

# Atmospheric Measurements Learning Module



[Source](#)

Collecting atmospheric data is crucial for understanding the global climate and for forecasting the weather around the world. In this module, we will learn about the weather instruments that meteorologists use to measure temperature, moisture, pressure, wind speed, and rainfall. This module will also introduce how to use one of the oldest and most important weather instruments—the weather balloon. Finally, we will investigate two of the most highly advanced weather observation systems—radar and satellites.

Through the completion of this module, students should be able to identify all types of weather instruments, understand weather balloon data plotted on an atmospheric sounding, and analyze satellite and radar data to recognize features within weather systems such as hurricanes and thunderstorms.

## Measuring Temperature

**Temperature** is a measure of the average speed of all the molecules in a substance (solid, liquid, or a gas) **1**. Air temperature is measured with a thermometer. A **thermometer** is a glass tube with a narrow inner column filled with a liquid. As the temperature rises, the liquid inside is heated and expands toward the top of the column. It stops rising when it is the same temperature as the surrounding air that is being measured. A thermometer is read using the scale on the outside of the column, which tells us the temperature in **degrees Fahrenheit (°F)**, **Celsius (°C)**, or **Kelvin (K)**. Watch the following videos to learn more about measuring temperature!

[Measuring Temperature](#) (7:54)

[Reading a Thermometer](#) (1:34)

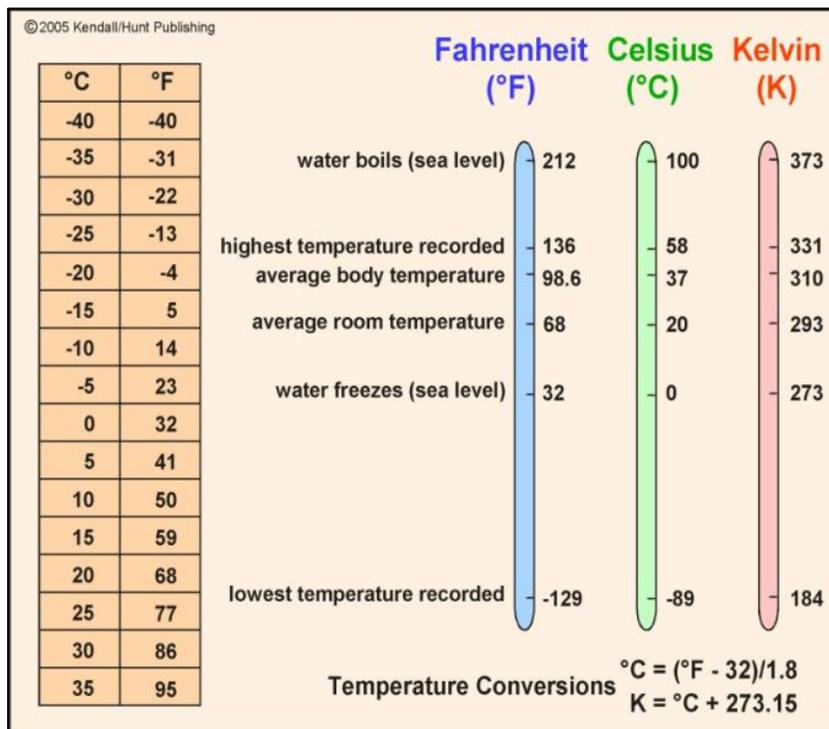


Figure 1. Temperature Scales

[Source](#)

## Measuring Moisture

Measuring water vapor and its concentration in the atmosphere is crucial for us to understand severe weather potential. To estimate the amount of water vapor, meteorologists use an instrument called a **hygrometer**. There are different types of hygrometers. The first was the hair hygrometer which uses human hair that is stretched between two clips connected to a lever and is connected to a marker that runs up and down on a cylinder to measure changes in relative humidity.

### [Measuring Moisture using Hygrometers](#) (0 - 3:00)

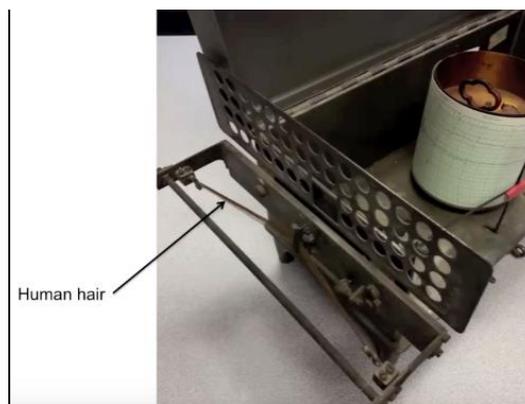


Figure 2. Hair Hygrometer

[Source](#)

Alternatively, it is common to use a psychrometer to measure the dewpoint temperature and relative humidity. A sling psychrometer consists of two thermometers. Initially, both thermometers will read the same air temperature. One of the thermometers is then given a wet wick around the bulb (wet bulb), while the other remains dry (dry bulb). The instrument is slung around in a circular path to increase the amount of evaporation and cool the wet bulb **11**. Evaporation will continue until the relative humidity of the wet bulb is in equilibrium with the surrounding relative humidity of the air. The temperature difference between the two thermometers is used to determine the dewpoint temperature and relative humidity by reading a chart.

### Measuring Moisture using Psychrometers (2:56)



Figure 3. Sling Psychrometers

[Source](#)

### **Video Lecture Notes** 2, 11

- Traditionally, a device used to measure changes in the relative humidity was the **hygrometer** (or hair hygrometer).
- Human hair is sensitive to changes in the amount of water vapor in the air.
- The more water vapor that is absorbed by the human hair, the longer it becomes and we can use that to determine the amount of water vapor in the atmosphere.
- A **psychrometer** (or sling psychrometer) is an alternative instrument to measure moisture and consists of two thermometers, one of which has a wet wick around its bulb (wet bulb) and the other that remains dry (dry bulb).
- By slinging the instrument around in a circular motion, the water evaporates off of the wick and removes heat from the thermometer. Evaporative cooling will continue on the wet bulb until the relative humidity of the wick is in equilibrium with the surrounding air.
- The temperature difference between the two thermometers is converted into a dewpoint temperature and relative humidity by a reading chart.

## Measuring Pressure

**Air pressure** is defined as the force per area applied by the air. Air pressure is measured using a **barometer**. There are three basic types of barometers: a liquid barometer, a mercury barometer, and an aneroid barometer. A **mercury barometer** consists of a large glass tube that has all the air evacuated from it to create a vacuum on the inside and stick it into a dish of mercury. That dish of mercury is open to the atmosphere. As soon as the tube that has the air evacuated from it goes into the dish, mercury goes shooting up on the inside until it reaches some equilibrium level. Under standard atmospheric pressure, the vacuum inside of that tube will allow the mercury to shoot up to 29.92 inches **3**.

Another common barometer is the **aneroid barometer**, which consists of a box made of a metallic material. As pressure changes, the box will change shape. By connecting a series of gears to a needle or pointer, as the box changes shape it causes the needle to move. Placing it on a dial allows the air pressure to be measured.

The most common units for pressure in atmospheric science are **inches of mercury (in of Hg)**, **millibars (mb)**, **pounds per square in (lbs/in<sup>2</sup>)**, and **atmospheres (atms)**. To learn more about how meteorologists measure air pressure, check out the videos below to learn about the history of the barometer and how pressure is related to weather!

