Global Temperature Learning Module

Source

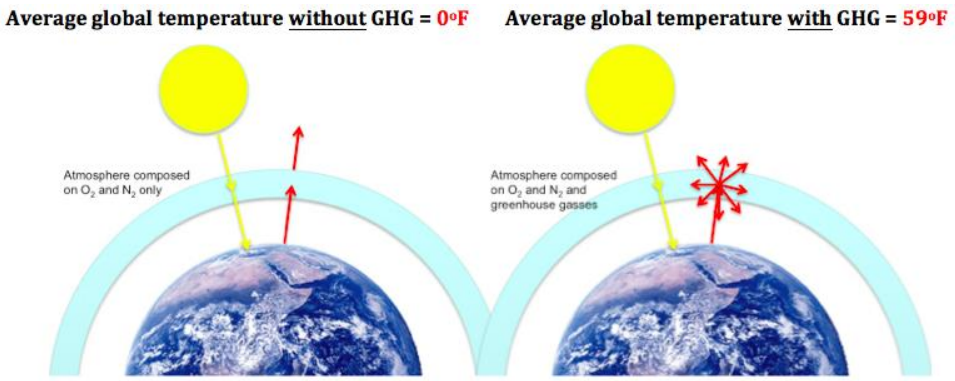
The very thin layer of gases surrounding our planet makes life possible on Earth. Without it, Earth may have looked more like the Moon or Mars. Earth is the only habitable planet we have discovered and in this video, you will gain some perspective on why life is possible on Earth.

Earth's Atmosphere (7:30)

Composition of Earth's Atmosphere

Imagine the planet as an apple; the atmosphere would be the equivalent thickness of the skin. Within this thin layer of gases, we find some amazing weather! The video lecture below will describe the composition of the atmosphere and explain how the gases in the Earth's atmosphere keep our planet warm.

Composition of Earth's Atmosphere (6:12)



Source

- *Left*: All gases are nearly transparent to the Sun's peak energy output (visible light: shown in yellow) and specifically, O_2 and N_2 are nearly transparent to the Earth's peak energy output (thermal infrared energy: shown in red).
- *Right*: On the other hand, greenhouse gases (shown in blue) are only transparent to the Sun's incoming visible light energy and allow it to pass through to Earth's surface, while GHGs absorb the outgoing thermal infrared energy that is emitted from Earth. This natural process warms the atmosphere and allows Earth to be inhabited.

Created by Tyra Brown, Nicole Riemer, Eric Snodgrass and Anna Ortiz at the University of Illinois at Urbana-Champaign. 2015-2016. Supported by the National Science Foundation CAREER Grant #1254428.

Video Lecture Notes 1

- Atmospheric air pressure and density decrease rapidly with height to the top of the atmosphere (120 km, 75 miles).
- 99% of our atmosphere is made of oxygen (O_2) at 21% and 78% nitrogen (N_2). These gases are transparent to both visible light from the sun and thermal infrared light from the earth.
- **Greenhouse gases**, like water vapor, carbon dioxide and methane, are vitally important for keeping our planet warm. Without greenhouse gases, the globally averaged temperature is 0°F. Although these gases are found in small concentrations, they are vitally important in maintaining a globally averaged temperature of 59°F.

Defining Air Temperature

Temperature is a measure of the average speed of all of the molecules in a substance (gas, liquid, or solid). The higher the air temperature, the faster the air molecules move. The faster they move, the more space is needed to move around. Therefore, warming the air will cause it to expand and cooling the air will cause it to contract. This is why warm air is less dense than cold air and what allows hot air balloons to fly! The first video lecture will describe how temperature is measured and look at some extremes of temperature. The second video lecture will finish with one of the most fundamental relationships in all of atmosphere science – the relationship between air temperature and air density!

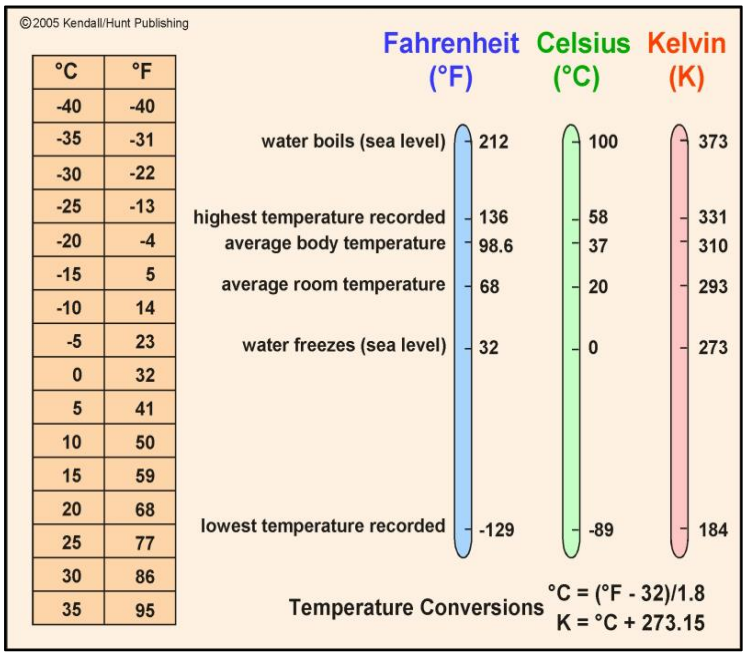
Source

Measuring Temperature (7:53)

