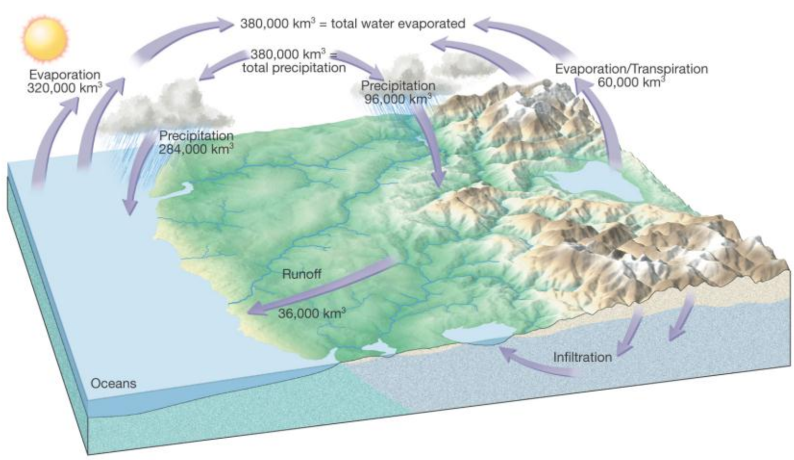
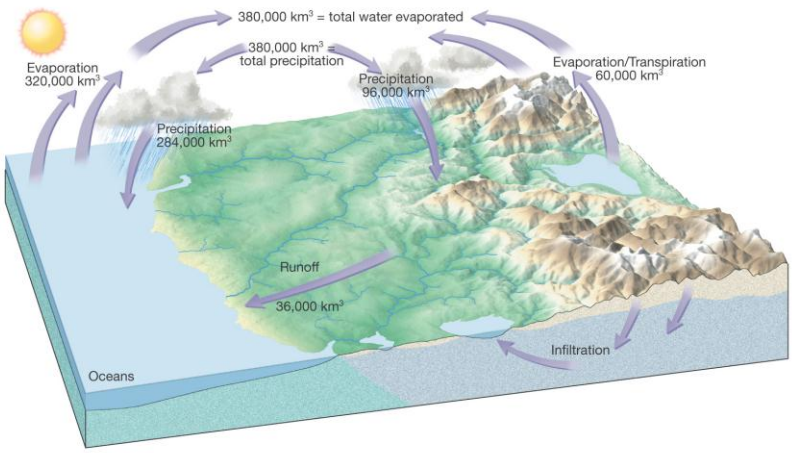
Chapter 4
Moisture and Atmospheric Stability

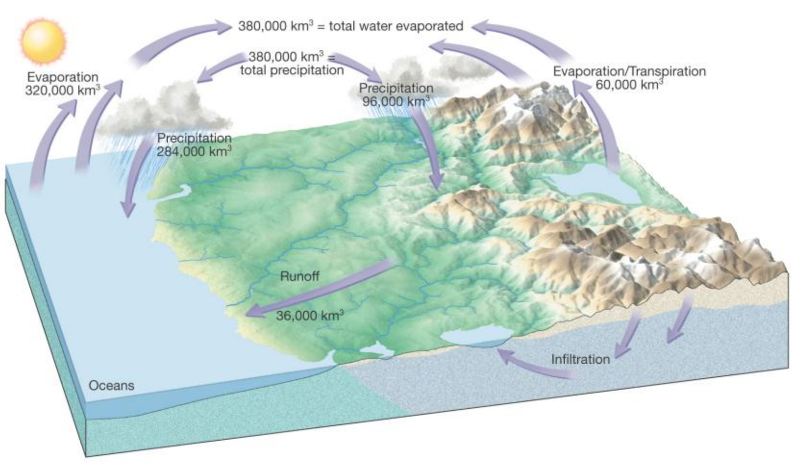
The Hydrologic Cycle: the unending circulation of Earth's water supply



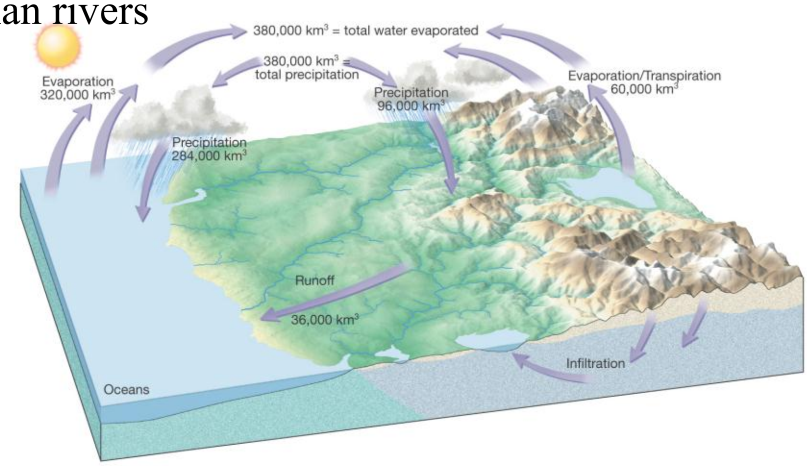
Processes: evaporation, precipitation, transpiration, infiltration, runoff