[Barometers](#) (1:45)

[Measuring Air Pressure](#) (9:39)

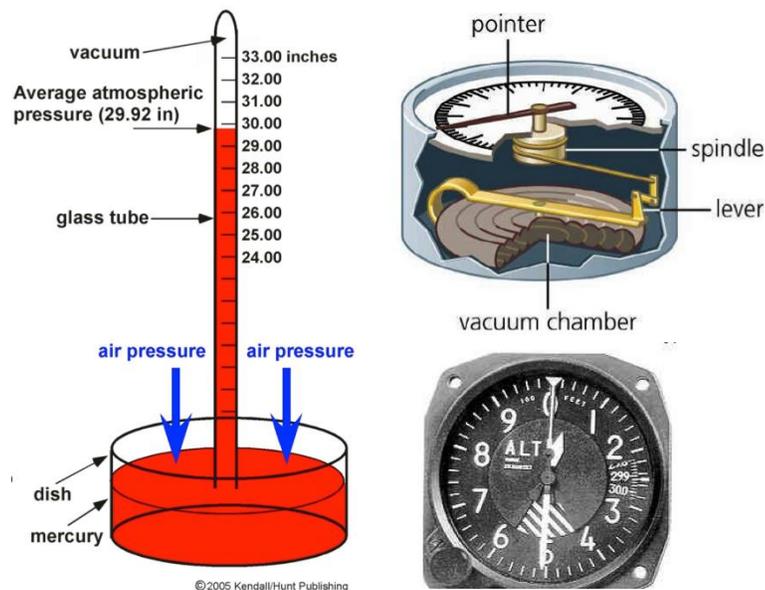


Figure 4. Types of Barometers

[Source](#)

## Measuring Wind

As we have learned in previous modules, the earth is a sphere and is unevenly heated by the sun. The wind blows as a result of this uneven heating of the earth's surface, which causes differences in air temperature and pressure. Because the atmosphere aims to achieve equilibrium or to be in balance with itself, the wind blows to restore balance of temperature and pressure across the globe <sup>4</sup>. The greater the temperature and pressure gradient in the atmosphere, the faster the wind blows. **Wind speed** is measured using an **anemometer**. The most common units for wind speed are **miles per hour (mph)** and **nautical miles per hour, or knots (kts)**.

**Wind direction** is defined as the direction in which the wind is blowing *from*. It is an important variable to measure to forecast the weather because it tells us where the weather is coming from. Additionally, a quick shift in wind direction often indicates the onset of interesting weather. Wind direction is determined using a **weather vane**. A **windmill anemometer** can measure both wind speed and direction. It is often used for atmospheric research to save space on data collection platforms. To see an example of an anemometer and weather vane, check out this video!

[Why the Wind Blows](#) (2:51)

[Measuring Wind Speed and Direction](#) (0:24)

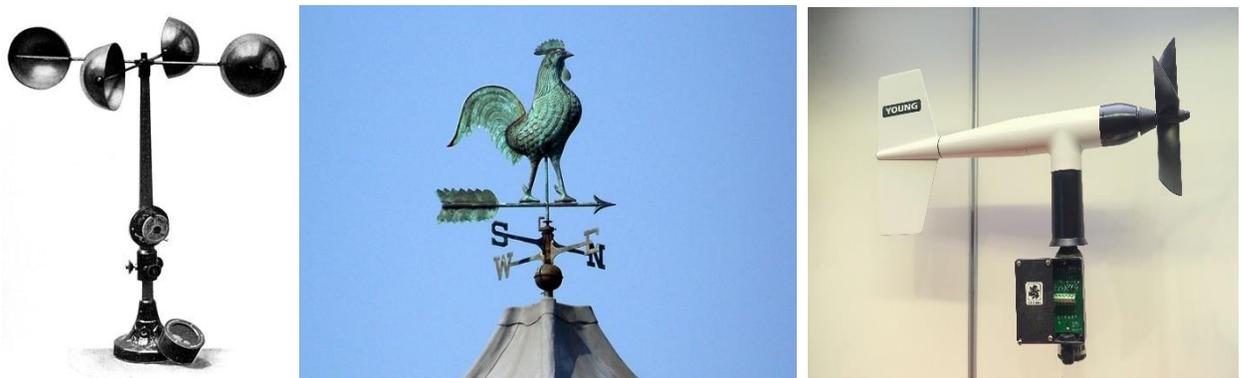


Figure 3. Left – Robinson cup anemometer [Source](#); Center – Traditional weather vane [Source](#); Right – Windmill anemometer [Source](#)

## Measuring Precipitation

Measurements of rainfall are crucial for monitoring agriculture, flooding, and even drought. Rainfall is measured using a cylindrical instrument called a **rain gauge**. A rain gauge measures the depth of the rain that has fallen over an area inside the cylinder. The lid of the rain gauge has a funnel to allow a large area to capture the rain and a smaller area to gain accurate measurements. To read a rain gauge, you should hold the cylinder level and look straight on at the scale. Typical units of rainfall are **inches (in)**, **millimeters (mm)**, and **centimeters (cm)**.

[Measuring Rainfall](#) (4:43)



[Source](#)

[Source](#)

*Figure 4. Rain Gauges*

## Introduction to Satellites

Satellite observations of the Earth and its weather systems have revolutionized our ability to observe and predict the weather. In these videos, we will learn about the origins of satellite observations and see an example of why satellites are so important to observing the weather around the globe.

[Satellites](#) (2:52)

[Hurricane Sandy \(2012\)](#) (3:05)



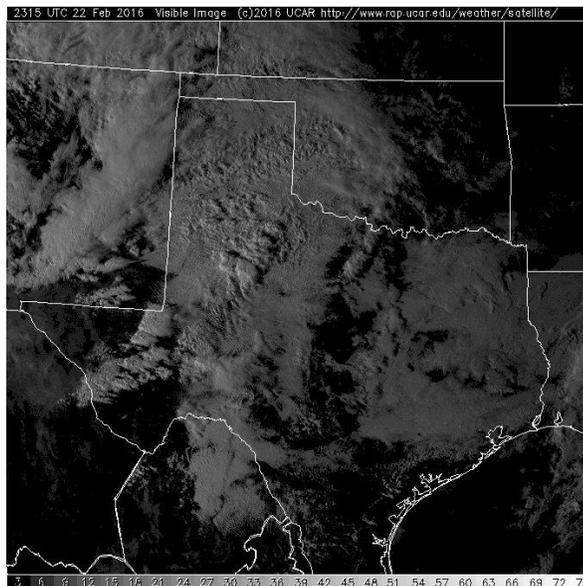
Figure 5. Satellite

[Source](#)

## Satellite Channels

A **satellite channel** is defined as a range in wavelength of light that the satellite's cameras are sensitive to [5](#). The three main channels that are used are visible, thermal infrared, and water vapor. The videos below explain each channel and what information can be gained by looking at these images.

