmospheric pressure, but due only to the water vapor molecules
  - often expressed in mbar (2-30 mbar common at surface)

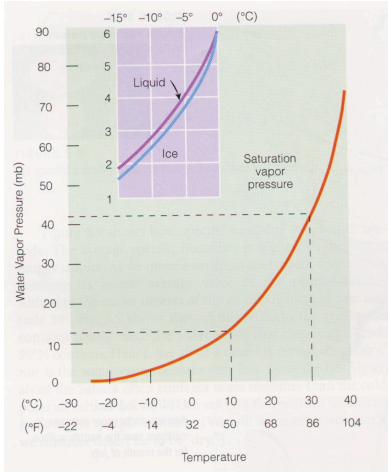
Water vapor saturation



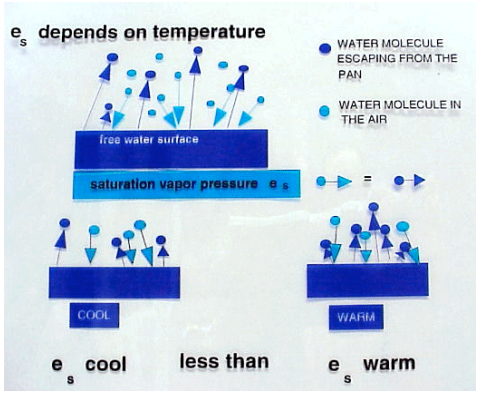
- Water molecules move between the liquid and gas phases
- When the rate of water molecules entering the liquid equals the rate leaving the liquid, we have equilibrium
  - The air is said to be saturated with water vapor at this point
  - Equilibrium does not mean no exchange occurs

e_S vs T plot

- The saturation vapor pressure of water increases with temperature
  - At higher T, faster water molecules in liquid escape more frequently causing equilibrium water vapor concentration to rise
  - We sometimes say "*warmer air can hold more water*"
- There is also a vapor pressure of water over an ice surface
  - The saturation vapor pressure above solid ice is less than above liquid water



e_S vs T schematic



Saturation vapor pressure depends upon temperature

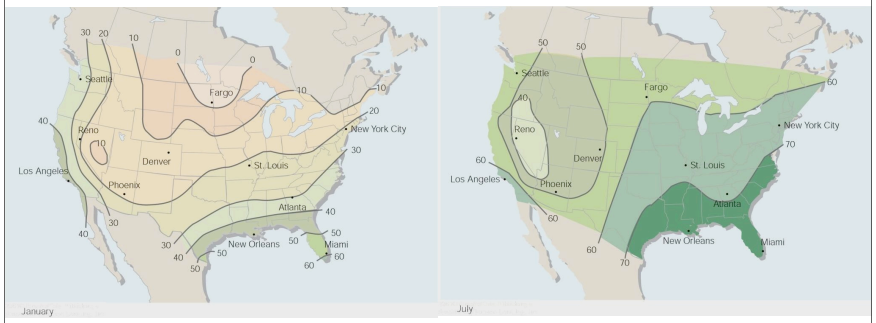
How do we express the amount of water vapor in an air parcel?

- Absolute humidity
  - mass of water vapor/volume of air (g/m^3)
  - *changes when air parcel volume changes*
- Specific humidity
  - mass of water vapor/mass of air (g/kg)
- Mixing ratio
  - mass of water vapor/mass of dry air (g/kg)
- Specific humidity and mixing ratio remain constant as long as water vapor is not added/removed to/from air parcel
- Dew point temperature

Expressing the water vapor pressure

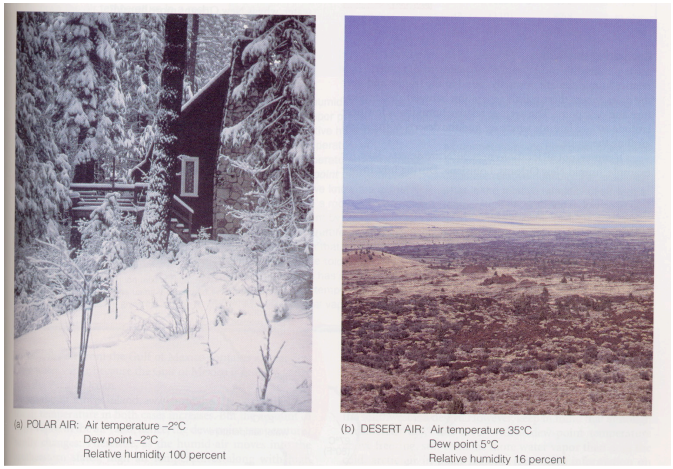
- Relative Humidity (RH) is ratio of actual vapor pressure to saturation vapor pressure
  - 100 * e/e_S
  - Range: 0-100% (+)
  - Air with RH > 100% is supersaturated
- RH can be changed by
  - Changes in water vapor content, e
  - Changes in temperature, which alter e_S

Dewpoint Temperatures



- Dewpoint is a measure of the water vapor content of the air
- It is not a measure of temperature!