The Water Balance: quantitative view of the hydrologic cycle



The Atmosphere: connects the ocean with the land surface. Greater movement of water through air than rivers



II. Water's Changes of State

Water = only substance that exists in all three states within the atmosphere

Ice: low kinetic energy, molecules arranged in an orderly network (**crystal lattice**)

Liquid Water: higher kinetic energy, molecules slide past each other

Water Vapor: highest kinetic energy, distance between molecules increase, highly compressible

Interesting Properties of Water

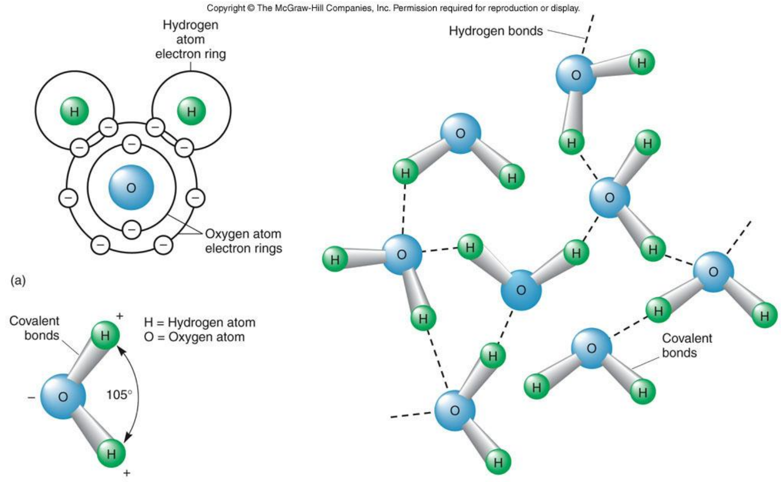
Readily converted between states

Solid phase (**ice**) is less dense than liquid phase

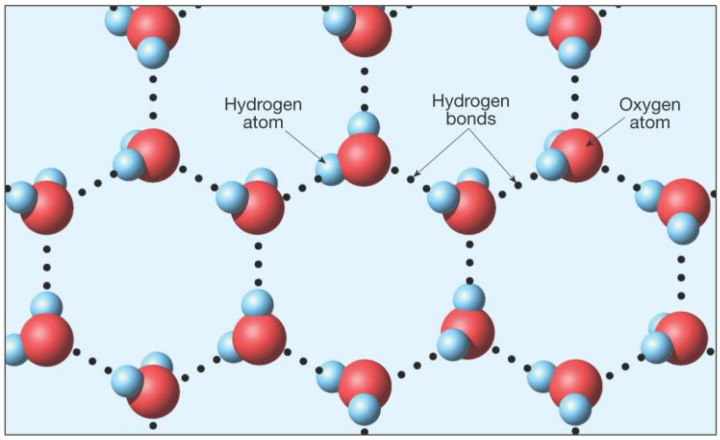
Unusually high **heat capacity**

hydrogen bonds

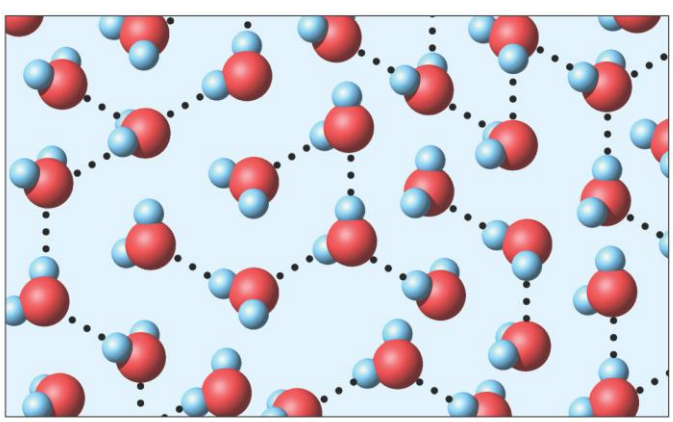
- **H_2O**
- **covalent bonds**: shared pairs of electrons
- **hydrogen bonds**: weak magnetic bonds between water molecules due to polar structure



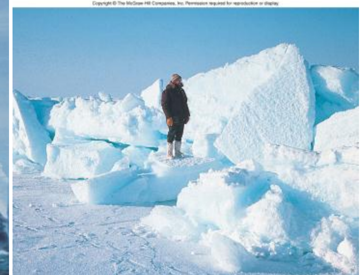
Ice: as kinetic energy decreases, hydrogen bonding becomes important in controlling the crystal structure