### [Visible Satellite Imagery](#) (2:18)



## Infrared Satellite Imagery (9:32)

### Satellite Channels: Infrared Imagery

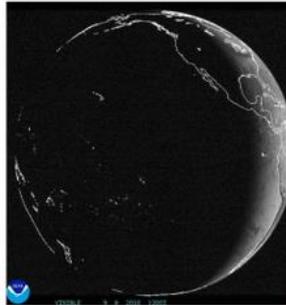
→ Measures: emitted IR radiation  
Measures the temperature of an object

→ Bright = cold objects  
high clouds like the tops of t-storms and  
high thin cirrus clouds

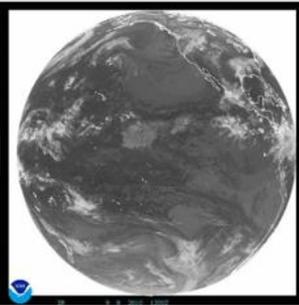
→ Dark = warm objects  
low clouds, the surface and snow

**Notes:**  
All objects emit radiation according to their temperature.  
\*\* Hotter objects emit more radiation than colder objects

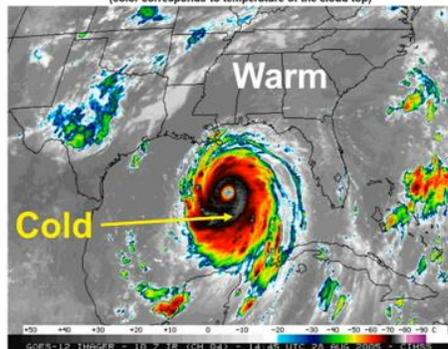
### visible image



### IR image



IR Image Enhanced with color  
(color corresponds to temperature of the cloud top)



[Source](#)

## Water Vapor Satellite Imagery (2:44)

### Satellite Channels: Water Vapor Imagery



### Satellite Channels: Water Vapor Imagery

→ Measures: emitted radiation from water vapor  
tells us the moisture content of the air

→ Bright = high water vapor content  
t-storms and thick clouds

→ Dark = low water vapor content  
cold, clear and dry areas

**Notes:**  
Serves as an excellent tracer of atmospheric motion

[Source](#)

## **Video Lecture Notes 5, 12**

- Weather satellites were first launched to observe hurricanes.
- **Visible channels** measure reflected sunlight. They work just like a digital camera without the flash. Because of this, you cannot use visible satellites at night to observe the weather.
  - **Albedo** is the ratio of reflected sunlight to the incident sunlight on an object.
  - **Bright:** High albedo (white objects such as snow, ice, and clouds).
  - **Dark:** Low albedo (darker objects such as land, and water).
- **Infrared (IR) channels** measure the emitted thermal infrared radiation from an object and can therefore measure the temperature of an object.
  - All objects emit radiation according to their temperature. The hotter the object becomes the more radiation it will emit.
  - Infrared images are inverted so that warm objects are dark and cold objects are bright (Remember: Temperature decreases as a function of altitude).
  - **Bright:** Cold objects (high clouds in the atmosphere where the temperature is very low).
  - **Dark:** Warm objects near the surface (low clouds, the earth's surface, and even snow).
- **Water vapor channels** measure emitted radiation from water vapor and tells us information about the moisture content of the atmosphere.
- Meteorologists use water vapor as a tracer of atmospheric motions.
  - **Bright:** Very high water vapor content (tropics).
  - **Dark:** Low water vapor content (deserts).

## **Doppler Radar**

Doppler radar has revolutionized our ability to observe severe weather—especially tornadoes. In the next few video lectures, we will learn about the history of Doppler radar and the current Doppler radar network. Pay attention to how this instrument is used to observe severe thunderstorms.

### **History of Weather Radar** (5:49)

Radar systems were first mass-produced during WWII. These radars were not designed for remotely sensing precipitation but rather for civil defense during the war. Precipitation was an annoyance when radar operators were searching for enemy aircraft and ships. First radar network in the United States was deployed in the late 1950s.

The current radar network, called the NEXRAD Network, uses 158 Doppler radars placed all over the United States. Most of these radars are located at National Weather Service offices. They look like large white soccer balls sitting on top of a metal structure. They are protected from the weather, critters, and people by a large fiberglass sphere called a **raydome**.

[NEXRAD Radar Network](#) (3:11)

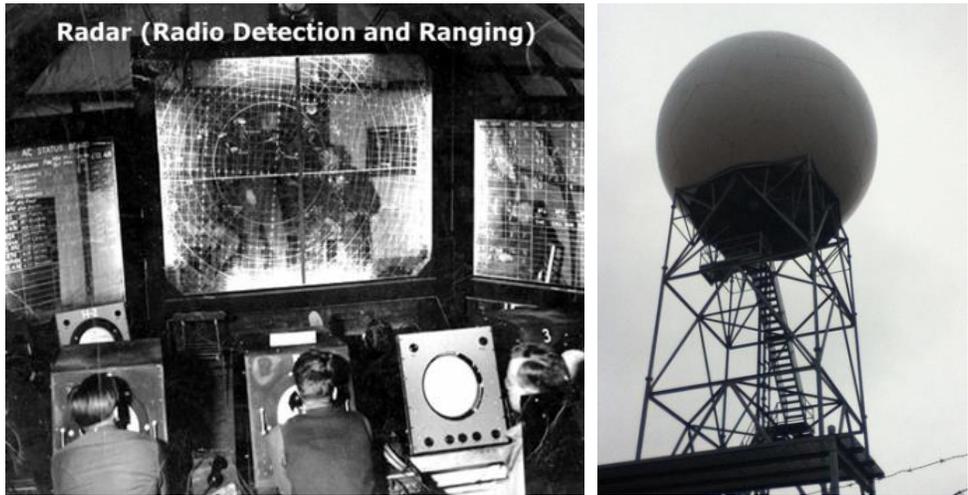


Figure 6. Early radar system (left) and raydome (right).

[Source](#)

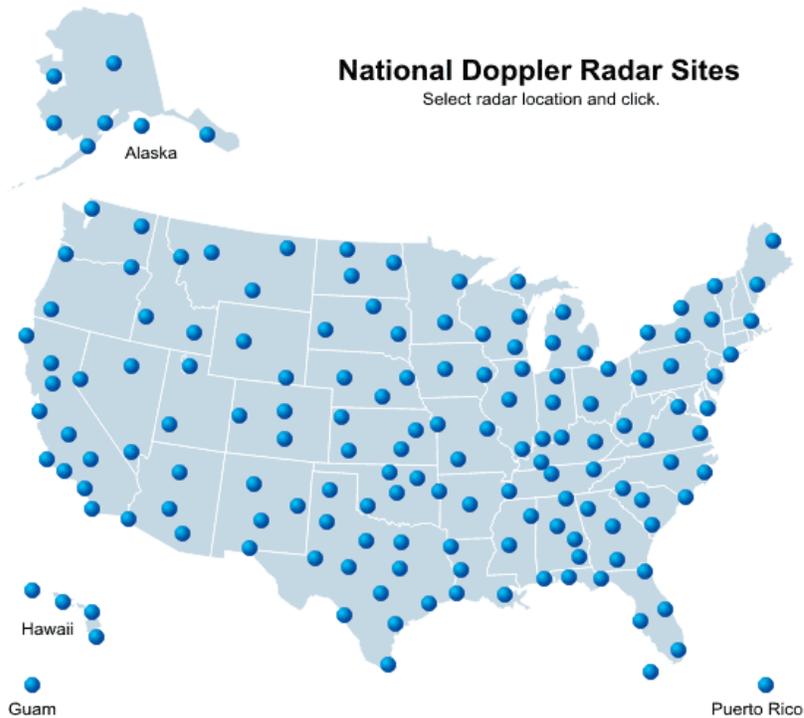


Figure 7. NEXRAD Radar Network

[Source](#)

