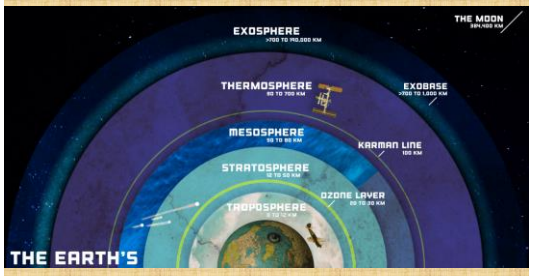


Chapter 11 Atmosphere

Objectives for Chapter 11

1. **I can describe the composition of the atmosphere. This means that I can**:
   A. List the name and percentages of the two main gases in the atmosphere
   B. Describe the importance of water vapor, carbon dioxide, and ozone.
2. **I can compare and contrast the various layers of the atmosphere. This means that I can:**
   A. List the layers in order.
   B. Describe how the temperature varies with altitude in the troposphere and stratosphere.
   C. Explain what causes the stratosphere to increase in temperature and what causes the other layers to decrease.
   D. Name the boundaries between the layers.
   E. Identify special characteristics in the troposphere and stratosphere.
3. **I understand the 3 methods of transferring energy (radiation, conduction, convection) throughout the atmosphere. This means that I can:**
   A. Identify characteristics of the earth's surface that increase or decrease the amount of radiation that is absorbed.
   B. Describe what part of the earth or atmosphere each method of energy transfers heat to/from, and how the heat is transferred.

Objectives #4-7

4. **I can describe the various properties of the atmosphere and how they interact. This means that I can:**
   A. Explain how temperature and density are related.
   B. Describe causes of temperature inversions and the effect of temperature inversions on pollution.
5. **I can explain why atmospheric properties (air pressure, density, temperature) change with changes in altitude.**
6. **I can explain how clouds are formed. This means I can:**
   A. List the 3 requirements for cloud formation, describe why they are needed and how they interact.
   B. Describe & explain the 2 main lift mechanisms that drive air upward and facilitate cloud formation.
   C. Compare & contrast humidity and relative humidity.
   D. Explain the concept of dew point and relate it to cloud formation.
7. **I can identify the basic characteristics of different cloud groups; cumulus, stratus, cirrus, cumulonimbus, fog. This means that I can:**
   A. Discuss features of each group..
   B. Compare and contrast the 2 types of fog discussed in class, identify the fog cloud type and explain how fog occurs.

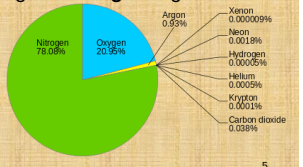
Objectives #8-11

8. **I can determine the relative humidity in the following 2 ways. I can:**
   A. Use a sling psychrometer and its data table to determine the relative humidity of air.
   B. Calculate the relative humidity if given the humidity and the water vapor capacity of a given air parcel.
9. **I can compare and contrast various phase changes,** including whether heat energy is absorbed or released.
10. **I can describe the water cycle using the following terms and describe their interrelationships:** evaporation, condensation, collision-coalescence, and precipitation.
11. **I can define and use the following miscellaneous terms:** heat, dew point, saturation, condensation, lifted condensation level (LCL), humidity, relative humidity, condensation nuclei, orographic lifting, frontal wedging, stable atmosphere, unstable atmosphere, latent heat, collision-coalescence.

Atmosphere

Composition/Main Components:

- 78% N_2, Nitrogen
- 21% O_2, Oxygen
- 1% mixture argon, CO_2, water vapor, H_2, etc.
- **NONE of these gases are responsible for the atmosphere absorbing **incoming** sunlight/solar radiation (energy).



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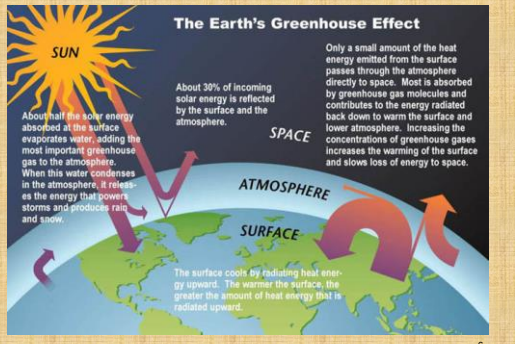
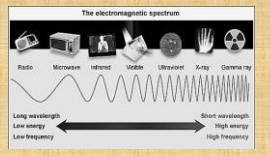
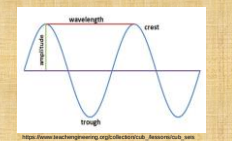
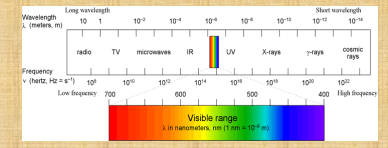
How DO CO2 and H2O affect atmospheric temp?



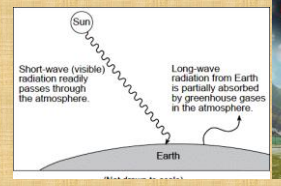
Wavelength & Solar Radiation

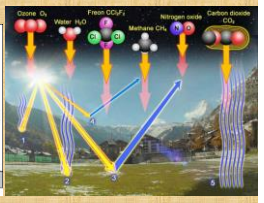






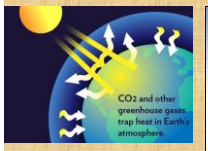
How DO CO2 and H2O affect atmospheric temp?