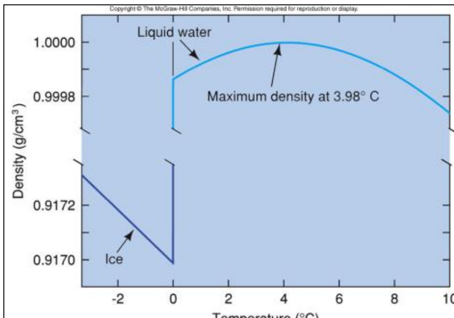


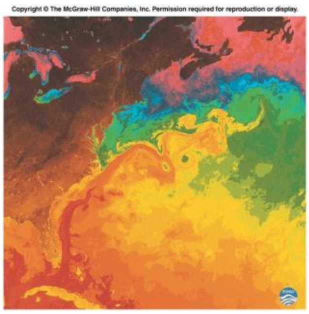
Water: as kinetic energy increases, hydrogen bonds are broken water molecules move closer together

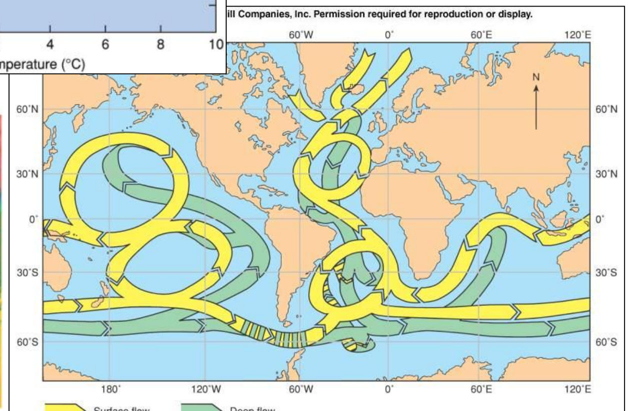



Castle berg




Liquid water
Maximum density at 3.98° C
Ice
Density (g/cm³)
1.0000
0.9998
0.9172
0.9170
-2
0
2
4
6
8
10
Temperature (°C)




N
60°N
30°N
0°
30°S
60°S
180°
120°W
60°W
0°
60°E
120°E
Surface flow
Deep flow

II. Water's Changes of State

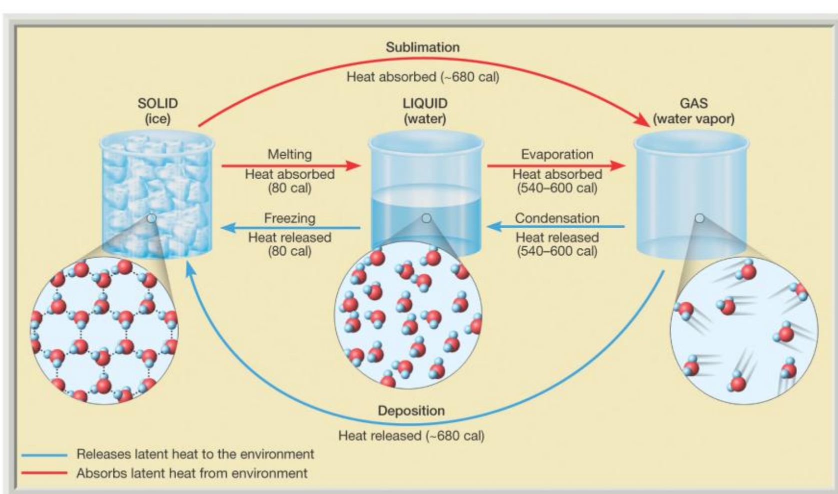
B. Latent (hidden) heat: heat required to change the state of water, without an accompanying rise in temperature