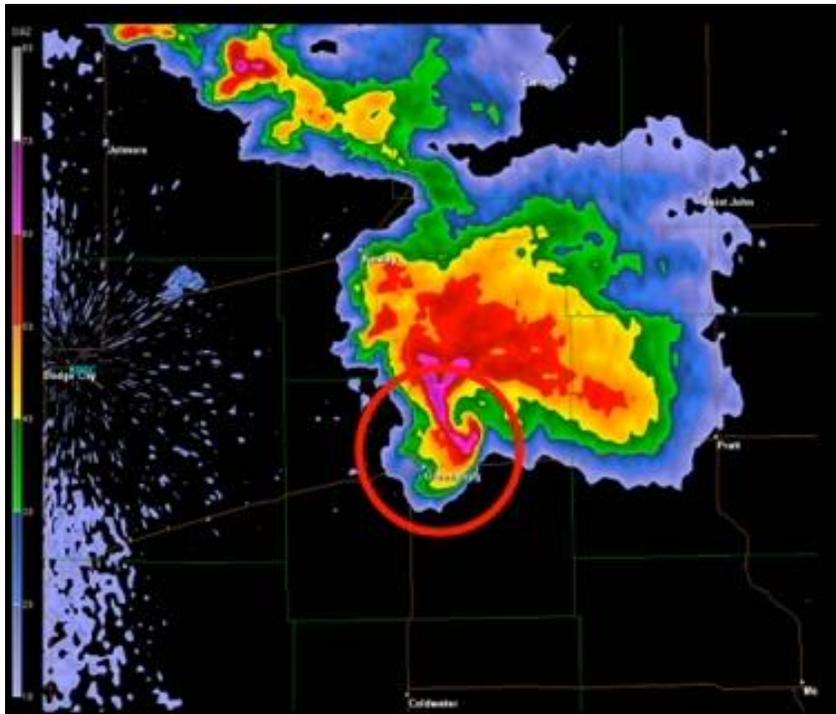
## Video Lecture Notes

- Radar systems were first mass-produced during World War II. Precipitation was an annoyance when radar operators were searching for enemy aircraft and ships.
- The current radar network, called the NEXRAD Network, uses 158 Doppler radars placed all over the U.S. Most of which are located at National Weather Service offices.
- Radars are protected from the weather, critters, and people by a large fiberglass sphere called a **raydome**.

Doppler radar's ability to remotely sense precipitation makes it a crucial tool for any meteorologist. In these next two videos, we will learn how Doppler radar works and what it is able to measure **5**.

[How Radar Works](#) (5:15)

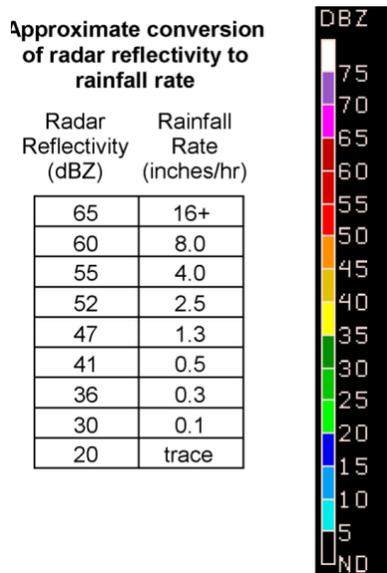
[Measuring Precipitation](#) (5:53)



*Figure 8. Radar image indicating hail (red circle).*

[Source](#)

Doppler radar is one of the best tools meteorologists have to estimate the intensity and amount of precipitation. Doppler radar images use color-coded maps, like those below, to show the coverage and intensity of precipitation. The color bar assigned to each Doppler radar image can indicate how heavy it is raining, but it can also be used to estimate how much rain will fall over a one-hour time span.



*Figure 9. A chart that relates the intensity of the rainfall (measured in dBZ) to a rainfall rate (measured in inches/hour).*

### **Video Lecture Notes 5**

- Doppler radar systems work by measuring the reflection of a microwave pulse off a raindrop.
- The radar sends out a powerful pulse of electromagnetic radiation that travels away from the radar at the speed of light. When this radiation hits a raindrop, an echo is produced as the pulse reflects off the raindrop. The echo travels back to the radar, where it is measured.
- The strength of the return signal is proportional to two properties of precipitation:
  - The number of particles
  - The size of the particles
- Radar echoes are displayed as radar reflectivity, which provides us with
  - Presence and coverage of the precipitation
  - Location of precipitation
  - Intensity of precipitation
  - Amount of precipitation
- Doppler radar can measure the variables above and wind speed and direction.
- Data are viewed using color-coded maps of precipitation intensity.
- If the radar reflectivity values exceed 55 dBZ (dBZ = decibels of reflectivity), then the radar beam has encountered hail in the storm. This will appear red, pink, purple, or white on a radar reflectivity image.
- Radar reflectivity values can also be used to estimate how much rain will fall over a location.

## The Doppler Effect

The best feature of the current Doppler radar network is its ability to measure the movement of the precipitation. Since this movement can only be caused by the wind, radar meteorologists can use this information to extract the wind speed and direction. It is this ability that has made tornado detection with Doppler radar possible. Check out the videos below to learn more [5](#)!

[The Doppler Effect](#) (9:02)

### **Video Lecture Notes** [5](#)

- If a raindrop is moving toward or away from the radar, the frequency and phase of the return echo will change compared to the pulse that was sent out. Doppler radar can measure these shifts in the frequency and phase of the echo to find the wind speed and direction of the precipitation.
- When looking at a Doppler radar radial velocity image,
  - Red colors indicate precipitation that is being blown away from the radar.
  - Green colors indicate precipitation is being blown toward the radar.

This radar animation shows the recent EF-5 tornado from El Reno, OK on May 31, 2013. This video has side-by-side images of radar radial velocity (left) and radar reflectivity (right).

[El Reno EF-5 Tornado](#) (1:23)

## Upper-Air Measurements

First invented in the 1930s, the **weather balloon** allowed meteorologists to gain valuable information about the behavior of the winds above the Earth's surface. While much has changed in the abilities of the instrument over the years, this is still one of the primary means by which weather information is collected globally. In this video lecture, we will learn about this instrument and why it is such an important tool for meteorologists.

[Rawinsondes](#) (0 – 8:00)

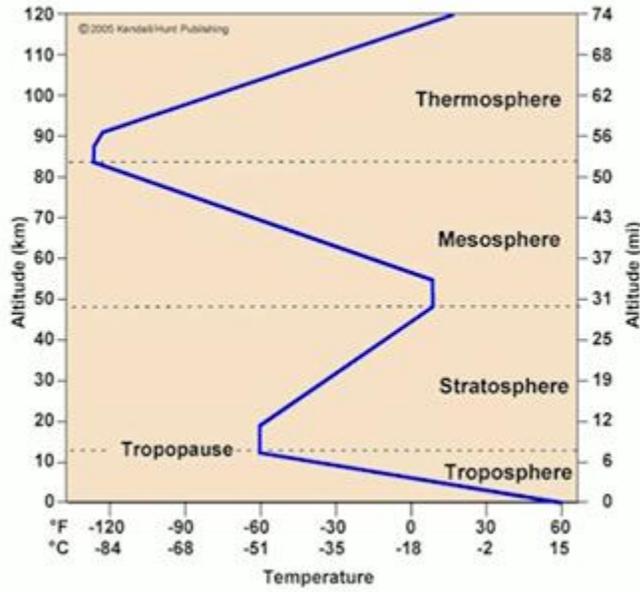
Once the data is collected from a rawinsonde, meteorologists display this data on a graph called a **sounding**.