Relating Temperature and Density (4:19)

Video Lecture Notes 2

- **Temperature** is a measure of the average speed of all the molecules in a substance.
- Air temperature is measured with a **thermometer** and there are three primary scales—Fahrenheit, Celsius, and Kelvin.
- The hottest the air temperature has ever been is 134°F and the coldest is -129°F.
- The higher the air temperature, the faster the air molecules move.
- Warming the air will cause it to expand and cooling the air will cause it to contract. This is why warm air is less dense than cold air.
- If you ever wanted to know what it is like to live in Antarctica where the temperatures often dip below -100°F, check out ***this video***.
- ***Link to the story*** about the record high temperature in Libya.

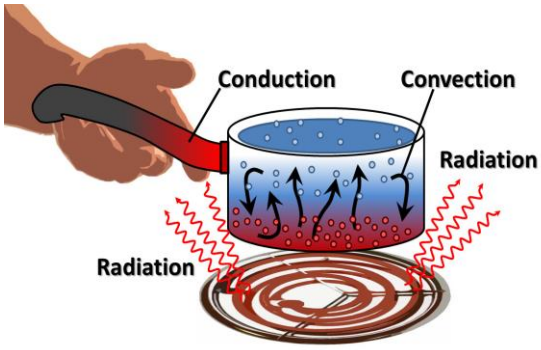


Source

Heat Transfer

Heat may be transferred by three methods: radiation, conduction, and convection. **Radiation** is the transfer of heat by a heat source, like how the pot is heated by the stovetop burner in the figure below. **Conduction** is the transfer of heat within a substance, like how the heat is transferred from the bottom of the pot to the handle because metal is good conductor. **Convection** is the transfer of heat by the movement of a fluid, such as water or air. Convection occurs in the pot as the water boils. The stove heats the water in the bottom of the pan causing the warmer water to become less dense and rise toward the top of the pot and the cooler, denser water at the top to sinks to the bottom.

In the atmosphere, radiation occurs when the sun heats the ground. The ground then heats the air closest to the surface through conduction. The warm air begins to expand, becomes less dense and begins to rise, which begins the process of convection. In this example, the sun and ground are the sources of heat transfer [2].



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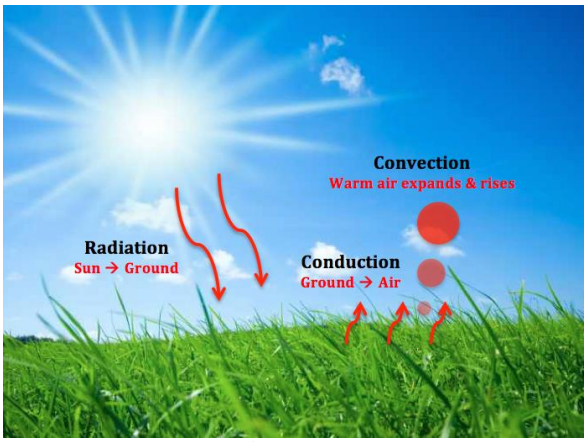
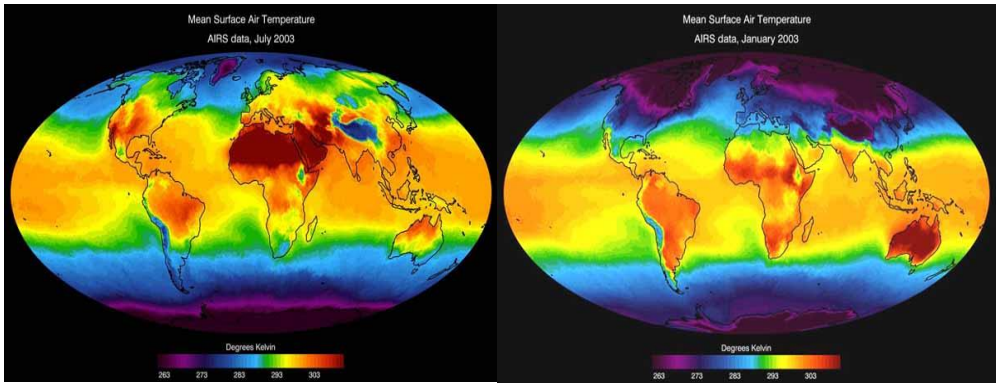