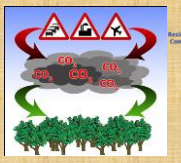


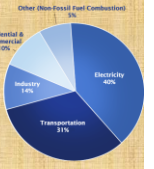


1. They do NOT absorb incoming solar radiation
   A. They ALLOW the Sun's incoming UV & visible light (short wavelength) radiation through to Earth's surface
   B. INSTEAD, they TRAP the infrared (longer wavelength) heat energy that is released/reflected from the warmed surface of the Earth

How Does CO2 affect atmospheric temp?





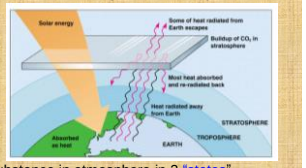


2. CO2, Carbon dioxide

A. Greenhouse gas:
- GOOD at natural levels for Greenhouse Effect
- BAD when increased by human action, causing global warming

B. Human actions that lead to increased CO2 levels:
- MAIN cause: burning fossil fuels (industry, cars, electricity production
- In addition, deforestation increases levels because there are fewer trees to take in CO2 for photosynthesis

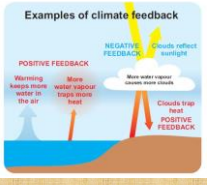
How Does H2O affect atmospheric temp?



3. Water Vapor

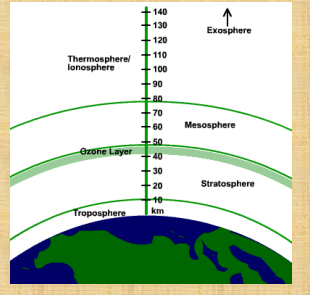
A. Unusual: It is the **only** substance in atmosphere in 3 "states"
   i. As water changes state, it absorbs or loses heat, and weather and climate are created
B. Weather and climate importance: Formation of clouds & precipitation
C. Greenhouse Gas:
- Water vapor is the most abundant GHG in the atmosphere
- Has the biggest impact on temperature compared to all the other GHGs (Traps 2/3 of all the heat trapped in the atmosphere, because it is the most abundant.)

H2O & Global Warming???



G. Global warming:
- Is it occurring?
- What is its cause?
- What is its effect?
- We'll investigate further in the Climate Unit!!!

Layers of the Atmosphere



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4 Main Layers of the Atmosphere, & the Exosphere Overview/Diagram

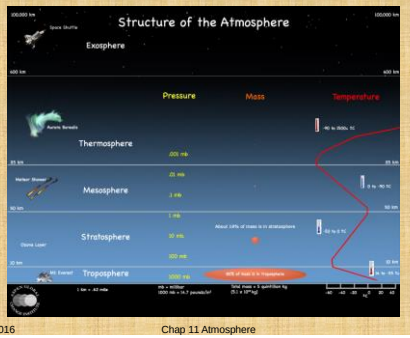
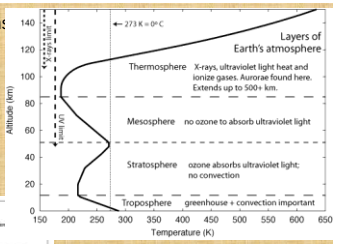
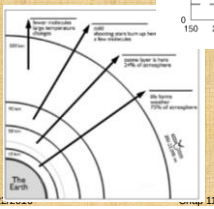


Fig 11-3 Temp Variations w/Altitude





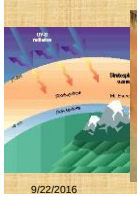
4 Main Layers of the Atmosphere, & the Exosphere

1. Troposphere- First layer, closest to earth
   - A. Temperature decreases with altitude. It is warmest near Earth.
     - Why decrease with altitude?
     - Less gravity means fewer particles & fewer collisions so lower temperature
   - B. Layer with the most mass
   - C. Has the highest gas concentration. It has more oxygen and water vapor than the other layers
   - D. Clouds, Weather & Pollution forms here
   - E. Upper limit/boundary is called the Tropopause

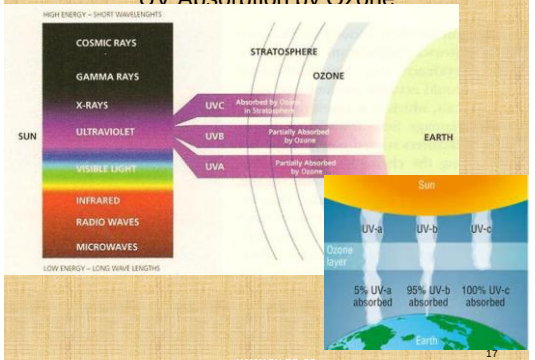
- **Birds can only fly in this layer**
- **Normal airplanes only use this layer**

4 Main Layers of the Atmosphere, & the Exosphere

2. **Stratosphere:** 2nd layer from Earth
   - A. Mostly ozone (O_3), which absorbs UV. The layer becomes heated due to absorbed UV.
   - *__Benefits__ of ozone:Protects us from harmful UV rays
   - *__Concern__ that ozone layer is thinning: If so, may see increased risk of skin cancer due to DNA damage from increased UV exposure.

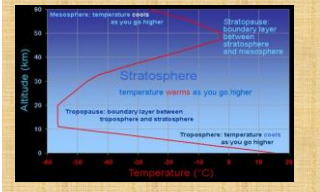


UV Absorption by Ozone



Stratosphere, Cont'd

- B. Temperature increases with altitude. The warmest part of the stratosphere is at the TOP of the layer.
- C. Upper limit/boundary is called the stratopause

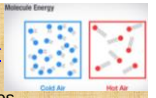


Heat vs. Temperature:They are NOT the same thing!