[Weather Balloon Launch](#) (3:43)

[The Sounding Diagram](#) (0 – 4:00)

[Analyzing a Sounding](#) (0 – 1:52)

## Displaying Rawinsonde Data: Sounding



## Displaying Rawinsonde Data: Sounding

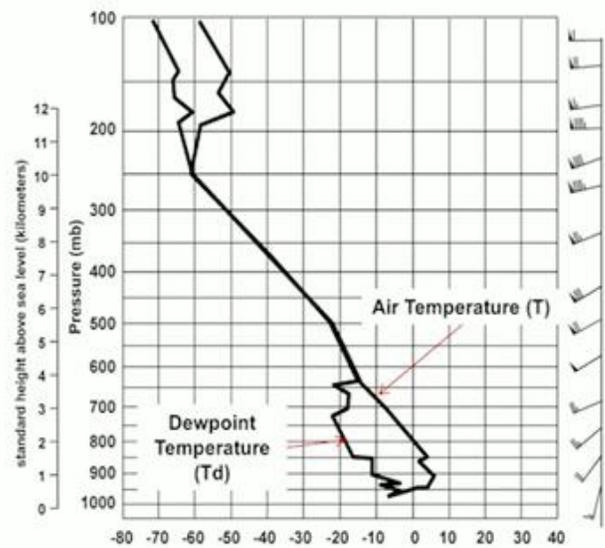


Figure 10. Vertical temperature sounding of each layer of the atmosphere (left) and an example sounding showing the temperature and dewpoint temperature (right).

[Source](#)

Figure 10 shows rawinsonde data displayed on a sounding diagram. A sounding shows the vertical changes in temperature and dewpoint temperature. On this diagram, temperature is shown in degrees Celsius on the x-axis and pressure (and height) is shown on the y-axis in millibars (and kilometers). Recall, temperature typically decreases with height, and pressure always decreases with increasing height in the atmosphere. The surface is at the bottom of the sounding near 1000 mb and at approximately 100 mb is the top of the troposphere, where the rawinsonde stopped recording data. As the rawinsonde ascends in the atmosphere, it records the air temperature (right, blue line) and dewpoint temperature (left, black line). When the temperature and dewpoint temperature line lie on top of one another (Temperature = Dewpoint

### Video Lecture Notes

- The instrument attached to a weather balloon is called a **rawinsonde**.
- Rawinsondes are carried through the depth of the troposphere by a helium or hydrogen-filled balloon. The balloon typically pops in the stratosphere and stops collecting data there.
- They are launched twice per day from National Weather Service offices.
- They collect a vertical profile of the air temperature, air pressure, humidity, height, wind speed and direction as they ascend at approximately 1,000 feet per minute.
- The type of data they collect is called **in situ**. In situ data collection is a direct measurement.

## **Pre-Class Activity 6**

**Instructions:** Before teaching about atmospheric measurements, have the students answer the questions below, followed by a question for in-class discussion between you and your students.

1. Which of the following instrument is used to measure air temperature?
  - a. Barometer
  - b. Thermometer
  - c. Anemometer
  - d. Weather vane
  - e. Rawinsonde
  
2. Which of the following instrument is used to measure air pressure?
  - a. Barometer
  - b. Thermometer
  - c. Anemometer
  - d. Weather vane
  - e. Rawinsonde
  
3. Which of the following instrument is used to measure wind speed?
  - a. Barometer
  - b. Thermometer
  - c. Anemometer
  - d. Weather vane
  - e. Rawinsonde
  
4. Which of the following instrument is used to measure wind direction?
  - a. Barometer
  - b. Thermometer
  - c. Anemometer
  - d. Weather vane
  - e. Rawinsonde
  
5. Which of the following instrument is used to measure the vertical profile of the atmosphere?
  - a. Barometer
  - b. Thermometer
  - c. Anemometer
  - d. Weather vane
  - e. Rawinsonde

**Discussion Question:** Atmospheric measurements are collected constantly all over the world. Why do you think it is so important that we collect these data?

\* If time permits, try [How to Make a Bottle Thermometer](#)

## **In-Class Activity 6, 9**

**Instructions:** In this project, your group will experiment using data from various weather instruments to analyze the atmospheric conditions. Each group member will choose one of the following variables and complete the tasks written at the end of each section.

1. Temperature and Pressure
2. Atmospheric Moisture
3. Upper-Air Soundings
4. Rainfall Measurements

### **Data: Temperature and Pressure 3, 8**

#### **Task #1: Temperature Conversions**

1. What is the instrument used to measure temperature?
2. What is the freezing point of water in degrees Fahrenheit?
3. What is the boiling point of water in degrees Celsius?
4. Show your work to explain why  $-40^{\circ}\text{F}$  is also  $-40^{\circ}\text{C}$ .

Now, click on the following link to get data on the current temperature in your area. [Click here](#) and enter your city, state OR zip code in the 'Local Forecast' box on the left side of the page.

1. What is the current temperature in your area in degrees Fahrenheit?
2. Convert this temperature to degrees Celsius and Kelvin and be sure to show all of your work and units in your answer.
3. Before closing this window, record your current air pressure in millibars and inches of mercury, you will need this information for the second task.

#### **Task #2: Measuring Air Pressure**

1. What is the instrument used to measure air pressure?
2. What is the current air pressure in your area (see instructions from Task #1)?
3. If the standard atmospheric pressure at sea level is 29.92 inches of mercury (1013.25 millibars), what type of weather conditions would you expect in your area today?
4. Briefly explain how a mercury barometer works.
5. How would the level of the mercury change if you began to climb a mountain?

### **Task #3: Broadcast**

As a scientist, it is important that you learn to properly convey weather information to the general public. Your task is to create a 5-minute broadcast describing air temperature and pressure and its importance to understanding the weather. Be sure to address the following topics in your broadcast:

1. Define temperature and the instrument used to measure it.
2. Tell the audience what the current temperature is outside in Fahrenheit and Celsius.
3. Compare this temperature to the freezing and boiling points of water.
4. Define air pressure and the instrument used to measure it.
5. Tell the audience what the current air pressure is in your area.
6. Compare this pressure to the standard atmospheric pressure at sea level.
7. Briefly explain what type of weather is typical under these conditions.

Build this weather broadcast using presentation software (like PowerPoint) and be sure to supplement everything you discuss with images. Be sure to be both informative and entertaining!

**Data: Atmospheric Moisture 2, 11**

**Task #1: Measuring Relative Humidity**

1. What instrument is used to measure the dewpoint temperature and relative humidity?
2. Briefly explain the purpose of using two thermometers to measure humidity.
3. What phase change of water causes the dry-bulb and wet-bulb temperatures to differ?

Now, click on the following link to get temperature and humidity data in your area. [Click here](#) and enter your city, state OR zip code in the 'Local Forecast' box on the left side of the page.