Source

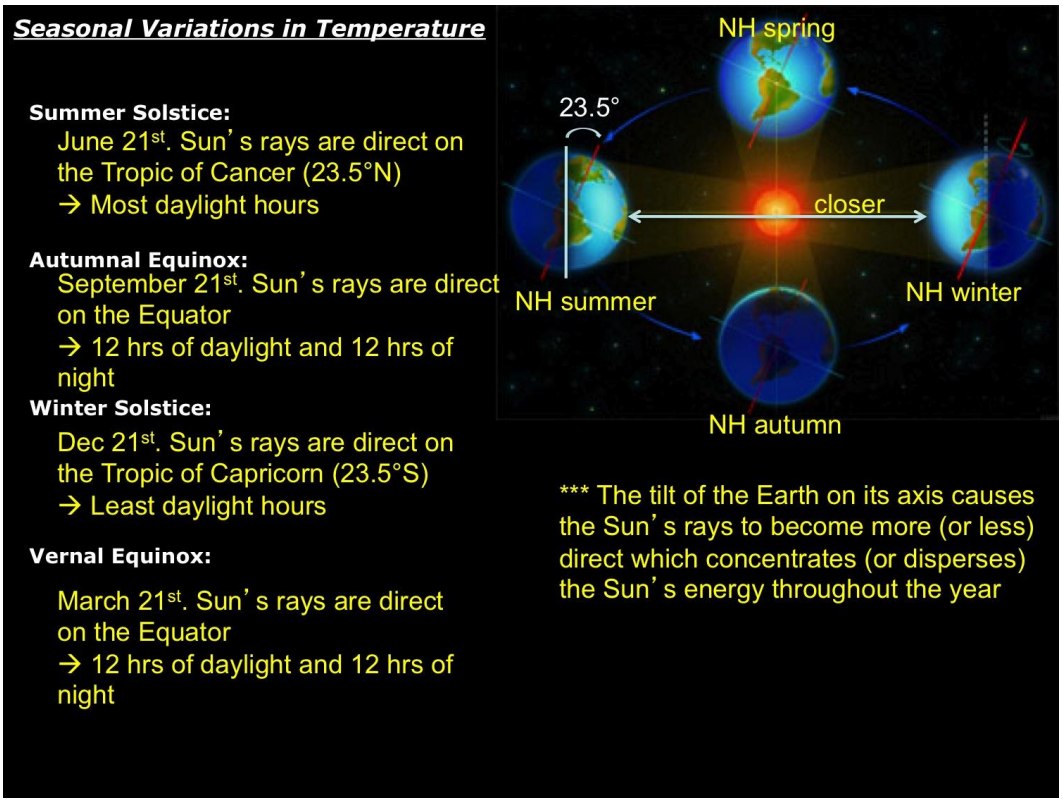
Global Temperature Variations

In the next video, you will learn what causes Earth to have changes in season and such a large range of air temperature.

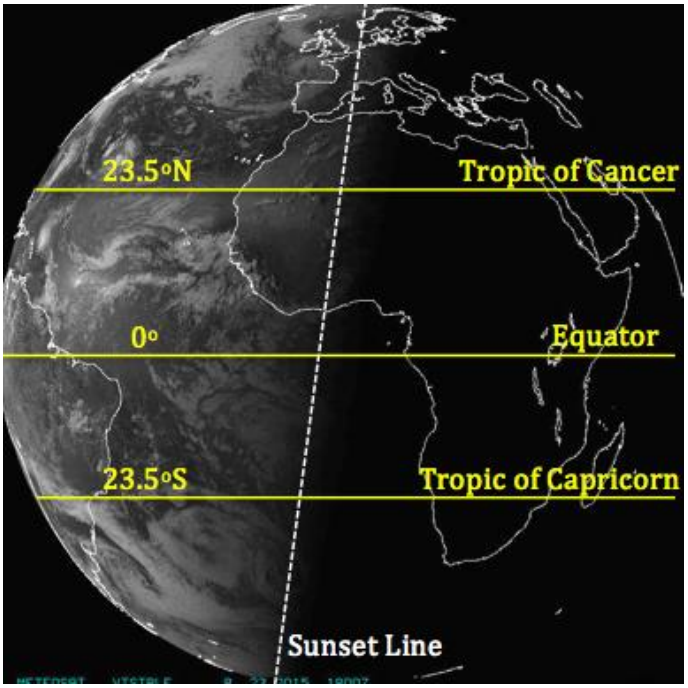
Earth's Seasons (15:58)



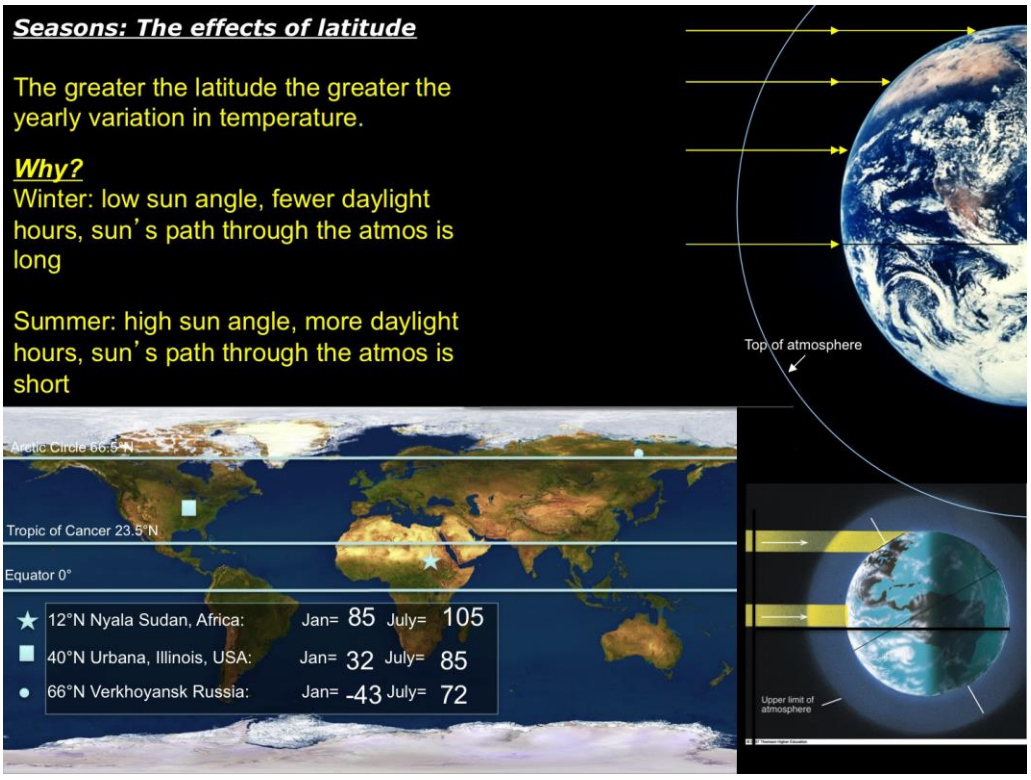
Globally averaged surface air temperature for July (left) and January (right).
Source