Heat: The transfer of energy between systems/substances/ objects/places

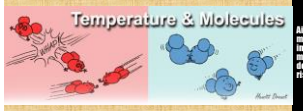
1. For heating to occur, the 2 substances/places must have different temperatures
2. Flow of energy (heat) flows from places of high energy (temperature) to places of low energy (temperature)
3. ***Heat fuels (causes) atmospheric processes and temperature measures the energy.

Temperature



Temperature = The measurement of how fast or slow molecules are moving

1. Related to the average speed of molecules
2. Faster movement = a higher temperature
3. Slower movement = a lower temperature
4. Measured in degrees F, C, or K (Kelvin)



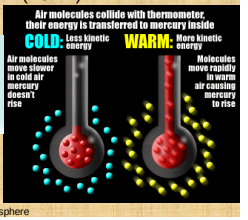
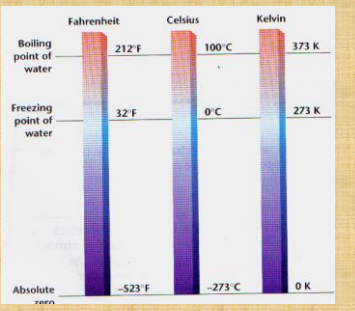
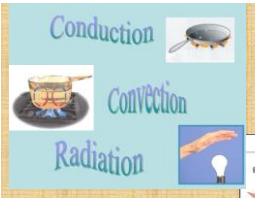
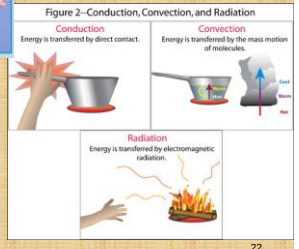


Fig 11-7 Temp Scale Comparisons p278





3 Methods of Heat Transfer



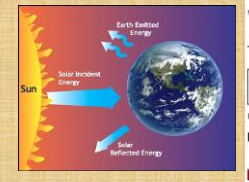
1. Radiation
2. Conduction
3. Convection

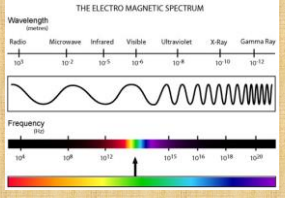
Picture source http://okfirst.mesonet.org/images/cond_conv_rad_small.jpg

****The Sun is the original source of all energy in the atmosphere. Energy is transferred in 3 ways:

Radiation: Transfer of energy through space by Electromagnetic (EM) waves: visible light, UV, etc.

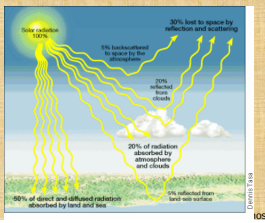
1. Earth absorbs solar radiation (waves), & also sends it back to space

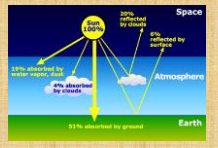




The Sun's Radiation Cont'd

2. Not all radiation is absorbed by Earth:
   A. Around 30% is reflected by clouds and earth's surface
   B. Around 15% is absorbed by the atmosphere before it hits earth
   C. Only 50% of incoming radiation is actually absorbed by the Earth's surface



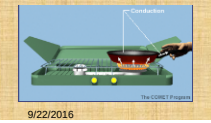
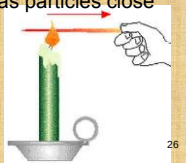


Solar Fundamentals Cont'd

3. **Rate of Earth's absorption depends on characteristics of area:**
   A. Color
   B. Material;
      A. Land heats faster, water heats slower
4. Radiation DOESN'T heat air directly
5. Radiation first warms the Earth and **then** the heat coming off of the Earth's surface heats the air through conduction.

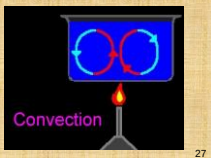
Conduction

1. Conduction is the transfer of energy through collision of molecules in CLOSE contact – TOUCHING.
2. Occurs near the Earth's surface
3. Substances must be **in contact** with each other
   A. Example: pot of water on the stove
   B. Example: Hot chocolate cup to your hand
   C. Example: Your body to a cold chair
4. Only air near Earth's surface has particles close enough for conduction

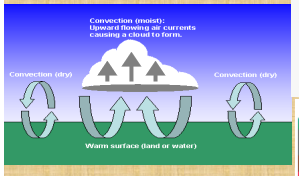
Convection

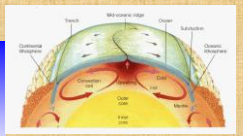
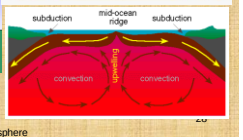
1. Convection is the **organized motion**/movement of large groups of molecules based on their relative **density**
2. Convection is also defined as the transfer of energy by flow of a heated substance; the **transfer of heat energy through a liquid or a gas**
   A. Example: How does hot water move in a pan when you cook pasta noodles?
3. Due to uneven heating of gases or liquids (**Part** of the liquid/gas is heated faster)



Convection, continued

4. Convection carries heat energy higher into the atmosphere than conduction
5. A **Convection Current** is a cycle (circle) of rising and falling air.

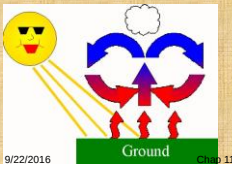


http://mabryonline.org

Convection Current Continued

6. **The Convection Process**
   A. Air above the conduction area becomes heated, expands, becomes less dense and rises
   B. As it rises, it cools, contracts, becomes denser, and sinks
   C. Reheats and rises. This keeps repeating
7. This motion of air leads to clouds & different types of weather.