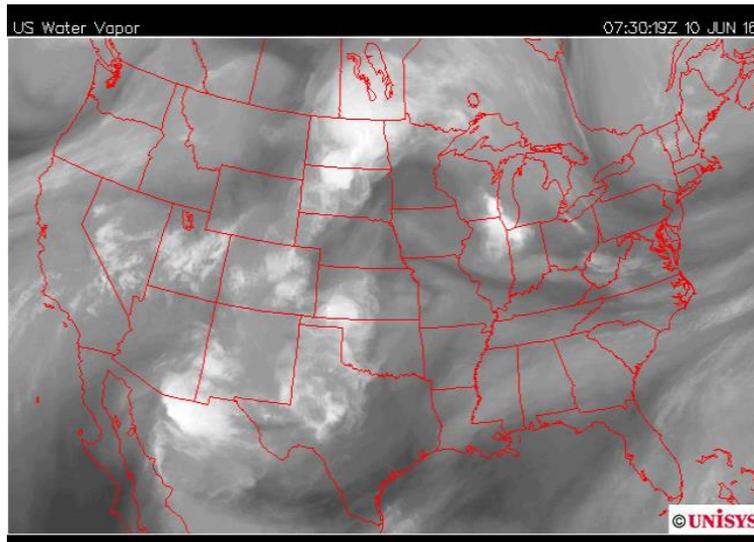
1. What is the percent of relative humidity in your area?
2. What is the current temperature in your area in degrees Celsius?
3. Assume the current temperature (°C) is equal to the dry-bulb temperature and the Dry-Bulb Depression is 4°C. Using Table 11-1, determine the relative humidity.
4. Now knowing the dry-bulb temperature and dry-bulb depression, what is the wet-bulb temperature?

**Relative Humidity (%)**

Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (C°)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-20	100	28														
-18	100	40														
-16	100	48														
-14	100	55	11													
-12	100	61	23													
-10	100	66	33													
-8	100	71	41	13												
-6	100	73	48	20												
-4	100	77	54	32	11											
-2	100	79	58	37	20	1										
0	100	81	63	45	28	11										
2	100	83	67	51	36	20	6									
4	100	85	70	56	42	27	14									
6	100	86	72	59	46	35	22	10								
8	100	87	74	62	51	39	28	17	6							
10	100	88	76	65	54	43	33	24	13	4						
12	100	88	78	67	57	48	38	28	19	10	2					
14	100	89	79	69	60	50	41	33	25	16	8	1				
16	100	90	80	71	62	54	45	37	29	21	14	7	1			
18	100	91	81	72	64	56	48	40	33	26	19	12	6			
20	100	91	82	74	66	58	51	44	36	30	23	17	11	5		
22	100	92	83	75	68	60	53	46	40	33	27	21	15	10	4	
24	100	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4
26	100	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9
28	100	93	86	78	71	65	59	53	47	42	36	31	26	21	17	12
30	100	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16

## Task #2: Satellite Imagery

1. Which type of satellite channel is best for estimating the amount of atmospheric moisture?
2. What does this channel measure?
3. Using the map below, determine whether Chicago, IL has a dry or moist air mass in place.



[Source](#)

1. Click [here](#) to view the most recent satellite image loop. Looking at your area, does the value for relative humidity that you recorded in Task #1 make sense?

## Task #3: Broadcast

As a scientist, it is important that you learn to properly convey weather information to the general public. Your task is to create a 5-minute broadcast describing moisture in the atmosphere and its importance to understanding the weather. Be sure to address the following topics in your broadcast:

1. Define relative humidity and the instrument used to measure it.
2. Briefly explain the technique used to measure relative humidity and dewpoint temperature.
3. Name the satellite channel used to estimate atmospheric moisture. What do bright and dark areas on this type of map represent?
4. Show the current satellite image and describe the type of weather is typical under these conditions.

Build this weather broadcast using presentation software (like PowerPoint) and be sure to supplement everything you discuss with images. Be sure to be both informative and entertaining!

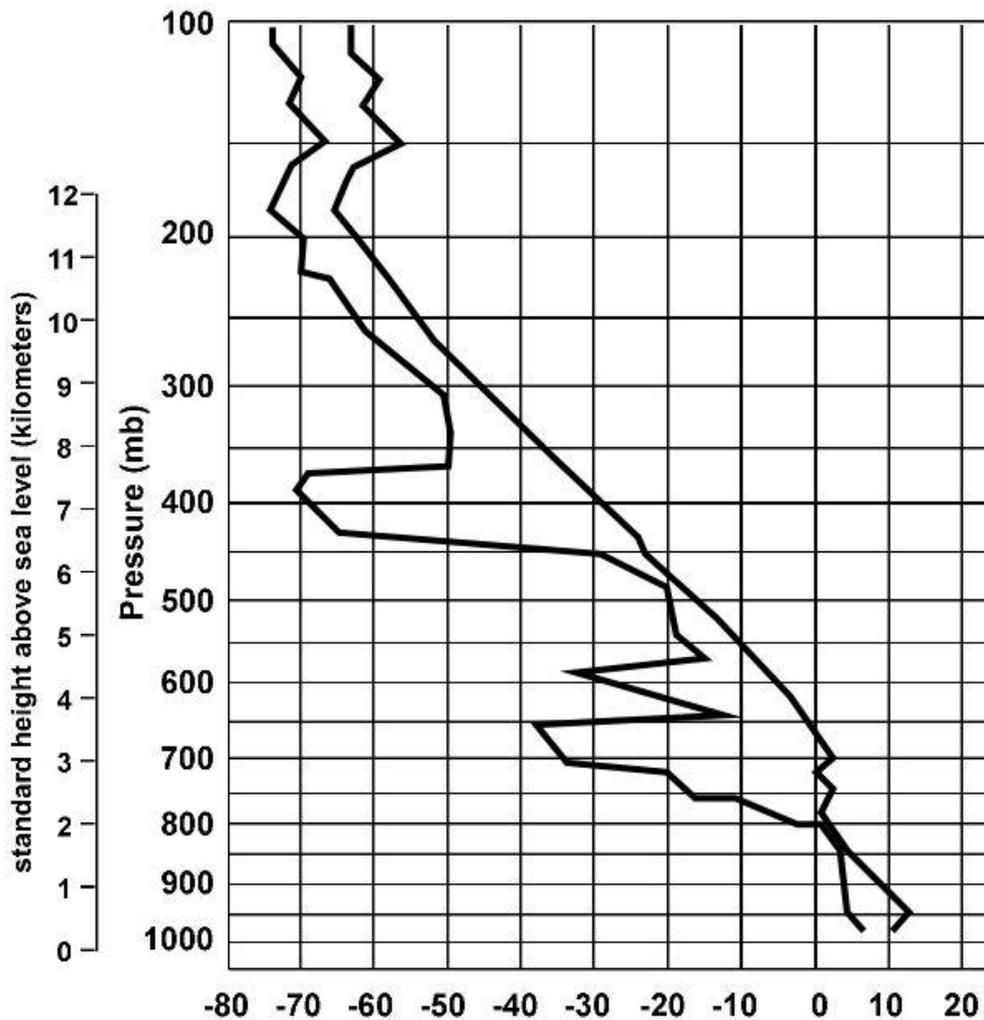
## Data: Upper-Air Soundings 8

### Task #1: Upper-Air Measurements

1. What two instruments are used to take measurements vertically in the atmosphere?
2. Name all of the variables that can be measured using this instrument pack.
3. What is the name of the chart that meteorologists plot upper air data on?
4. Where in the atmosphere do these instruments begin and end their measurements typically?

### Task #2: Soundings

Using the chart below, answer the following questions. Don't forget units in your answer.



1. Label the air temperature (T) and dewpoint temperature (Td) lines.
2. What is the air temperature at the surface?
3. What is the dewpoint temperature at the surface?
4. What is the difference between the surface temperature and dewpoint temperature?
5. Is the surface temperature above or below the freezing point of water? By how many degrees?
6. What is the surface pressure?
7. Is the surface pressure higher or lower than standard atmospheric pressure at sea level?
8. At approximately what pressure would you expect there to be clouds present?