• when water changes states heat is exchanged between water and the surroundings

• **calorie** = amount of heat required to raise 1gm water 1^{o}C

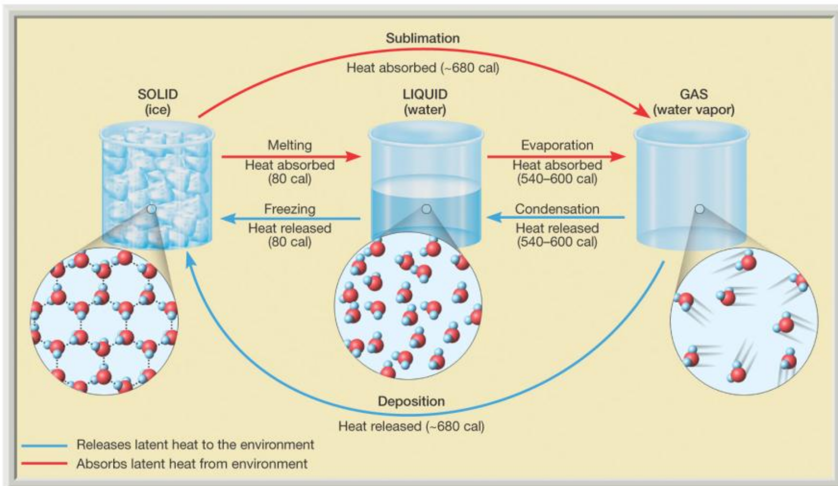
Latent heat of melting: 80 cal/gm

Latent heat of fusion: 80 cal/gm



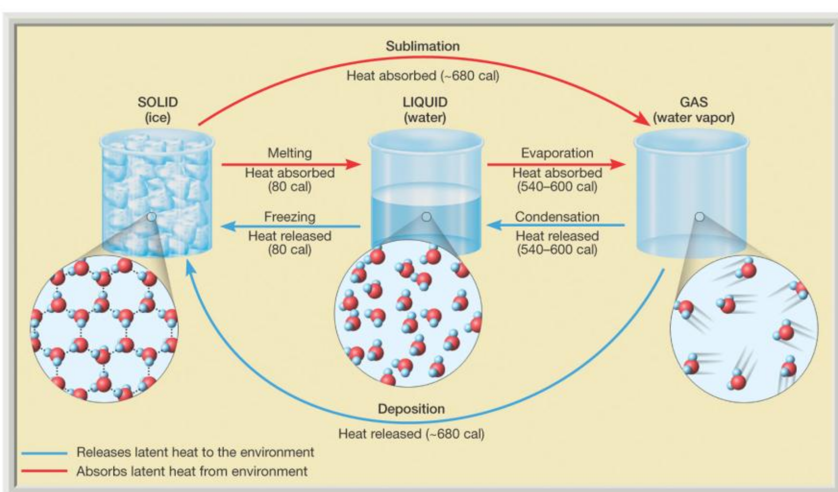
Evaporation: process of converting a liquid to a gas (vapor)

Latent heat of vaporization: 540 cal/gm – 600 cal/gm

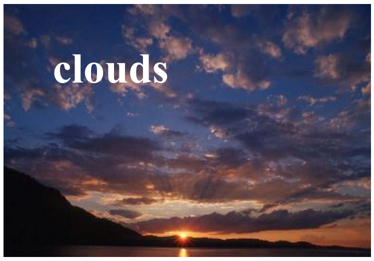


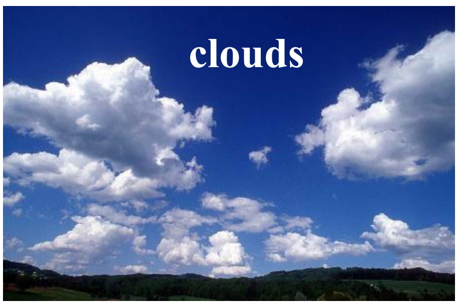
Condensation: process of converting a gas to a liquid

Latent heat of condensation: 540 cal/gm – 600 cal/gm



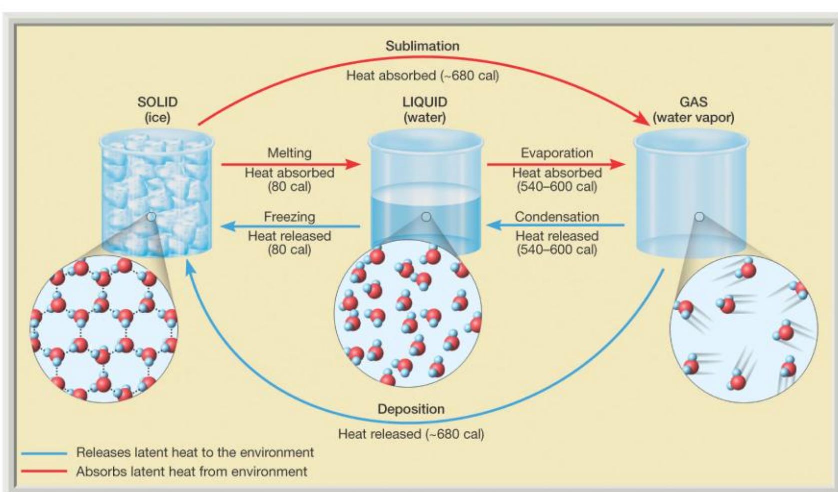
Condensation: energy released to atmosphere



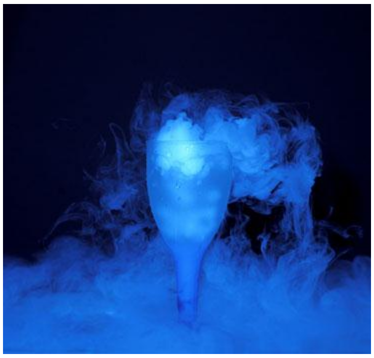


Sublimation: process of converting a solid to a gas **680** cal/gm

Deposition: process of converting a gas to a solid **680** cal/gm



Dry Ice



Frost

III. Humidity: Water Vapor in the Air

1/10 – 4% water vapor by volume

the most important gas in the atmosphere when understanding atmospheric processes