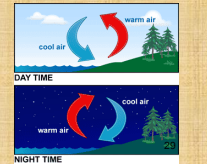


Diagram-3 Ways to Transfer Energy

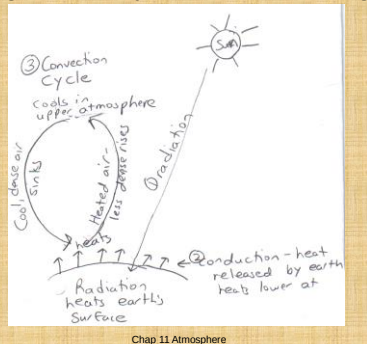
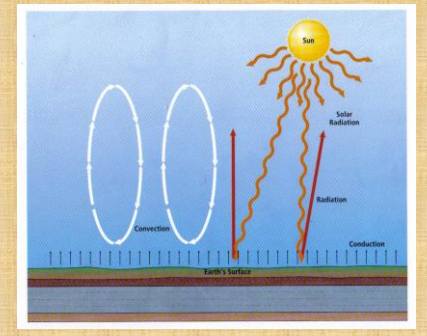
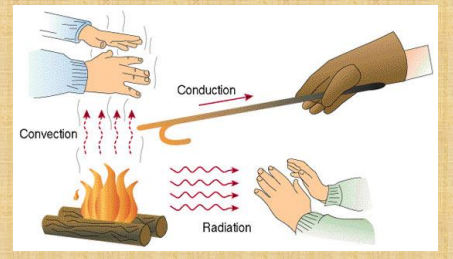


Fig 11-5 The 3 Methods of Energy Transfer (p276)

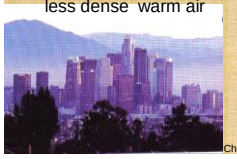


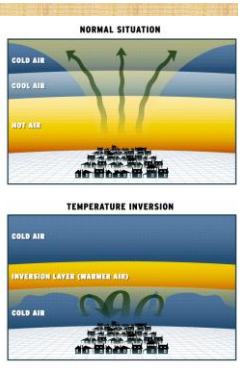
3 Methods Review



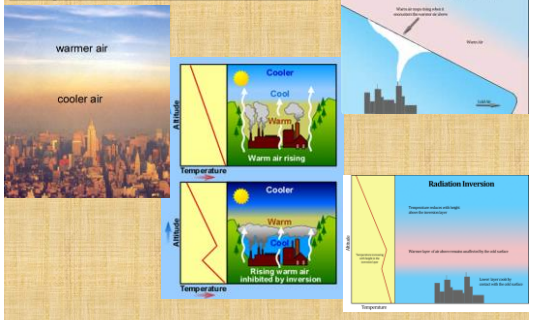
Temperature Inversion

A. **Usually** temperature decreases with height in the troposphere
B. Inversion is where temperature increases with height (opposite of what's expected)
C. Can worsen air pollution- because cooler polluted air is dense and trapped under the less dense warm air





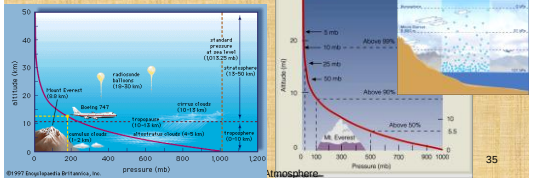
Temperature Inversion Contind

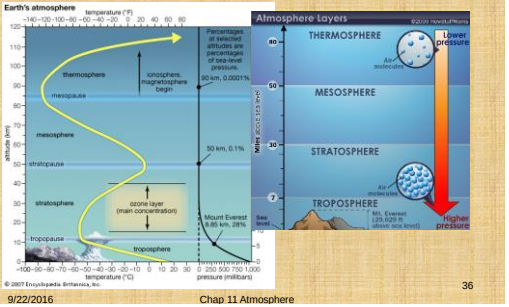


Air Pressure & Density

Temperature, Pressure and Density

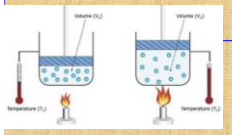
1. Both decrease as you move higher above the earth, because gravity is less
2. Less gravity means fewer air particles are pulled in, which means a decrease in pressure
3. This also means a decrease in temperature because there are fewer particles colliding
4. Both pressure & density increase closer towards Earth's surface because there are more molecules pulled in by gravity and pressing down on you.

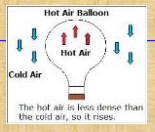


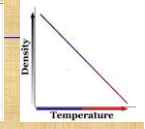


Temperature & Density

1. Remember: Temperature is the average speed of molecules
2. When temperature ↑, pressure ↑. Then density ↓ as the increased pressure causes molecules to spread out.
3. When temperature ↓, pressure ↓. Then density ↑ as the decreased pressure causes molecules to get closer.



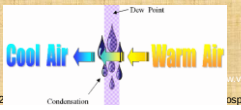




Dew Point, Lifted Condensation Level & Humidity

1. **Dew Point** = Temperature air needs to be cooled to until it can hold no more water
   - A. **Saturation**: The point where air holds as much water vapor as it can
   - B. At this point water will condense
   - C. **Condensation** is when matter changes state from a gas to a liquid
   - D. Dew Point is AKA "Condensation Point"
   - E. NOTE: **Dew ≠ rain** & **Cloud condensation ≠ rain**

VIDEO – show before Dew Point Lab
http://www.youtube.com/watch?v=brf5MXYCqog



Vertical Temperature Changes

2. Vertical Temperature Changes
   - A. In the troposphere, temperature decreases with altitude
   - B. Warm air rises until it reaches cooler atmosphere with the temperature of its dew point (condensation point)
   - C. Lifted Condensation Level (LCL) is the altitude where condensation occurs.
     - i. It is level with the bottom of clouds.
     - ii. Clouds form when water vapor condenses
     - iii. See Fig. 11-8, p. 279

