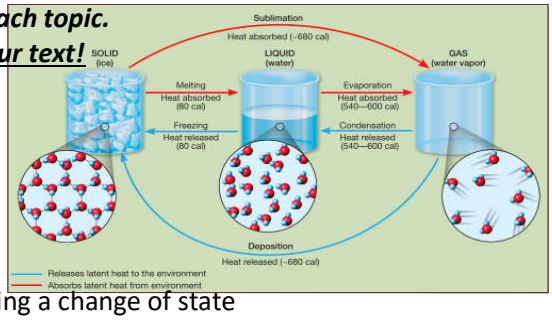
# Chapter Outlines

***NOTE: This is intended to help students 'organize' their understanding of each topic.***
***It is <u>not</u> a comprehensive study guide for quizzes or midterms, i.e. <u>study your text!</u>***

## Moisture, Clouds, Precipitation

Phase changes in water…



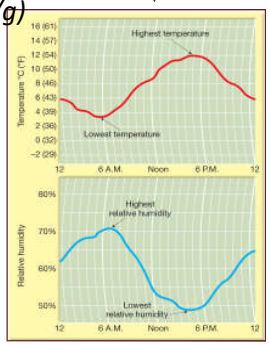

### I. Changes of state of water

A. Heat energy
1. Measured in calories —1 calorie is the heat necessary to raise the temperature of 1g of water 1°C
2. **Latent heat** – Stored *(hidden)* heat absorbed or released during a change of state

Condensation, melting, evaporation (all three)

B. Three states of matter *(including water)* are: solid, liquid, gas
C. For substance to change state, heat must be absorbed or released
D. Processes
1. **Evaporation**: heat absorbed by water *(600 Cal/g)* is the latent heat of evaporation
2. **Condensation**: Water vapor changed to liquid, latent heat of evaporation *(600 Cal/g)* is released
3. **Melting**: the heat absorbed by the ice *(80 Cal/g)* is the latent heat of melting
4. **Freezing**: the latent heat of melting *(80 Cal/g)* is released
5. **Sublimation**: Solid is changed directly to a gas - heat is absorbed *(680Cal/g)*
6. **Deposition**: Water vapor *(gas)* changed directly to a solid - heat is released *(680Cal/g)*

Change in humidity resulting from change in temperature

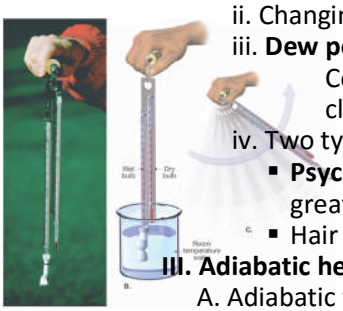



### II. Humidity – the amount of water vapor in the air *(warm air can hold more moisture than cold air)*

A. Water vapor adds pressure *(called **vapor pressure**)* to the air
B. Measuring humidity
1. **Mixing ratio** – 'water vapor mass/dry air mass'… in a unit of air in g/kg
**Saturation Mixing Ratio** – the maximum amount of water a unit of air can hold in g/kg
2. **Relative humidity** – the percent 'full' the air is with water vapor *(varies with T°)*

$$\textit{Relative humidity} = \frac{\textit{water vapor content}}{\textit{saturation mixing ratio}}\ x\ 100\%$$

a. **Saturated air** – *(100% humidity)* the air cannot hold any additional moisture
b. Relative humidity can be changed in two ways…
i. Add to or subtract moisture from the air *(add moisture = higher mixing ratio & higher relative humidity)*
ii. Changing the air T° *(lowering T° results in higher relative humidity)*
iii. **Dew point** - Temperature to which a parcel of air would need to be cooled to reach saturation. Cooling the air below the dew point causes condensation. Forms include: dew, fog, or cloud formation *(water vapor requires a surface or particles on which to condense)*
iv. Two types of hygrometers are used to measure humidity
- **Psychrometer** - compares T° of a wet-bulb thermometer and a dry-bulb thermometer…the greater the difference between the readings, the lower the relative humidity
- Hair **hygrometer** - reads the humidity directly using material that changes with moisture