### **Task #3: Broadcast**

As a scientist, it is important that you learn to properly convey weather information to the general public. Your task is to create a 5-minute broadcast describing the vertical profile of the atmosphere and its importance to understanding the weather that occurs at the surface. Be sure to address the following topics in your broadcast:

1. Define atmospheric sounding and the instruments used to collect upper-air data.
2. Briefly explain the technique used to collect the data.
3. Show an example of a sounding.
4. Discuss what each line represents and where you expect clouds to be present (be sure to explain why!)
5. Tell the audience what the air temperature, dewpoint temperature, and pressure is at the surface.
6. Answer whether the surface pressure is higher or lower than the standard atmospheric pressure (1013.25 mb) and describe the type of weather expected under these conditions.
7. Briefly explain the importance of these soundings to forecasting the weather.

Build this weather broadcast using presentation software (like PowerPoint) and be sure to supplement everything you discuss with images. Be sure to be both informative and entertaining!

## Data: Rainfall Measurements 5, 8

### Task #1: Measuring Rainfall

1. What instrument is used to measure rainfall?
2. List two units used to describe the amount of rainfall.
3. What instrument is used to estimate precipitation location, motion, intensity, and amount?
4. What is the Doppler effect?
5. Name one reason why monitoring rainfall is important.

### Task #2: Radar Imagery

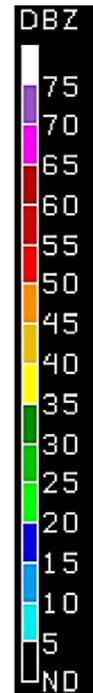
Click here to access the most recent Doppler radar images and answer the following questions.

1. In which states is precipitation occurring?
2. Based on the time of year and location of the precipitation, what type of precipitation do you expect to be occurring?
3. Which state has the highest radar reflectivity values? What is the radar reflectivity value there (include units)?
4. Using the chart below, how many inches per hour will fall at the location from Question 3?
5. Are there any areas where you expect hail to be occurring?

#### Approximate conversion of radar reflectivity to rainfall rate

Radar Reflectivity (dBZ)	Rainfall Rate (inches/hr)
--------------------------------	---------------------------------

65	16+
60	8.0
55	4.0
52	2.5
47	1.3
41	0.5
36	0.3
30	0.1
20	trace



### **Task #3: Broadcast**

As a scientist, it is important that you learn to properly convey weather information to the general public. Your task is to create a 5-minute broadcast describing techniques used to measure rainfall and its importance to understanding the weather and beyond. Be sure to address the following topics in your broadcast:

1. Describe the two instruments used to estimate rainfall.
2. Show a picture of each instrument and describe the techniques to measure rainfall.
3. Explain the Doppler effect and how it's used to measure wind speed and direction.
4. Include the radar image that you retrieved for Task #2.
5. Point out any areas where precipitation is occurring and the values of radar reflectivity.
6. Summarize your findings from Task #2.
7. Describe the importance of collecting rainfall measurements.

Build this weather broadcast using presentation software (like PowerPoint) and be sure to supplement everything you discuss with images. Be sure to be both informative and entertaining!

## Take Home Assignment 6

### Part 1. Matching

**Instructions:** Fill in the missing instrument name, type of measurement, and units in the table below.

<b>Instrument Name</b>	<b>Measurement</b>	<b>Units</b>
Thermometer		
	Pressure	
Rain Gauge		
		Miles per hour
Sling Psychrometer		
	T, Td, P, Wind Speed and Direction	-
	Cloud Cover	-

### Part 2. Short Answer 6, 12

**Instructions:** Answer the following short answer questions about satellites.

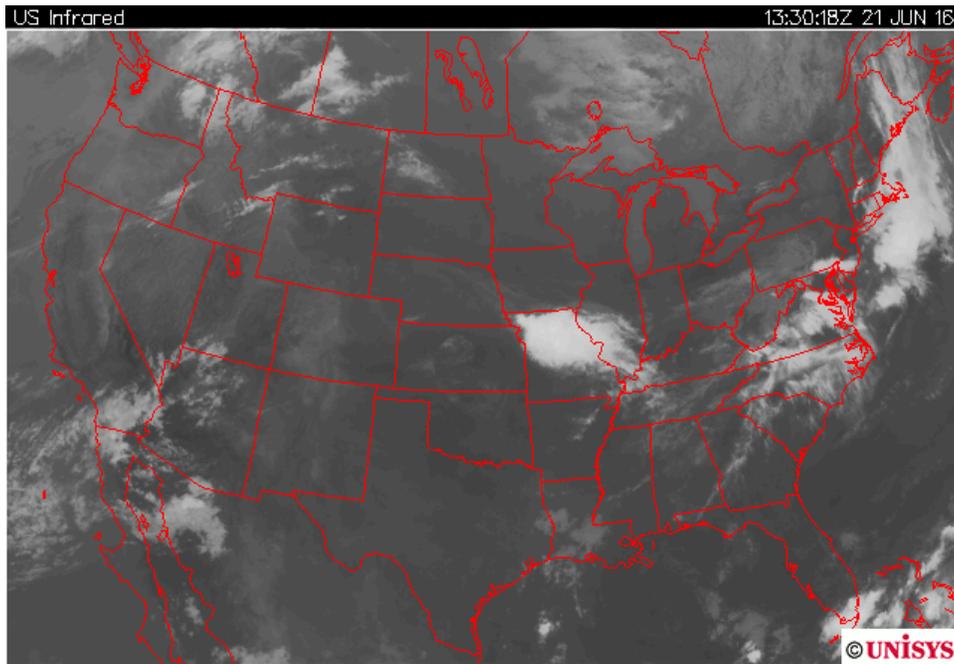
1. Name the satellite channels used to monitor weather around the globe.

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2. Using the image below, name the satellite channel shown and briefly describe how you can tell whether there are high or low clouds present in southwest Illinois.



Satellite Channel: \_\_\_\_\_

Circle one:    Low clouds                      High Clouds

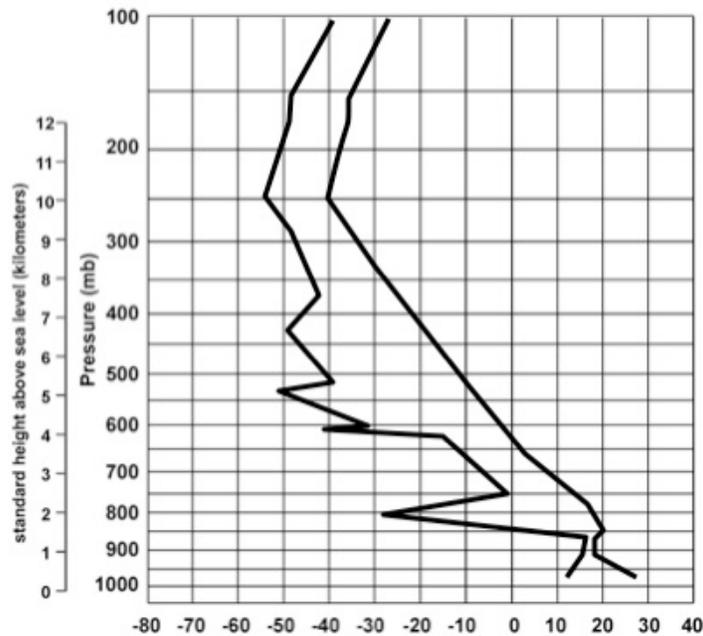
Explanation:

3. If you were looking at a visible satellite image at night, what would you expect to see?

- Briefly explain the importance of using water vapor satellite imagery (Hint: Think about the relationship between water vapor and the weather).