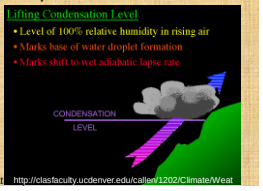
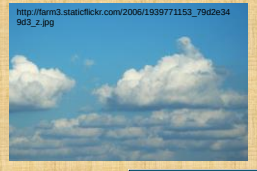
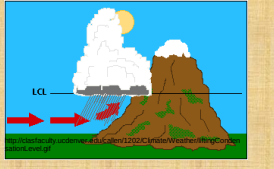


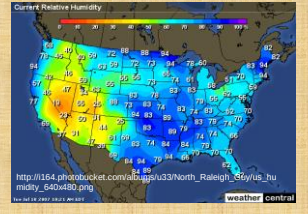
Fig 11-8 Lifted Condensation Level





Humidity vs. Relative Humidity

3. **Humidity vs. Relative Humidity**
   - A. Humidity is the ACTUAL/Absolute amount of water vapor in the air
   - B. Relative humidity is a ratio comparing the humidity (ACTUAL/Absolute amount) to how much water vapor the air is CAPABLE of holding

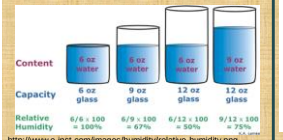


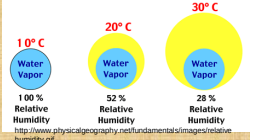
Humidity vs. Relative Humidity - Continued

i. **Warm** air can hold more water vapor
ii. **Cold** air is capable of holding less water vapor
iii. Relative humidity is expressed as percentage
   - ➢ 100% relative humidity = saturation
   - ➢ Equation:

   Relative Humidity = Actual Humidity ÷ Capacity x 100%

iv. Relative humidity percentage is related to the probability of cloud formation & precipitation





Relative Humidity Calculation Practice

Temp °C	Water Vapor Capacity (g/m^3)
0	5
10	9
25	23
40	51

1. Air at 25C contains 15g water vapor. What is its relative humidity? Show your work.
2. Air at 40C contains 15g water vapor. What is its relative humidity? Show work.
3. If a sample of air contains 9g of water vapor, what is its dew point?

Relative Humidity Table (wet/dry bulb method) Psychrometer Table Practice

Dry Bulb (°C)	Wet Bulb depression (°C) 0	1	2	3	4	5	6	7	8	9	10	12	14
2	99%+	84%	68%	52%	37%	22%	8%						
4	99%+	85%	70%	56%	42%	29%	26%	3%					
6	99%+	86%	73%	60%	47%	34%	22%	11%					
8	99%+	87%	75%	63%	51%	39%	28%	18%	7%				
10	99%+	88%	76%	65%	54%	44%	33%	23%	14%	4%			
12	99%+	89%	78%	67%	57%	47%	38%	29%	20%	11%	3%		

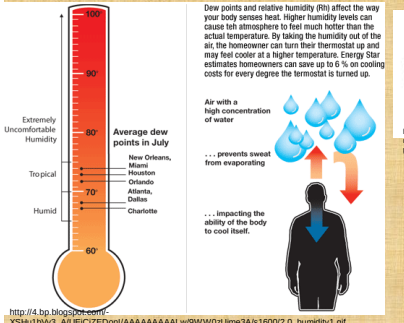
Background: Quickly Demo/Discuss a Psychrometer for tonight's Pre-Lab.

NOTE: Your table tonight does NOT have % sign, but is still relative humidity%.

Wet-bulb depression = Temp dry bulb – Temp wet bulb

1. Using the table above: After slinging the psychrometer 50 times, the Dry-bulb temperature was 10C and the Wet-bulb reading was 7C. Using the table above, what is its relative humidity?
2. If the dry bulb was 12C and the wet bulb was 1C, what is its relative humidity?
3. If both thermometers had the same temperature what would the relative humidity be?

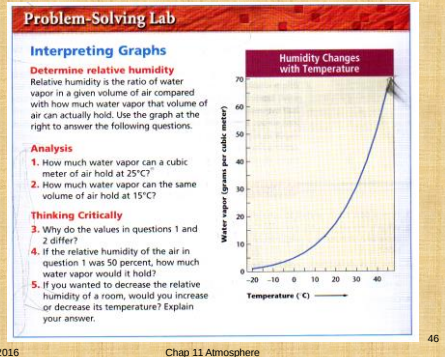
Why Does a Humid Day Feel So Warm?



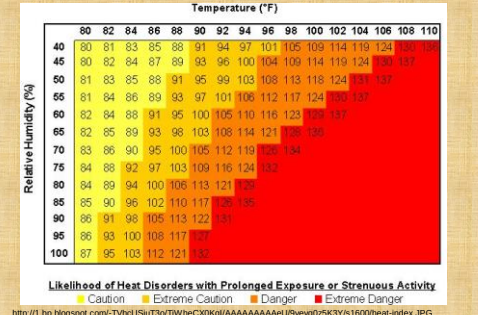
http://stalewidemn.files.wordpress.com/2009/08/heat_humidity_sticker_p217235008092483348qz1_400.jpg

http://4.bp.blogspot.com/-XSHu1bVv3_A/UEjCjZEDonI/AAAAAAAAALw/9WW0zUime3A/s1600/2.0_humidity1.gif