Methods to express the water-vapor content of the air

A. Absolute humidity and mixing ratio
B. Vapor pressure and saturation
C. Relative humidity
D. Dew point temperature

A. Absolute humidity: the mass of water vapor in a given volume of air (gm/m^3)

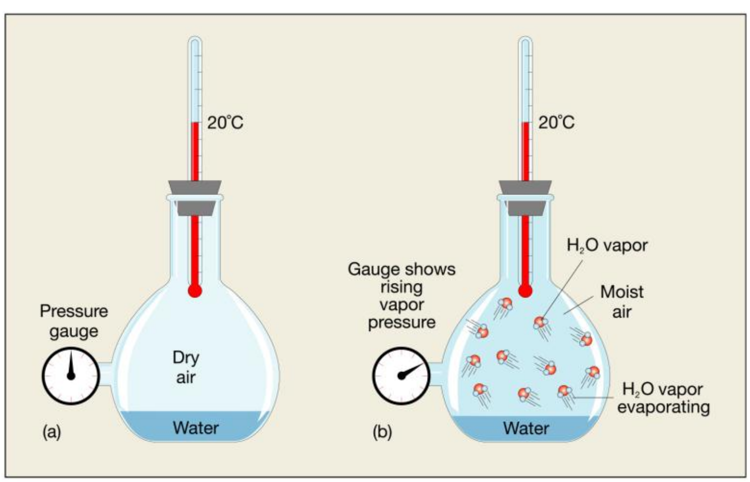
$$\text{abs hum} = \frac{\text{mass of water vapor (gm)}}{\text{volume of air } (m^3)}$$

*Problem: air is highly compressible

mixing ratio: the mass of water vapor in a unit of air compared to the mass of the remaining dry air (gm/kg)

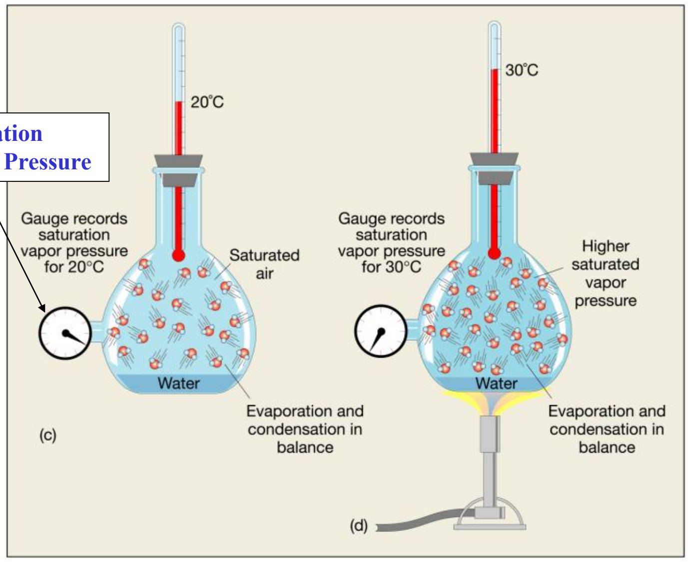
$$\frac{\text{mass of water vapor (gm)}}{\text{mass of dry air (kg)}}$$

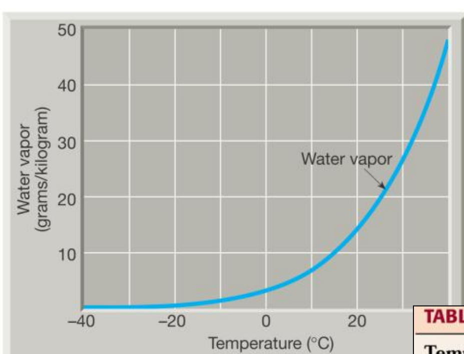
B. Vapor pressure: the part of the total atmospheric pressure attributed to the water vapor content



Saturation: rate of evaporation of water molecules equals the rate of condensation back to surface

Saturation Vapor Pressure





Saturation mixing ratios are **temperature dependant**

TABLE 4-1 Saturation Mixing Ratio (at Sea-Level Pressure)

Temperature °C (°F)	Saturation Mixing Ratio g/kg
−40 (−40)	0.1
−30 (−22)	0.3
−20 (−4)	0.75
−10 (14)	2
0 (32)	3.5
5 (41)	5
10 (50)	7
15 (59)	10
20 (68)	14
25 (77)	20
30 (86)	26.5
35 (95)	35
40 (104)	47

C. Relative Humidity: ratio of the air's actual water-vapor content compared with the amount of water vapor required for saturation at that temperature and pressure

How near air is to **saturation**, not actual quantity of water vapor

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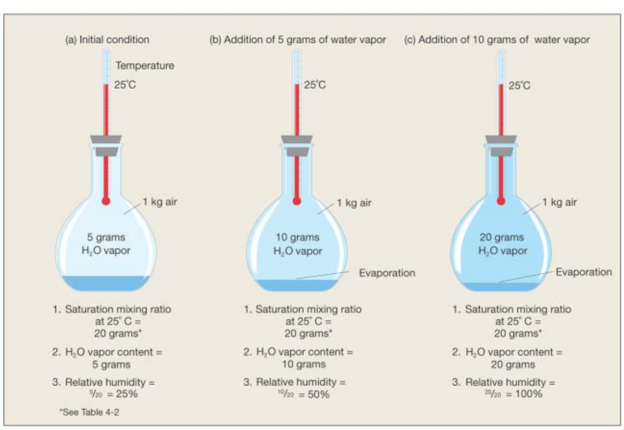
Give Example