Seasonal variations in temperature at the solstices and equinoxes.
Source



Sunset occurring over Africa on August 23, 2015.
Source



The effects of latitude on seasonal temperature variations.
Source

Video Lecture Notes [3, 4]

- The Earth is not flat.
- Uneven surface heating drives atmospheric circulations (i.e., the weather). There are two reasons why Earth has such a large range in temperature:
  1. The directness of the Sun's rays and the length of daylight hours are not constant.
  2. The Earth is covered with many different surface types that absorb energy differently.

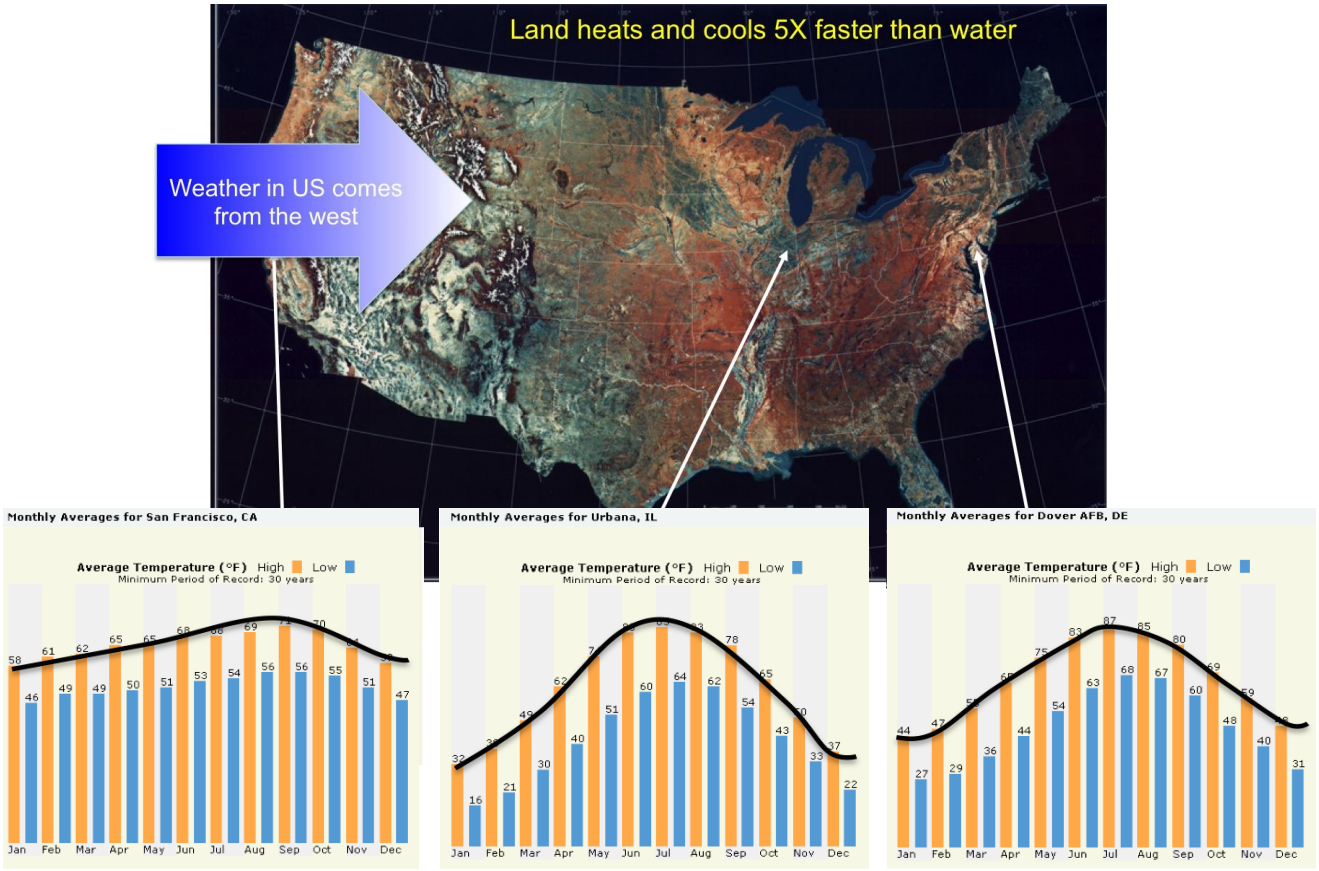
- The Earth has seasons because it is tilted on its axis. The tilt of the Earth on its axis causes the Sun's rays to become more (or less) direct, which concentrates (or disperses) the Sun's energy throughout the year. Four important dates to remember:
  1. **Summer Solstice**: June 21. The Sun's rays are shining directly on the Tropic of Cancer (23.5°N). Most daylight hours in the Northern Hemisphere (NH).
  2. **Autumnal Equinox**: September 21. The Sun's rays are shining directly on the Equator. Every location on Earth has 12 hours of daylight and 12 hours of night.
  3. **Winter Solstice**: December 21. The Sun's rays are shining directly on the Tropic of Capricorn (23.5°S). Most daylight hours in the Southern Hemisphere (SH).
  4. **Vernal Equinox**: March 21. The Sun's rays are shining directly on the Equator. Every location on Earth has 12 hours of daylight and 12 hours of night.