PSL p.283: Humidty Changes w/Temp



Humidity & Heat Index

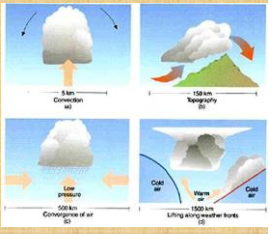


http://1.bp.blogspot.com/-TVhcUSiuT3o/TiWheCX0KqI/AAAAAAAAAeU/9vevq0z5K3Y/s1600/heat-index.JPG

Section 11.3: Moisture in the Atmosphere

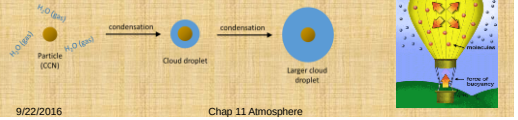
Cloud Formation: Requires 3 things:

1. Water vapor
2. Condensation nuclei
3. Lifting mechanism



Section 11.3: Moisture in the Atmosphere

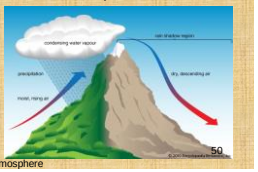
1. **Water vapor**
   A. Clouds form when moist warm air rises, then cools & condenses at the LCL
   B. Buoyancy is the tendency to rise or sink due to density differences
2. **Condensation Nuclei** are small particles in the atmosphere that water droplets condense on, forming clouds
   A. Examples: Dust, salt, smoke particles
   B. As air reaches area with temperature of its dew point, water vapor condenses on the nuclei



Lift Mechanisms

3. **Lift mechanisms:**
   - Warm, moist air does expand and rise, but to quickly form clouds, the warm, moist air must be forced upward faster than convection can carry it.
   - **There are 2 main Lift Mechanisms:

1st Method: **Orographic lifting =** Lifting when wind encounters a mountain and has nowhere to go but up
   A. Air rises until it hits condensation temperature at the LCL & clouds form
   ***Notice the difference in plant growth on the 2 sides of the mountain



Lift Mechanisms Cont'd…

2nd Method: **Frontal** Wedging = Lifting when two air masses of different temperatures collide
   A. Cold air is very dense, therefore the warm air is forced up.
   B. Warmer air mass is less dense and rises. Clouds form when the warm air reaches its dew point temperature at its LCL

Video – Bill Nye Condensation (AFTER Cloud Formation Lab)

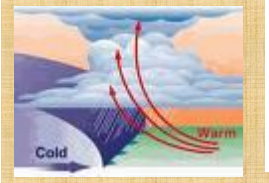
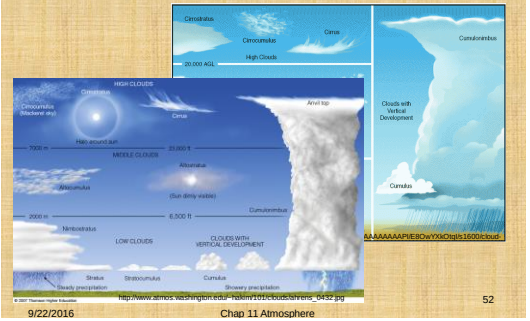


Fig 11-13 p286: Lift Mechanisms

Types of Clouds There are many types of clouds. You are responsible for **five** types which can be differentiated based on their shape and appearance.



Cloud Descriptions

1. **Cirrus -** Wispy. Very high in the sky. Looks stringy, wispy, curled up at end. "Like hair".
2. **Cumulus** = Puffy & lumpy. Looks like cotton balls or popcorn
3. **Stratus** = "Stretched" into "layer" . Continuous cloud. Looks like a sheet or blanket.

4. Cumulonimbus

A. It is a special storm cloud AKA "thunderhead"
B. It is a "Vertical Development Cloud". Develops and reaches through **all altitudes from low to high** in the troposphere.
C. Top has ice crystals
D. Strong winds give the top an anvil shape
E. Capable of strong rains and winds, thunderstorms

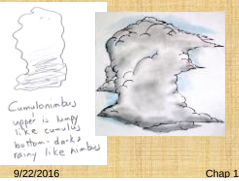
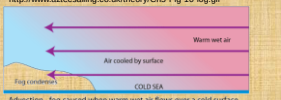


Fig 11-14 p. 288 Types of Clouds

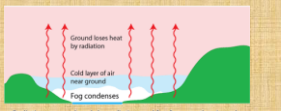
Fog

5. **Fog** =Stratus cloud that forms when the dew point of water vapor is reached close to Earth's surface
   - Many mechanisms can cause fog. We'll discuss two in class that can cause this cooling close to ground.

http://www.aztecsailing.co.uk/theory/Ch5-Fig-10-fog.gif



Advection - fog caused when warm wet air flows over a cold surface

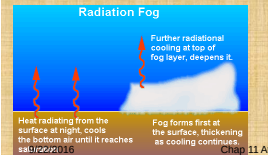


Radiation - ground cools by radiation, and fog forms as the air cools

1st Method: Radiation Fog

Radiation Fog – occurs on land on **cool/clear/calm nights**

A. Type of fog in Iowa
B. Heat (infrared radiation) from earth's surface is lost to space with no clouds to trap it.
C. Air next to ground cools, becomes saturated & condenses
D. Fog goes away quickly when sun comes up. Why? _____

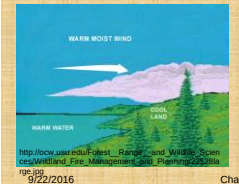


http://www.nebraskaweatherphotos.org/Dsc_0178d7 000sm5.jpg

2nd Fog Method: Advection Fog

Advection Fog– Moist warm ocean air moves over cold land

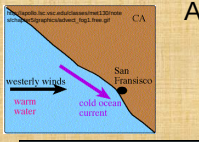
A. Occurs along coastal areas
B. Ocean stays warmer than land at night
C. Moist warm air from ocean moves the cooler land.
D. The air cools, becomes saturated & condenses
E. Fog goes away quickly when sun comes up. Why? _____