Relative humidity changes:

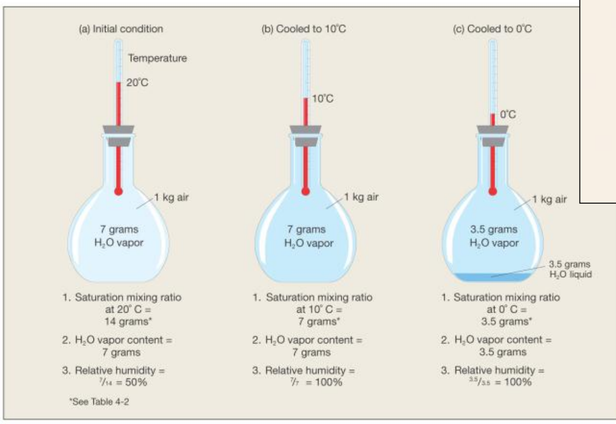
- addition or removal of water
- changes in temperature



evaporation

condensation

transpiration



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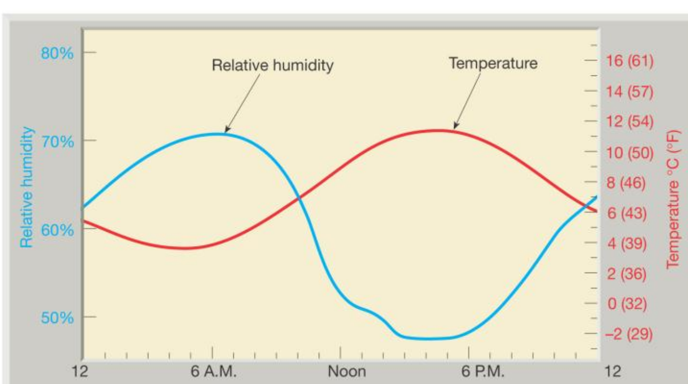
Decrease Temperature = Increase Relative Humidity
Increase Temperature = Decrease Relative Humidity

continued cooling after saturation will induce **condensation**

Natural Changes In Relative Humidity:

- daily temperature changes (day – night)
- horizontal movement of air (advection)
- vertical movement of air (convection)



Phoenix, Arizona, Jan

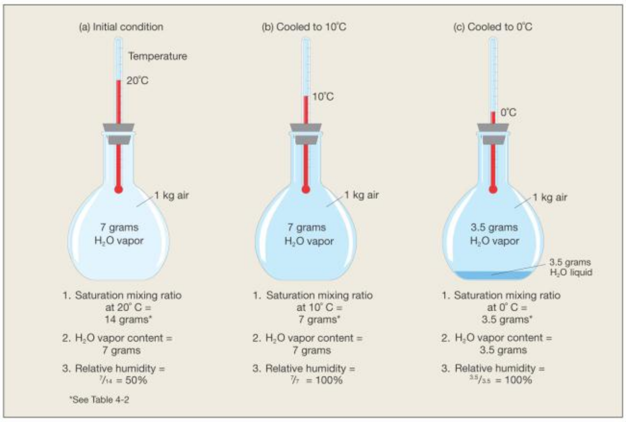
International Falls, Minnesota, Jan

Which has more Moisture?
Which has higher Relative Humidity?

Higher Temperature
Lower Relative Humidity
with MORE Moisture!

Lower Temperature
Higher Relative Humidity
with LESS moisture!

D. Dew Point Temperature: temperature to which a parcel of air would need to be cooled to reach **saturation**



Frost Point: saturation occurs at temperatures below freezing
- gas to solid, **deposition**

Dew Point: good indicator of moisture content

high dew point = moist air
low dew point = dry air

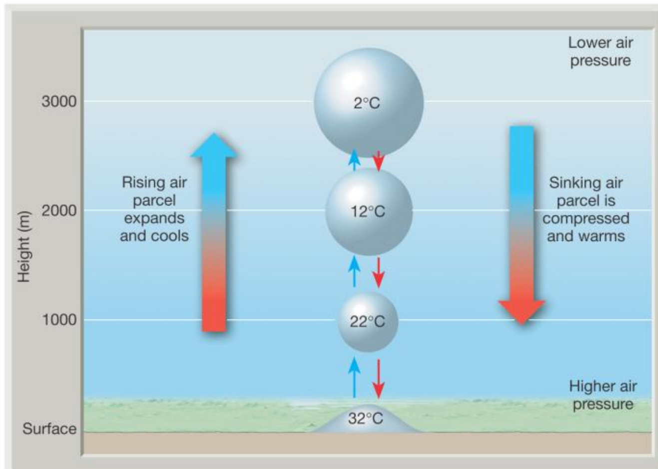
Adiabatic Temperature Changes And Cloud Formation