- As latitude increases, yearly variation in air temperature also increases. Why?
  - Winter: low sun angle, fewer daylight hours, sun's path through the atmosphere is long
  - Summer: high sun angle, more daylight hours, sun's path through the atmosphere

Controls of Temperature

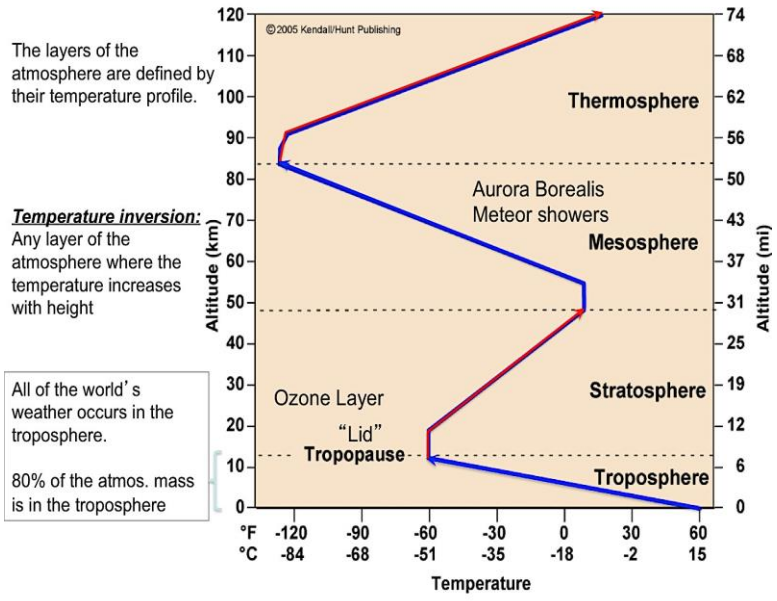
In this last video on air temperature, we will look at the influence that large bodies of water have on the climate of coastal cities. To finish, we will find how air temperature changes with height in the atmosphere and how we use this change to define the four layers of the atmosphere.

Controls of Temperature and Layers of the Atmosphere (8:52)



Annual Temperature Fluctuations for San Francisco, CA, Urbana, IL, and Dover, DE
Source

Vertical Temperature Variations



Source

Video Lecture Notes [4]

- Land heats and cools five times faster than a large body of water. This property of water helps to moderate the climate of coastal locations and prevents them from experiencing large fluctuations in temperature throughout the year.

- The layers of the atmosphere are defined by air temperature. These layers are (from bottom to top):
    1. **Troposphere** (cools with height, includes all the weather)
    2. **Stratosphere** (warms with height, includes the ozone layer)
    3. **Mesosphere** (cools with height)
    4. **Thermosphere** (warms with height)

- The rate at which the atmospheric temperature decreases with altitude is the **environmental lapse rate**. The average environmental lapse rate is expressed as a change in temperature per change in height [5].

- **Temperature inversions** are any layers in the atmosphere where the air temperature increases with height.

Pre-Class Activity

Instructions: Before teaching about Earth's atmosphere and temperature, have the students answer the questions below, followed by the scenario question for in-class discussion between you and your students.

1. What causes the earth to experience seasons?
    a. The changing temperature of the sun
    b. The tilt of the earth's axis toward and away from the sun
    c. The rotation of the earth
    d. The changing temperature of the oceans

2. Which of the following is an example of a greenhouse gas?
    a. Oxygen
    b. Nitrogen
    c. Aerosols
    d. Carbon dioxide
    e. Lithium

3. Which of the following is the least dense?
    a. Warm and dry air
    b. Warm and moist air
    c. Cold and dry air
    d. Cold and moist air

4. Take a guess at what the world record hottest temperature is.
    a. 134°F
    b. 199°F
    c. 210°F
    d. 101°F
    e. 99°F

5. Take a guess at what the world record coldest temperature is.
    a. -129°F
    b. -50°F
    c. -156°F
    d. -45°F
    e. -87°F

Discussion Question: You are at Chicago O'Hare International Airport sitting at the window seat on a plane on the ground and it is raining. The plane takes off and rises to 30,000 feet. What do you think might happen to any raindrops remaining on your window? Explain why.