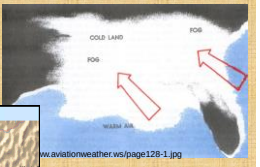


http://iocw.usu.edu/Forest_Range_and_Wildlife_Sciences/Wildland_Fire_Management_and_Planning/2052bla rge.jpg

http://4warmwxteam.files.wordpress.com/2011/04/advection-fog.jpg

Advection Fog Continued





http://www.aviationweather.ws/page128-1.jpg

http://home.comcast.net/~rhaberlin/images/atpptfg.gif

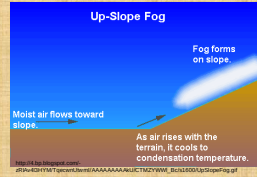
Fog Differences & Other Types

- Stationary vs. Horizontal Movement
- Cooling Mechanism
- Fog Video: https://www.youtube.com/watch?v=PsvtJ8DQiHg

http://www.aztecsailing.co.uk/theory/Ch5-Fig-10-fog.gif

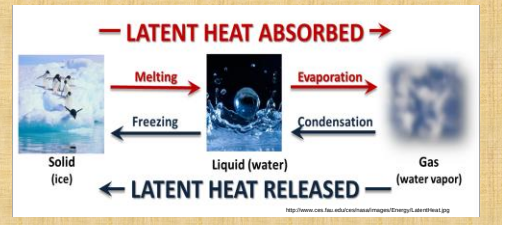
Advection - fog caused when warm wet air flows over a cold surface

Radiation - ground cools by radiation, and fog forms as the air cools



Latent Heat

Latent heat: the energy absorbed by or released from a substance during a phase change from a gas to a liquid or a solid or vice versa



http://www.ces.fau.edu/ces/nasa/images/EnergyLatentHeat.jpg

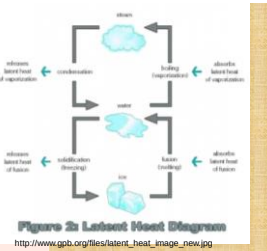
Latent Heat & Evaporation

1. **Evaporation:** For liquid water to change to vapor, energy must be absorbed (added)
   - A. Energy is needed to spread out the molecules into the less dense vapor (gas)
   - B. Example: you must heat water to cause boiling & evaporation
   - C. The absorbed (added) energy is stored in the water vapor

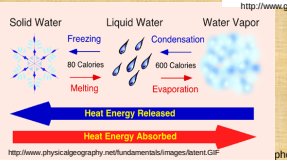
http://thecollegiatecooker.files.wordpress.com/2013/08/boiling_water.jpg

http://www.aboutcivil.org/imajes/evaporation.jpg

Evaporation vs. Condensation Opposites in Latent Heat



http://www.gpb.org/files/latent_heat_image_new.jpg



http://www.physicalgeography.net/fundamentals/images/latent.GIF

Latent Heat – Condensation & Cloud Formation

3. **Condensation & Cloud Formation:** Latent Heat energy is released when condensation occurs
   - A. Condensation = Phase change from water vapor (gas) to liquid water
   - B. For molecules to slow down and come closer together, latent heat energy is released (given off) during condensation
   - C. This released **heat** energy warms the atmosphere around the forming cloud, causing air to continue to rise.
   - D. If lots of condensation & cloud formation occur, the latent heat energy heats the atmosphere & causes air to keep rising & more clouds to form.

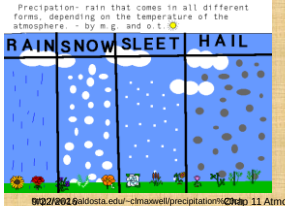
http://wallpoper.com/images/00/24/89/79/drops-condensation_00248979.jpg

http://ts4.mm.bing.net/th?id=HN.607989901381142235&pid=15.1&P=0

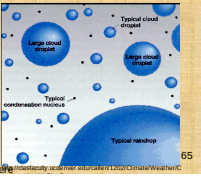
http://ts3.mm.bing.net/th?id=HN.608040143904441302&pid=15.1&P=0

Precipitation

1. Includes all forms of water, both liquid and solid, that fall from the sky
   - A. Rain, snow, sleet, hail, etc.
   - B. Caused by collision-coalescence: the formation of larger droplets as small cloud droplets collide and join together
   - C. Droplet finally becomes too heavy and gravity pulls it to Earth as precipitation

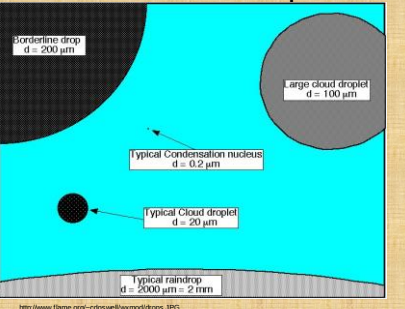


http://www.valdosta.edu/~clmaxwell/precipitation%20



http://classfaculty.ucdenver.edu/carle/1202/Climate/WeatherC

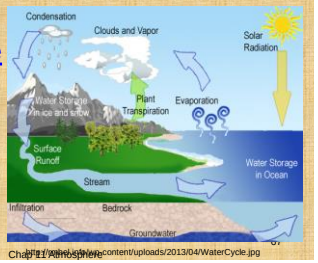
Actual Size? Of Nuclei & Raindrops?