### Part 3. Calculations 6, 8, 9

**Instructions:** Use the atmospheric sounding below to answer the following questions. Don't forget to include units in your answer.



- From the sounding, determine the air temperature at the surface in degrees Celsius.
- Convert the air temperature at the surface from Celsius to degrees Fahrenheit. Show your work.

3. From the sounding, determine the dewpoint temperature at the surface.
  
4. Remember that the air temperature is equal to the dry-bulb temperature. Using your answers from Questions 1 and 3, determine the difference between the wet-bulb and dry-bulb temperatures (Dry-Bulb Depression) from Table 1. Show your work.

Dry-Bulb Temperature = \_\_\_\_\_

Dewpoint Temperature = \_\_\_\_\_

**Dry-Bulb Depression = \_\_\_\_\_**

**Dewpoint Temperatures (°C)**

Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (C°)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-20	-20	-33														
-18	-18	-28														
-16	-16	-24														
-14	-14	-21	-36													
-12	-12	-18	-28													
-10	-10	-14	-22													
-8	-8	-12	-18	-29												
-6	-6	-10	-14	-22												
-4	-4	-7	-12	-17	-29											
-2	-2	-5	-8	-13	-20											
0	0	-3	-6	-9	-15	-24										
2	2	-1	-3	-6	-11	-17										
4	4	1	-1	-4	-7	-11	-19									
6	6	4	1	-1	-4	-7	-13	-21								
8	8	6	3	1	-2	-5	-9	-14								
10	10	8	6	4	1	-2	-5	-9	-14	-28						
12	12	10	8	6	4	1	-2	-5	-9	-16						
14	14	12	11	9	6	4	1	-2	-5	-10	-17					
16	16	14	13	11	9	7	4	1	-1	-6	-10	-17				
18	18	16	15	13	11	9	7	4	2	-2	-5	-10	-19			
20	20	19	17	15	14	12	10	7	4	2	-2	-5	-10	-19		
22	22	21	19	17	16	14	12	10	8	5	3	-1	-5	-10	-19	
24	24	23	21	20	18	16	14	12	10	8	6	2	-1	-5	-10	-18
26	26	25	23	22	20	18	17	15	13	11	9	6	3	0	-4	-9
28	28	27	25	24	22	21	19	17	16	14	11	9	7	4	1	-3
30	30	29	27	26	24	23	21	19	18	16	14	12	10	8	5	1

Table 1. Dewpoint Temperature

5. Using your answer from Question 4 and Table 2, determine the relative humidity. Show your work.

Dry-Bulb Temperature = \_\_\_\_\_

Dry-Bulb Depression = \_\_\_\_\_

**Relative Humidity** = \_\_\_\_\_

**Relative Humidity (%)**

Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (C°)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-20	100	28														
-18	100	40														
-16	100	48														
-14	100	55	11													
-12	100	61	23													
-10	100	66	33													
-8	100	71	41	13												
-6	100	73	48	20												
-4	100	77	54	32	11											
-2	100	79	58	37	20	1										
0	100	81	63	45	28	11										
2	100	83	67	51	36	20	6									
4	100	85	70	56	42	27	14									
6	100	86	72	59	46	35	22	10								
8	100	87	74	62	51	39	28	17	6							
10	100	88	76	65	54	43	33	24	13	4						
12	100	88	78	67	57	48	38	28	19	10	2					
14	100	89	79	69	60	50	41	33	25	16	8	1				
16	100	90	80	71	62	54	45	37	29	21	14	7	1			
18	100	91	81	72	64	56	48	40	33	26	19	12	6			
20	100	91	82	74	66	58	51	44	36	30	23	17	11	5		
22	100	92	83	75	68	60	53	46	40	33	27	21	15	10	4	
24	100	92	84	76	69	62	55	49	42	36	30	25	20	14	9	4
26	100	92	85	77	70	64	57	51	45	39	34	28	23	18	13	9
28	100	93	86	78	71	65	59	53	47	42	36	31	26	21	17	12
30	100	93	86	79	72	66	61	55	49	44	39	34	29	25	20	16

Table 2. Relative Humidity



9. Radar is an extremely useful instrument used to detect the intensity and location of precipitation. Briefly describe how a radar detects precipitation (drawing a sketch may be helpful).

10. The freezing point of water occurs at 273.15 K. What is the freezing point in degrees Fahrenheit? Please show your work.

<b>Temperature Conversions</b> $^{\circ}\text{C} = (\text{F} - 32)/1.8$ $\text{K} = \text{C} + 273.15$
--

- a.  $0^{\circ}\text{F}$
- b.  $32^{\circ}\text{F}$
- c.  $134^{\circ}\text{F}$
- d.  $237.15^{\circ}\text{F}$
- e.  $510.3^{\circ}\text{F}$

## 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-PS3.A](#)

<b>MS-PS3.A. Definitions of Energy</b> (Disciplinary Core Idea from MS-PS3-4)
Temperature is a measure of the average kinetic energy of particles of matter.
Lecture: Measuring Temperature

### 2. [NGSS.MS-PS3-4](#)

<b>MS-PS3-4. Energy</b>
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.
Lecture: Measuring Moisture; In-Class Activity: Atmospheric Moisture

### 3. [NGSS.MS-ESS2.5](#)

<b>MS-ESS2-5. Weather and Climate</b>
Provide evidence for air pressure systems and resulting weather conditions.
Lecture: Measuring Pressure; In-Class Activity: Temperature and Pressure

### 4. [NGSS.MS-PS2.2](#)

<b>MS-PS2.2. Forces and Interactions</b>
Emphasis on balanced and unbalanced forces in a system and an object's motion ( $F = ma$ ). This includes a specification of units.
Lecture: Measuring Wind

5. [NGSS.MS-PS4-2](#)

<b>MS-PS4.2. Electromagnetic Radiation (DCI PS4.B)</b>
When light shines on an object, it is reflected, absorbed, or transmitted through an object, depending on the object's material and the frequency of the light.
Lecture: Satellite Channels, Doppler Radar, The Doppler Effect; In-Class Activity: Rainfall Measurements; Student Evaluation

6. [CCSS.ELA-LITERACY.RST.6-8.4](#)

<b>Grade 6-8: Science and Technical Subjects</b>
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; Pre-Class Activity; In-Class Activity; Take Home Assignment; Student Evaluation

7. [CCSS.ELA-LITERACY.RST.6-8.7](#)

<b>Grade 6-8: Science and Technical Subjects</b>
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

9. [CCSS.ELA-LITERACY.RST.6-8.3](#)

<b>Grade 6-8: Science and Technical Subjects</b>
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
In-Class Activity; Take Home Activity: Part 3

10. [CCSS.ELA-LITERACY.RST.6-8.8](#)

<b>Grade 8: Science and Technical Subjects</b>
Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
Student Evaluation

11. [NGSS.MS-PS4-2](#)

<b>MS-PS1-6. Chemical Reactions</b> (Disciplinary Core Idea PS1.B)
Some chemical reactions release energy, others store energy.
Lecture: Measuring Moisture; In-Class Activity: Atmospheric Moisture

12. [NGSS.MS-ESS2-5](#)

<b>MS-ESS2-5. Weather &amp; Climate</b> (DCI ESS2.C)
The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.
Lecture: Measuring Moisture; Take Home Assignment: Part 2