- temperature changes that result from compression or expansion of gas, without corresponding exchange of heat

expansion = cooling
compression = warming

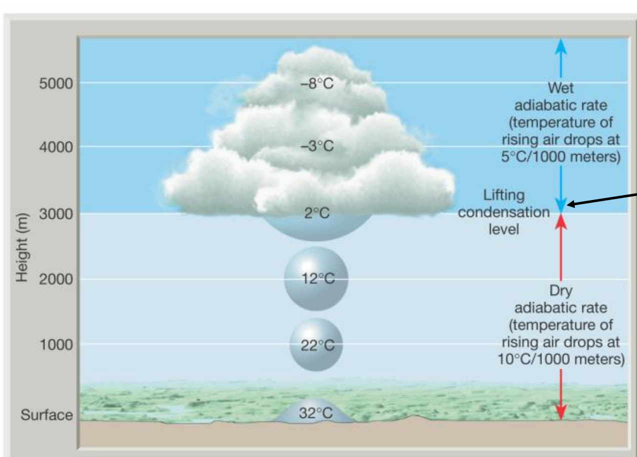
- energy can either be used to do the work of expansion, or to maintain the temperature of the parcel, but it can't be used for both

Unsaturated air cools ~10^{o}C/1000 m rise = **dry adiabatic rate**



Saturated air 5-9^{o}C/1000 m rise = **wet adiabatic rate**

rate is slower because of release of latent heat (phase change)



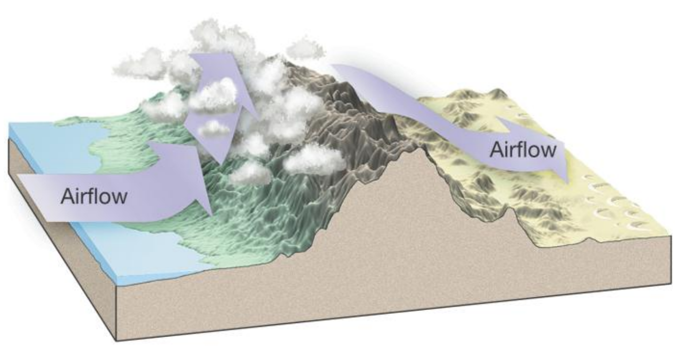
Lifting Condensation Level

Processes That Lift Air

1. Orographic Lifting = air forced over mountains
2. Frontal Wedging = less dense air forced over denser air
3. Convergence = pileup of air masses
4. Local Convective Lifting = unequal surface heating

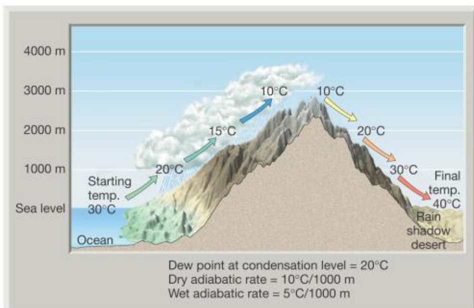
Processes That Lift Air

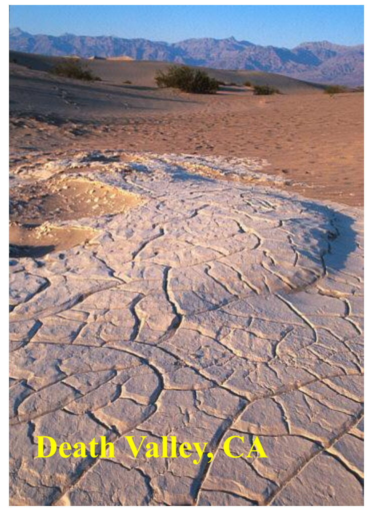
1. Orographic Lifting = air forced over mountains



Orographic Lifting

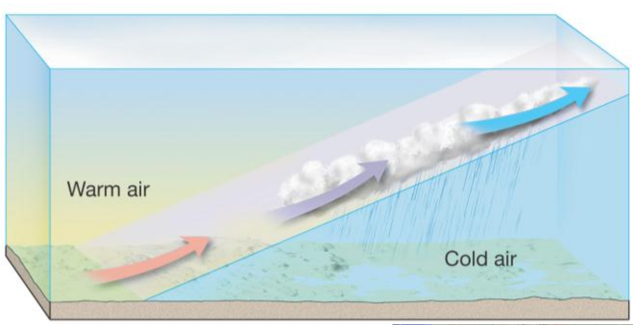
- rain shadow desert results from the combined influence of water loss and release of latent heat