http://www.flame.org/~cdoswell/wxmod/drops.JPG

1. Is the constant movement of water between the atmosphere and Earth's surface
2. The total amount of water on Earth has been constant for millions of years:
   A. 97% salt water
   B. 3% fresh water, and 2/3 of fresh water is frozen in the polar ice caps

The Water Cycle

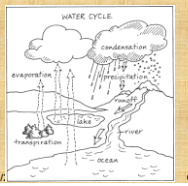


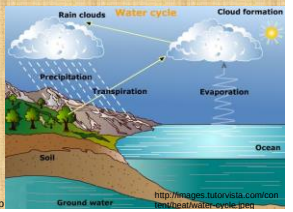
http://pbhol.info/wp-content/uploads/2013/04/WaterCycle.jpg

Steps of the Water Cycle

1. Evaporation: Adds water to atmosphere through the process of changing from liquid to gas
   - What is Evapotranspiration? Evaporation & water loss from plants
2. Condensation: Cloud formation due to cooling as air rises in convection cycle
3. Precipitation: Returns to earth's surface

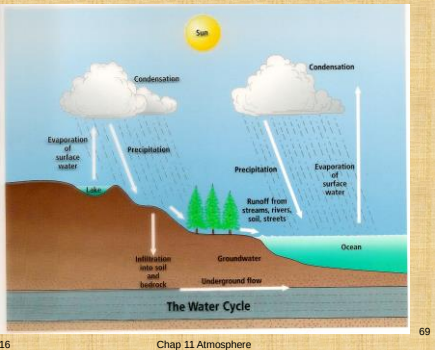
The Cycle then repeats





http://images.tutorvista.com/content/beat/water-cycle.jpeg

TT #30 The Water Cycle



Cloud Formative Assessment

A

B

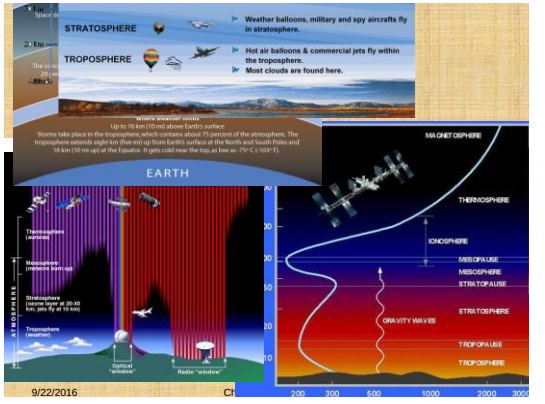
C

D

- What type of cloud is Cloud A? B? C? D?

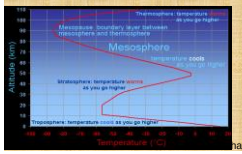
Study Tips

1. Textbook reading
   A. Objectives at the beginning of this note outline and of each textbook section
   B. Vocab words: italicized at the beginning of each section, and bold throughout text
   C. Questions at the end of each section and at the end of the chapter
   D. Summary page at end of chapter
2. Notes and worksheets from class
3. Take an on-line quiz. Go to the link on my webpage, or to the link below.
   A. http://www.glencoe.com/sec/science/earthscience/index.html
   B. Chapter Resources
   C. Unit 4
   D. Chapter 11
   E. On-line Study Tools
   F. Select either online quiz, or interactive tutor (game)



3. Mesosphere: 3rd Layer from Earth

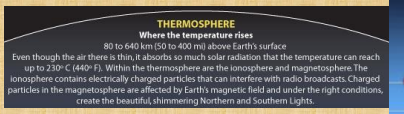
A. 2 reasons temp decreases with altitude:
   A. **Like Troposphere: Less gravity means fewer particles & fewer collisions so lower temperature**
   B. No ozone or anything else that can absorb solar energy ** Does NOT absorb ANY solar energy
B. Therefore, the temperature decreases with altitude
C. The top = the mesopause (Boundary between the Mesosphere & the next layer
D. Uniqueness:
   - "Shooting stars" seen here as meteorites burn up in this layer



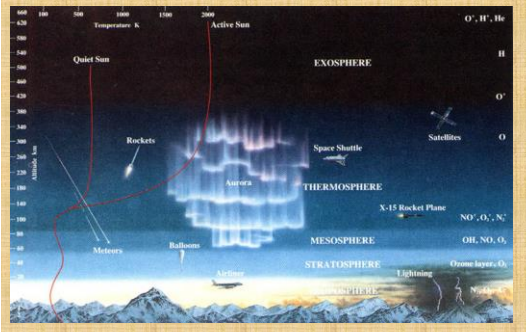
4. Thermosphere: 4th Layer from Earth.

Is the last "main" layer of the atmosphere – the one furthest away.

A. Very little mass
B. Temperature increases with altitude, 1000ºC!
   - Heated because it contains the ionosphere, a "sublayer" with electrically charged particles (ions)
   - Heated as absorbs & protects from high energy X-ray & Gamma radiation
C. Contains the fewest molecules and therefore has the smallest mass



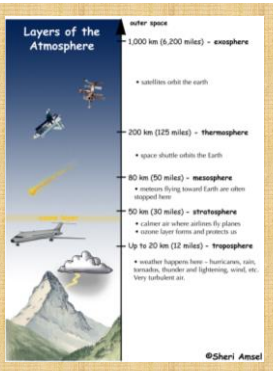
4. Thermosphere: Cont'd



5. Exosphere

Beyond the Thermosphere, the atmosphere thins until it disappears into space. This area is called the Exosphere.

A. Light gases are present: H2 and He which are the 2 main gases in the universe
B. Above this is outer space



4. Thermosphere: Cont'd

E. Uniqueness:
   - Aurora Borealis/Norther Lights happen here when there is a solar storm that energizes the ionosphere