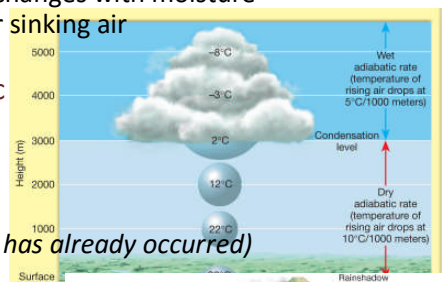


Wet bulb, dry bulb psychrometer

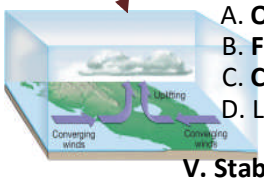
### III. Adiabatic heating/cooling – a temperature change resulting from rising or sinking air

A. Adiabatic temperature changes occur when…
1. Air descends *(is compressed)* and becomes warmer
2. Air rises *(expands)* and becomes cooler
B. Adiabatic rates
1. **Dry adiabatic rate** *(T° remains above dew point)*
… 10°C per 1000m *(cools when rising, warms when sinking)*
2. **Wet adiabatic rate** *(T° has dropped below dew point & condensation has already occurred)*
… 5°C to 9°C per 1000m *(cools when rising – normally never sinks)*

Adiabatic rates




Convergence uplift

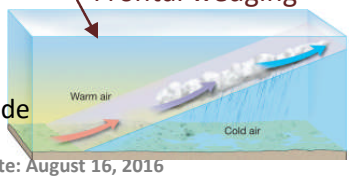



### IV. Processes that lift air

A. **Orographic lifting** – lifting of air as it moves over mountains
B. **Frontal wedging** – warm air mass is forced up and over a dense cold air mass
C. **Convergence** – converging air masses cause the air to turn up
D. Localized heating of the ground causes **convective lifting**

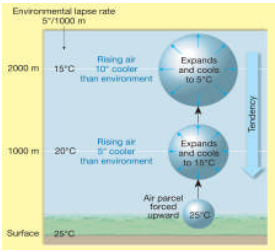
Orographic lifting


Frontal wedging



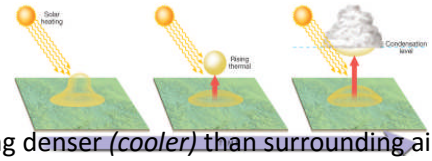

### V. Stability of air – whether or not air 'wants' to rise

A. **Environmental lapse rate** – is the local *(current)* T° decrease with altitude



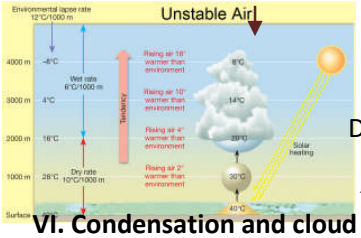

'Stable' air

Convective lifting



B. '**Stable**' air resists rising due to being denser *(cooler)* than surrounding air. '**Absolute stability**' occurs when the environmental lapse rate is less than the wet adiabatic rate

C. **Unstable** air rises due to being less dense *(warmer)* than the surrounding air. Then, before it reaches surrounding air with similar T°, its water vapor condenses when it reaches the dew point, releasing latent heat of evaporation, and it continues to rise until it reaches surrounding air with similar T°, thereby creating towering cumulus clouds. This '**absolute instability'** occurs when the environmental lapse rate is greater than the dry adiabatic rate.



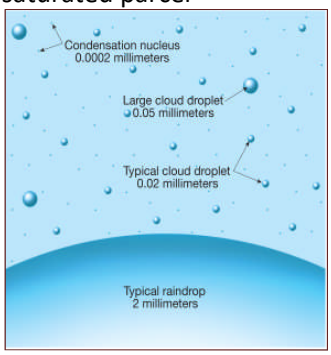

D. '**Conditional instability'** occurs when the atmosphere is stable for an unsaturated parcel of air but unstable for a saturated parcel

'Unstable' air

## VI. Condensation and cloud formation

A. Condensation – when water vapor in the air changes to a liquid and forms dew, fog, or clouds

1. Water vapor requires a surface on which to condense: grass, a car window, and so forth
2. Condensation in the air *(clouds)* requires small particles called **condensation nuclei** – includes dust, smoke, ocean salt crystals, & similar particles