In-Class Activity

Part 1. Multiple Choice (Circle one)

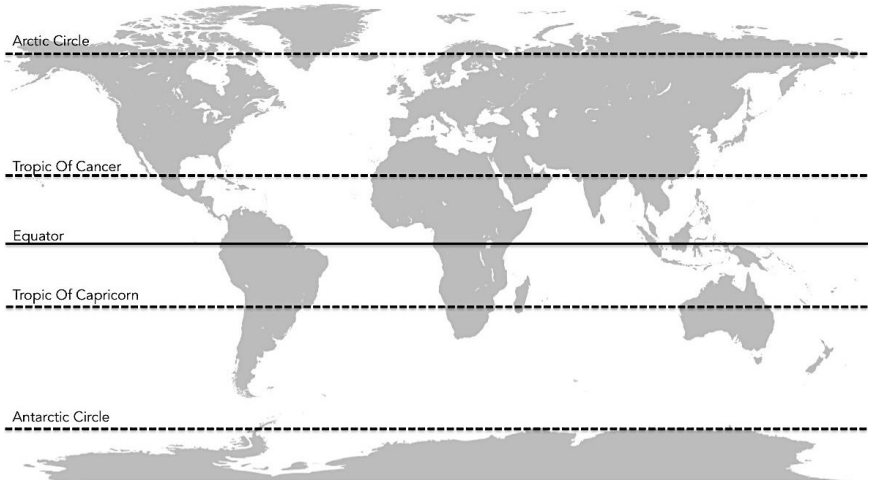
1. Which day of the year receives the most daylight hours in the Northern Hemisphere?
    a. March 21
    b. December 22
    c. July 21
    d. June 21

2. Which of the following gases is the most abundant in the earth's atmosphere?
    a. Oxygen
    b. Nitrogen
    c. Greenhouse gases
    d. Carbon Dioxide

3. Which city experiences the greatest temperature variation throughout the year?
    a. Los Angeles, CA
    b. Seattle, WA
    c. San Diego, CA
    d. Boston, MA

4. Which layer of the atmosphere contains all the world's weather and has the temperature cool with height?
    a. Tropopause
    b. Stratosphere
    c. Mesosphere
    d. Troposphere

5. At which latitude would you expect to have the largest yearly range in temperature?
    a. 5^{o}S
    b. 15^{o}N
    c. 40^{o}N
    d. 60^{o}N



Part 2. True/False (Circle one) 6

6. As the temperature increases, so does the speed of the air molecules. T F

7. Conduction is the process that allows hot air balloons to fly. T F

8. The Earth has seasons because the temperature of the sun changes drastically. T F

9. The sun heating the ground is an example of radiation. T F

10. A large body of water heats and cools five times faster than land. T F

Part 3. Calculation 7

1. The global average temperature is 59°F due to the presence of greenhouse gases in the atmosphere. Calculate the global average temperature in Celsius and Kelvin using the conversions provided below.

Temperature Conversions	°C = (°F - 32)/1.8 K = °C + 273.15

Temperature (°C) =	Temperature (K) =

Take Home Assignment

Part 1. Solar Angles 3

Instructions: Using the following link, calculate the solar elevation angle at your house for both solstices and both equinoxes. Next, calculate the solar angle on your birthday, your friend's birthday, and tomorrow (Be sure to write the dates of the birthdays).

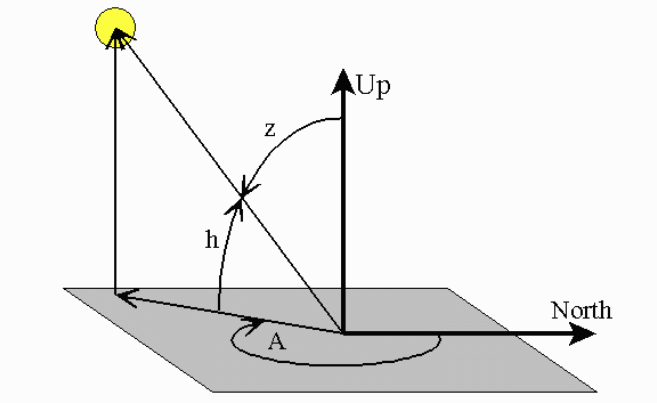
Solar Calculator

Use Google to find the latitude and longitude coordinates of your home to the nearest whole number (record below). Both values should be positive when you enter them into the solar position calculator. In the second box, enter the dates (you may leave the time as it appears).

Location: Latitude _____ Longitude _____

	Solar Elevation Angle
Winter Solstice	
Vernal Equinox	
Summer Solstice	
Autumnal Equinox	