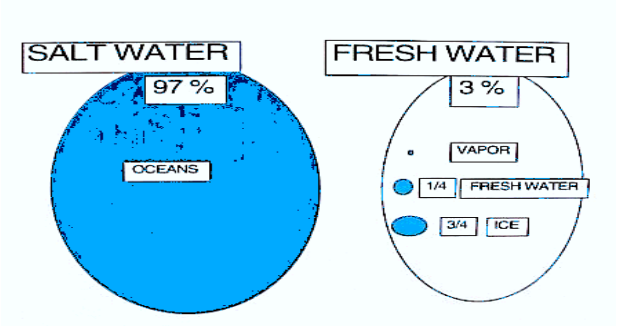
Which environment has higher water vapor content?



Water vapor is distributed throughout the atmosphere

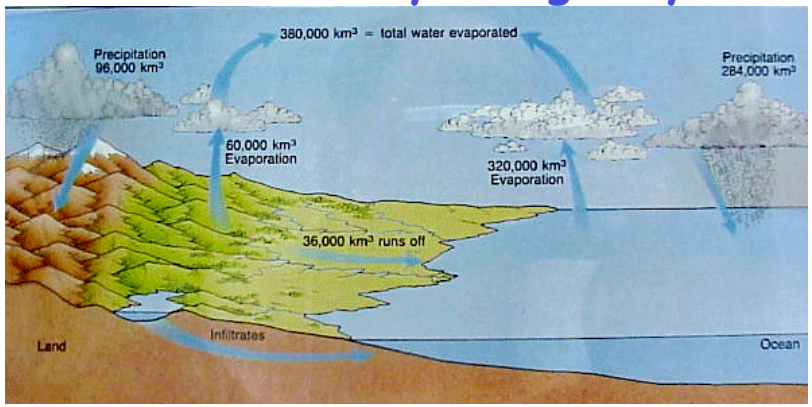
- Generally largest amounts are found close to the surface, decreasing aloft
  - Closest to the source - evaporation from ground, plants, lakes and ocean
  - Warmer air can hold more water vapor than colder air

Fresh vs. salt water



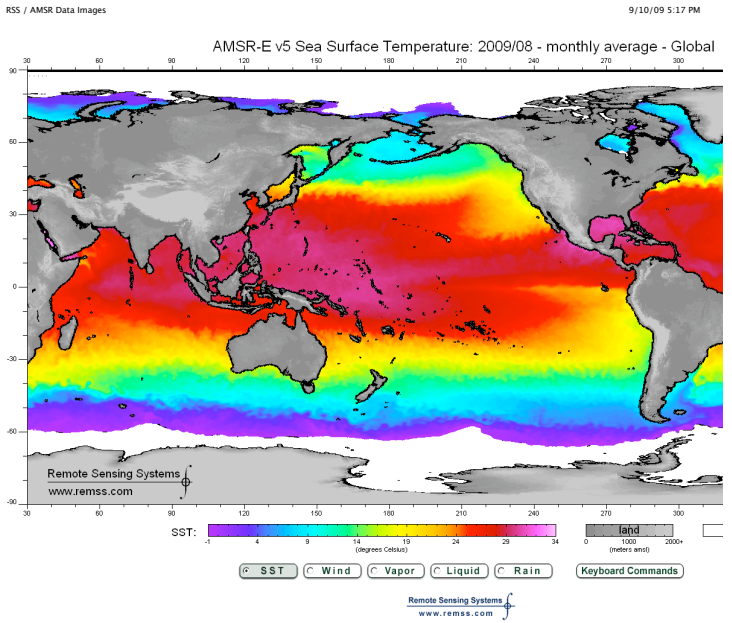
- Most of the earth's water is found in the oceans
- only 3% is fresh water and 3/4 of that is ice
- The atmosphere contains only ~ 1 week supply of precipitation

The Earth's Hydrologic Cycle



Why is the southwest coast of the US hot and dry while the Gulf coast is hot and moist?

- Both are adjacent to large bodies of water
- Both experience onshore wind flow on a regular basis
- Why does one have a desert like climate and the other ample moisture and rainfall?



AMSR-E v5 Atmospheric Water Vapor: 2009/08 - monthly average - Global