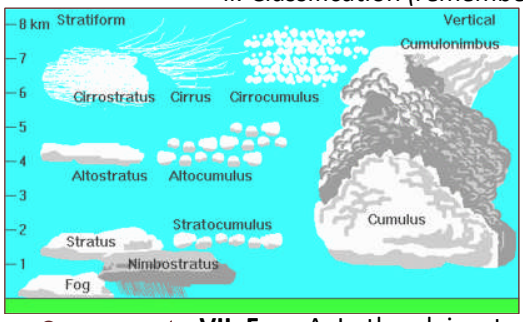



Condensation nuclei To cloud droplets

B. Clouds

i. Composition - Millions of tiny water droplets or millions of tiny crystals of ice

ii. Classification *(remember…**nimbus** means 'rainy')*




Common cloud names

a. Form *(three basic forms):…* <u>**Cirrus**</u> - high, white, thin; <u>**Cumulus**</u> - globular cloud masses; <u>**Stratus**</u> - Sheets or layers

b. Height

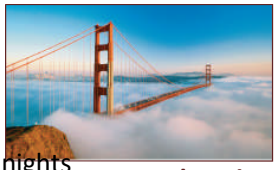
1. High clouds - above 6000 meters include: **Cirrus**; **Cirrostratus**; **Cirrocumulus**
2. Middle clouds - 2000 to 6000 meters include: **Alto cumulus**; **Altostratus**
3. Low clouds - below 2000 meters include: **Stratus**; **Stratocumulus**; **Nimbostratus**
4. Clouds of vertical development - extend from low to high altitudes …called **cumulonimbus**, often produce rain showers and/or thunderstorms

## VII. Fog

A. In the plainest sense is simply a cloud with its base at or near the ground

B. Types of fog

1. **Advection fog**—warm, moist air moves over a cool surface
2. **Radiation fog** – from Earth's surface cooling rapidly during cool, clear, calm nights
3. **Upslope fog** - humid air moves up a slope causing adiabatic cooling
4. **Evaporation fog** – surface water evaporates causing air near the surface to become saturated



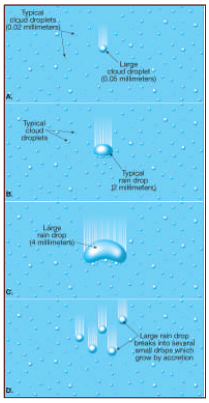
Advection fog

## VIII. Precipitation

A. Cloud droplets form first - less than 0.02 millimeter in diameter, and fall incredibly slowly

B. Formation of precipitation *(<u>these have variations</u>)*

1. **Bergeron process:** a) temperature in the cloud is below freezing, b) ice crystals collect water vapor, c) large snowflakes form and either fall to the ground as snow or melt on their descent and form rain, d) this sequence is dominant in the middle latitudes
2. **Collision/coalescence process:** a) warm clouds, b) large hygroscopic condensation nuclei, c) large droplets form, d) droplets collide with other droplets during their descent, e) this sequence is common in the tropics



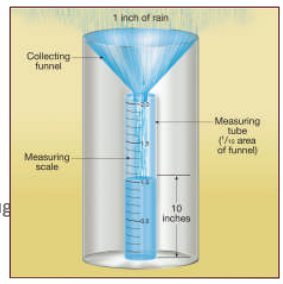
Coalesence then breaking apart

C. Forms of precipitation

1. **Rain** - droplets ≥ 0.5 mm diameter; **drizzle** - droplets ≤ 0.5-mm diameter
2. **Snow**—ice crystals or aggregates of ice crystals
3. **Sleet** - Small particles of ice formed when rain falls into freezing air from overlying warmer air
4. **Glaze** – supercooled droplets freeze upon impact with any object *(hopefully not on your airplane!)*
5. **Hail** – 1 to 5cm frozen pellets formed during violent up&down drafts in cumulonimbus clouds
6. **Rime** – supercooled fog particles freeze on contact with anything

D. Measuring precipitation

1. Rain *(easiest form to measure)* measured with various types of rain gauges
2. Snow *(measured by depth)* is often converted to a 'water equivalent' which varies widely, but in general can be estimated at 10 snow units to 1 water unit




Typical rain gauge