Date	Solar Angle (Azimuth)
Birthday:	
Friend's Birthday:	
Tomorrow	



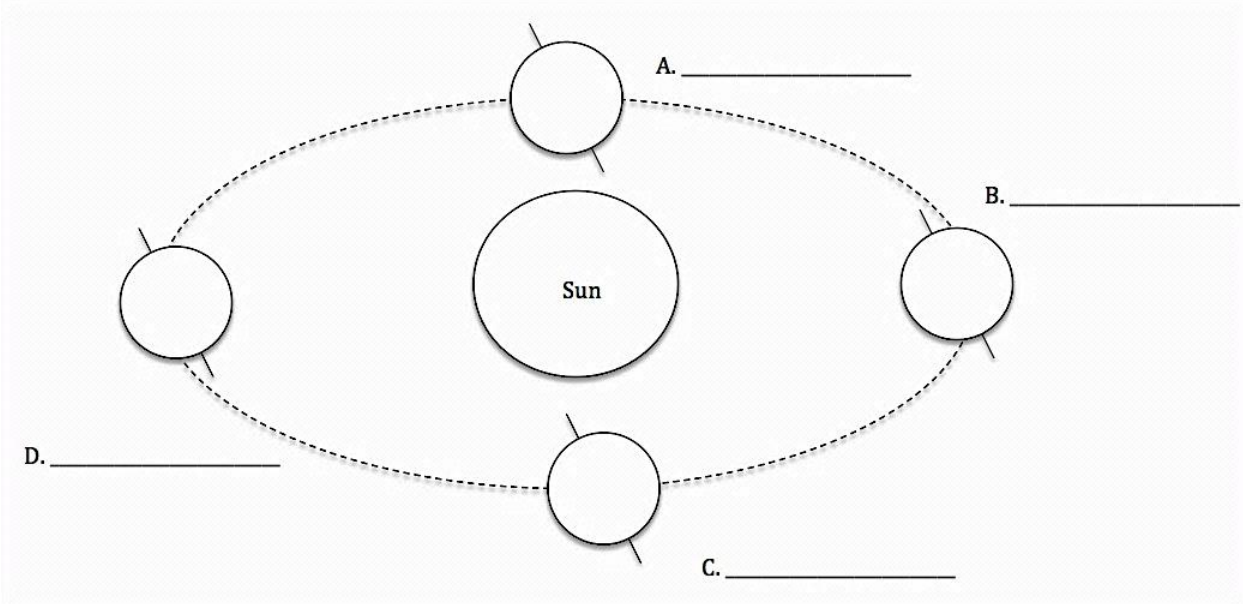
h = elevation angle, measured up from horizon

z = zenith angle, measured from vertical

A = Azimuth angle, measured clockwise from North

Part 2. Earth's Seasons [3]

Instructions: Using the diagram below, label the earth's equinoxes and solstices and answer the following questions about Earth's seasons.



6. What causes the Earth's seasons?

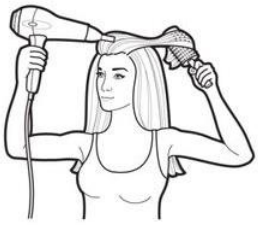
7. At which two points are the sun's ray directly on the Equator?
   a. A and B
   b. B and C
   c. A and C
   d. B and D

8. At which point does the Northern Hemisphere receive the most daylight?
   a. A
   b. B
   c. C
   d. D

9. At which point does the Southern Hemisphere receive the most daylight?
   a. A
   b. B
   c. C
   d. D

Part 3. Heat Transfer [8]

Instructions: In each of the following examples, identify whether the heat is being transferred through conduction, convection, or radiation. Some may have two possible answers. Choose the answer that best fits the situation.



A blow dryer heating and drying hair

A_____

Warm air rising in a chimney from a hot fire

B_____

The sun melting Frosty the snowman

C_____

A hot frying pan cooking an egg

D_____

Burning your hand when you touch a hot stovetop

E_____

A flame heating the inside of a balloon causing it to rise

F_____

Student Evaluation

Instructions: After completing the lesson on temperature, please have the students answer the following questions below.

The map below shows the location of three U.S. cities (City A: Portland, OR, City B: Madison, WI, City C: Providence, RI). Using what you have learned about temperature, answer Question 1.

1. Which city experiences the warmest summers and coolest winters?
    a. City A (Portland, OR)
    b. City B (Madison, WI)
    c. City C (Providence, RI)

2. As air temperature increases,
    a. air molecules move faster and expand causing the air to become more dense.
    b. air molecules move faster and expand causing the air to become less dense.
    c. air molecules move slower and contract causing the air to become more dense.
    d. air molecules move slower and contract causing the air to become less dense.

3. The sun emits
    a. rainbows.
    b. visible light energy.
    c. thermal infrared energy.
    d. all wavelengths of radiative energy.

4. The earth emits
    a. conduction.
    b. visible light energy.
    c. thermal infrared energy.
    d. all wavelengths of radiative energy.

5. Which instrument measures temperature?
    a. Barometer
    b. Sling psychrometer
    c. Thermometer
    d. Anemometer