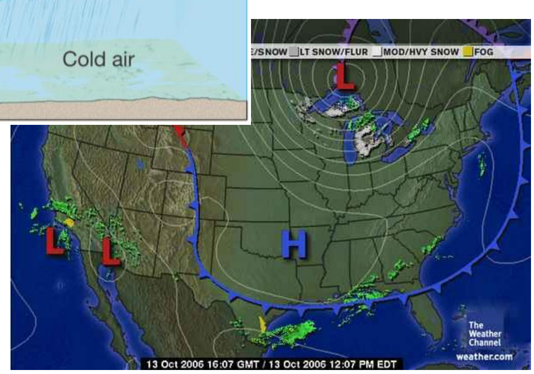




Processes That Lift Air

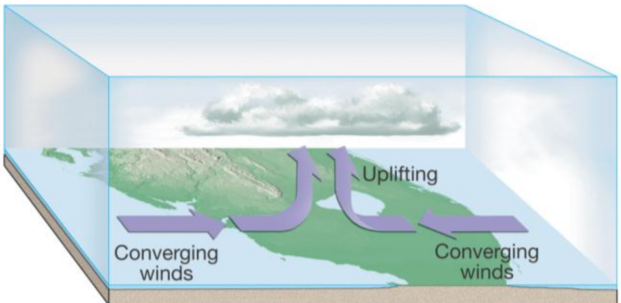
2. Frontal Wedging = less dense air forced over denser air





Processes That Lift Air

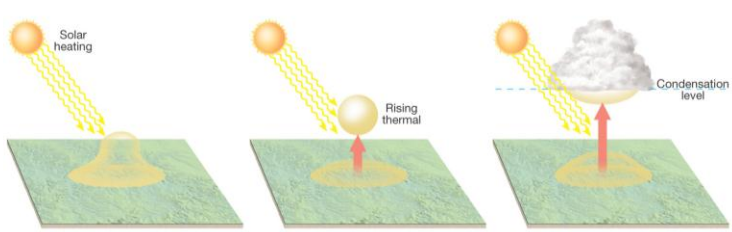
3. Convergence = pileup of air results in vertical movement



Processes That Lift Air

4. Local Convective Lifting = unequal surface heating

- short lived, scattered shower, can be heavy at times

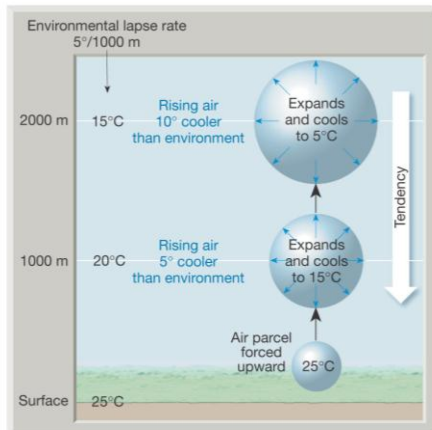


'thermals' : rising parcels of warmer air

Atmospheric Stability

- consider parcel relative to surrounding air

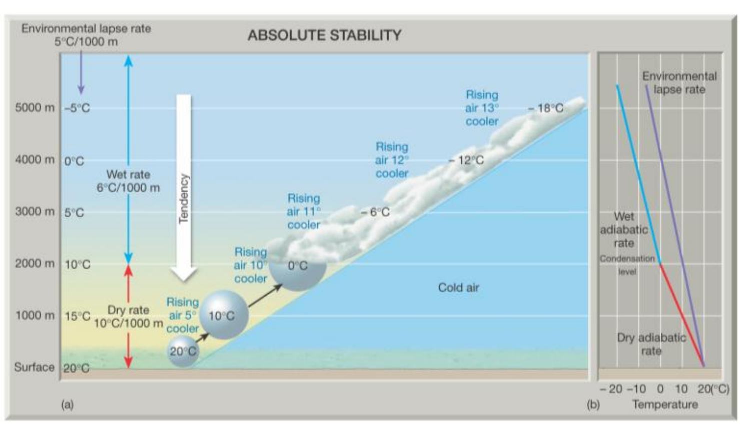
- stable: parcel is cooler, more dense than surrounding air and will resist vertical motion
- unstable: air warmer, less dense than surrounding, and will continue to rise until temp is equal



Types of Atmospheric Stability

absolute stability: environmental lapse rate is less than the adiabatic wet rate

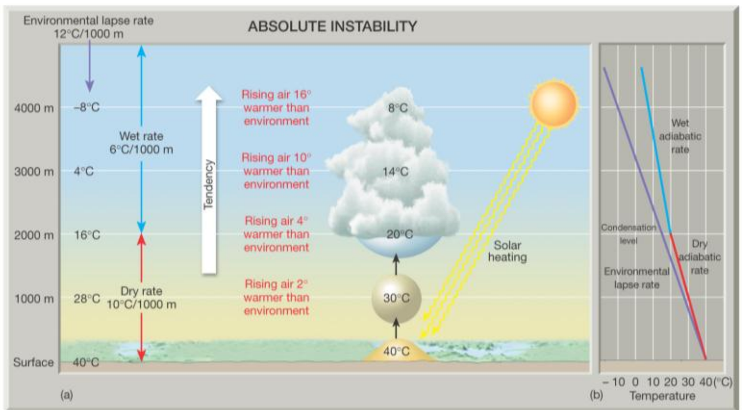
air tendency: is to return to the surface



Types of Atmospheric Stability

absolute instability: environmental lapse rate is greater than the adiabatic dry rate

air tendency: is to rise, extends a few kilometers



Types of Atmospheric Stability

conditional instability:
adiabatic wet rate < environmental lapse rate < adiabatic dry rate