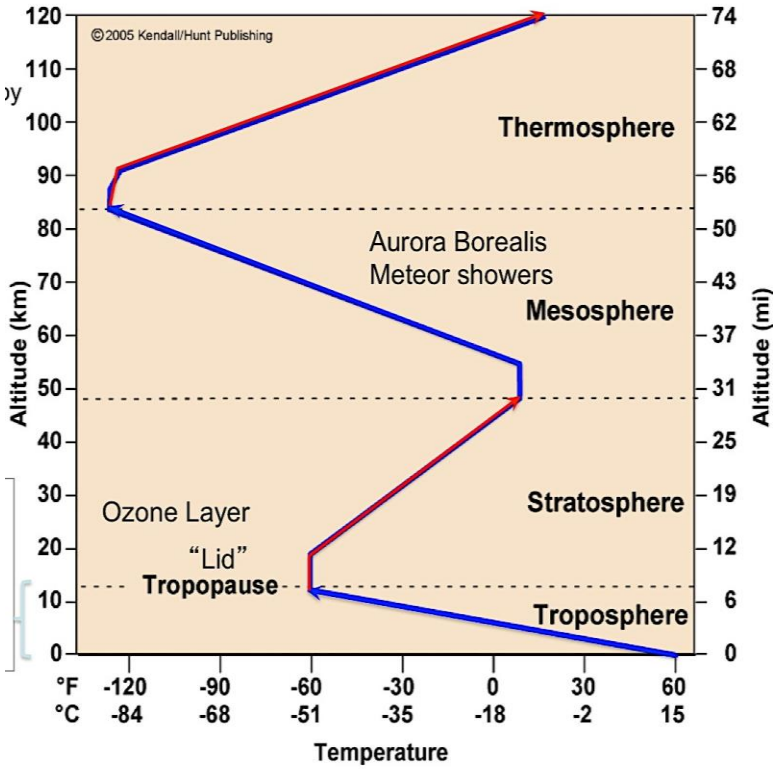
6. Which of the following is <u>not</u> a unit of temperature?
    a. Celsius
    b. Fahrenheit
    c. Temps
    d. Kelvin

7. How does latitude effect how temperature varies throughout the year?
    a. Locations at higher latitudes generally experience warmer temperatures.
    b. Locations at lower latitudes generally experience colder temperatures.
    c. The greater the latitude, the greater the yearly variation in temperature.
    d. The smaller the latitude, the greater the yearly variation in temperature.

8. Which is <u>not</u> true about summer in the Northern Hemisphere?
    a. There is a high sun angle.
    b. The sun's path through the atmosphere is shortest.
    c. There are fewer daylight hours.
    d. The sun's rays are direct on the Tropic of Cancer (23.5^{o}N).

9. Greenhouse gases such as carbon dioxide are vital to life on Earth. Currently, the global average temperature is 59^{o}F. What would happen to the global average temperature if the concentration of carbon dioxide were doubled?

The environmental lapse rate is defined as the rate at which the air temperature decreases with altitude. Determine the environmental lapse rate in the troposphere in degrees Celsius per kilometer. (Use the equation and chart below to determine the changes in temperature and altitude from the surface and the top of the troposphere.)



Change in Temperature (ºC) = ΔT = $T_{Surface} - T_{Top}$ = _____

Change in Altitude (km) = ΔA = $A_{Surface} - A_{Top}$ = _____

ELR = - (ΔT / ΔA) = _____

10. The environmental lapse rate in the troposphere is
    a. -6 ºC/km
    b. +6 ºC/km
    c. -10 ºC/km
    d. +10 ºF/km
    e. 3 ºC/km
    f. 3 ºF/km

Common Core State Standards (CCSS) Initiative
To learn more, visit http://www.corestandards.org

Next Generation Science Standards (NGSS)
To learn more, visit http://www.nextgenscience.org

The following standards are met in this learning module:

1. **NGSS.MS-PS4-2**

MS-PS4-2. Waves and Electromagnetic Radiation
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
Lecture: Composition of Earth's Atmosphere; Student Evaluation: Questions 3 & 4

2. **NGSS.MS-PS3.A**

MS-PS3.A. Definitions of Energy (Disciplinary Core Idea from MS-PS3-4)
Temperature is a measure of the average kinetic energy of particles of matter.
Lecture: Defining Air Temperature; Student Evaluation: Question 2

3. **NGSS.MS-ESS1-1**

MS-ESS1B. Earth and the Solar System (Disciplinary Core Idea from MS-ESS1-1)
Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
Lecture: Global Temperature Variations; Take Home Assignment: Parts 1 & 2; Student Evaluation: Questions 7 & 8

4. **NGSS.MS-ESS2-6**

MS-ESS2.D. Weather and Climate (Disciplinary Core Idea from MS-ESS2-6)
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
Lecture: Global Temperature Variations; Student Evaluation: Question 1

5. **CCSS.MATH.CONTENT.8.SP.A.3**

Grade 8: Statistics & Probability
Use the equation of a linear model to solve problems in the context of bivariate measurement data, interpreting the slope and intercept.
Lecture: Controls of Temperature

6. **CCSS.ELA-LITERACY.RST.6-8.8**

Grade 8: Science and Technical Subjects
Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
In-Class Activity: Part 2

7. **CCSS.MATH.CONTENT.7.NS.A.1.c.d**

Grade 7: The Number System
Apply properties of operations as strategies to add, subtract, multiply, and divide rational numbers.
In-Class Activity: Part 3

8. **NGSS.MS-PS3-4**

MS-PS3-4. Energy
Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of particles as measured by the temperature of the sample.
Take Home Assignment: Part 3

9. **NGSS.MS-ESS3-5**

MS-ESS3.D. Global Climate Change (Disciplinary Core Idea from MS-ESS3-5)
Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
Student Evaluation: Question 9

10. **CCSS.ELA-LITERACY.RST.6-8.4**

Grade 6-8: Science and Technical Subjects
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific science or technical context relevant to grades 6-8 texts and topics.
Lectures: Bolded text; Student Evaluation: Questions 5 & 6

11. **CCSS.ELA-LITERACY.RST.6-8.7**

Grade 6-8: Science and Technical Subjects
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
Video lectures