Drought and Heat Safety Learning Module

Source

No other weather phenomenon has shaped human existence more than drought. Extreme heat and drought are the world leader in deaths due to weather events. In the past, drought has caused famine, mass migration, war, and widespread poverty.

Introduction

When a drought is combined with a heat wave, the impact on humans can be unimaginable. Figure 1 shows weather fatalities in the U.S. The red columns indicates the number of people that died for each given hazardous weather type in 2010 while the blue column indicates the average number of fatalities over a 10 year time period. It is clear from this figure that heat waves are the deadliest form of weather in recent years. In this learning module we will uncover the meteorological symptoms of a drought and learn how a heat wave can be so deadly.

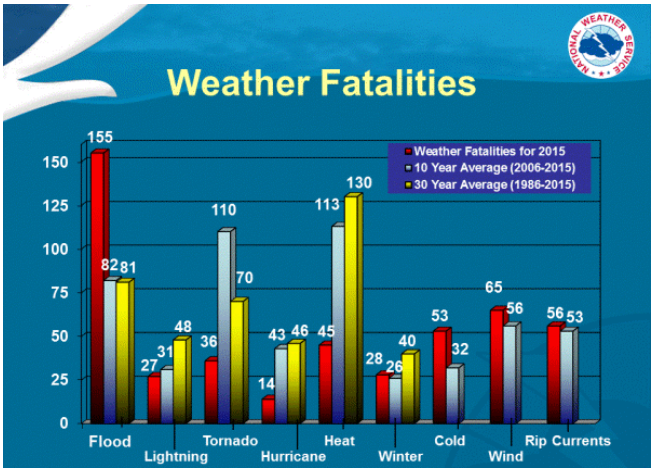


Figure 1. Statistics of weather fatalities in the United States.
Source

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.

Drought

Drought is difficult to define because it is region-specific. For example, if Tokyo Japan were to receive 20" of rain this year, they would have the worst socioeconomic drought in their history. However, if the same 20" of rain fell on Cairo, Egypt they would experience flooding of biblical proportions. This is because Tokyo typically receives 60"+ of rain each year while Cairo only receives about 2" of rain each year. This illustrates how drought must be defined on a regional basis and also explains why there is no universal definition for drought.

Introduction to Drought (3:58)

Implications of Drought

The impacts of a drought are far reaching and as you read, drought can cause war, famine, malnutrition, and mass migration. One place on earth that has dealt with all of this due to a recent prolonged drought is the Sahel in Africa. Figure 2 shows a map of the Sahel, which is a region that is sandwiched between the rainforest of central Africa and the Saharan Desert. This area has slowly been drying out over the past 30-40 years as the Saharan Desert expands southward. The graph in the upper right of Figure 2 shows a rainfall index where positive values represent wetter than normal years and negative values indicate drier. Notice that since 1970, the Sahel has seen a major rainfall deficit that has resulted in major desertification – the conversion of an area into a desert. Notice also that Lake Chad, which used to be one of the largest lakes on earth, has shrunk considerably over this same time period. Because of this prolonged drought, millions have had to flee the Sahel in search of a more habitable place to live and this mass-migration has placed a huge strain on this part of the world. In 1985, several prominent and famous musicians banded together to raise money for the Sahel by recording the now famous song, "We are the World." [2]

Implications of Drought (7:59)

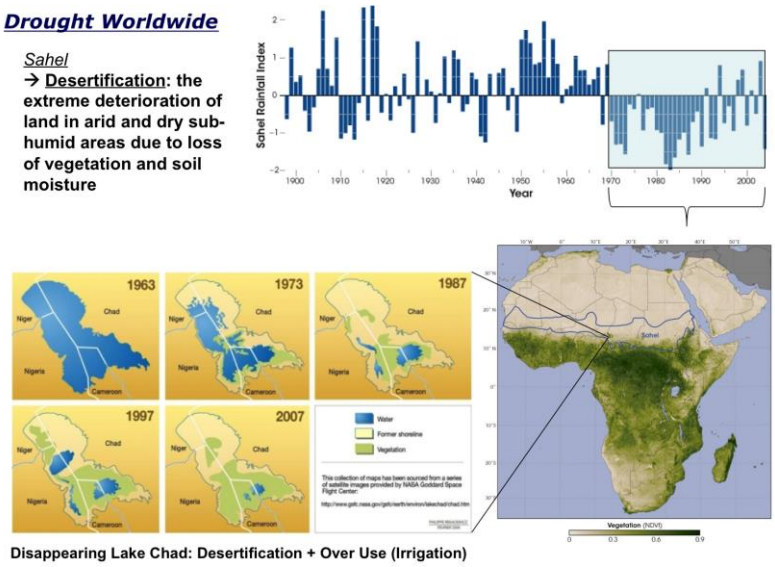


Figure 2. Impacts of long term drought in the Sahel.
Source

Drought Formation

The most common cause of drought is a persistent departure from normal weather conditions. In the U.S., drought forms when high air pressure systems repeatedly form and reside over a particular area. Normally, the U.S. experiences alternating weather patterns where high and low-pressure systems repeatedly form and track across the U.S. However, if this progression slows down or stops, so does the variety in weather we typically experience in the U.S. Figure 3 is a map of air pressure patterns when the central U.S. is experiencing drought. Notice the large area of high-pressure found in the middle of the country. High-pressure systems are typically associated with light winds, clear skies, and dry conditions. In Figure 3, if a high-pressure system like this one does not move over an extended period of time a drought will form [3].

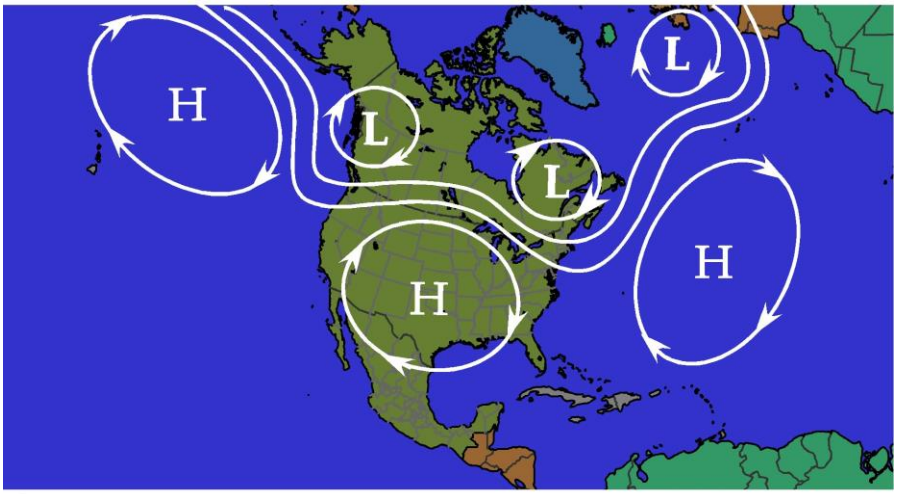


Figure 3. A map of air pressure that shows the location of high and low-pressure systems when a drought is forming in the central U.S.
Source

If you live in the mountainous western part of the U.S., meteorologists pay close attention to the wintertime snow pack. A drought in the west will typically begin in winter, as much of the water supply for the western states comes from snow melt. In the central and eastern U.S., drought typically begins in spring or summer. A drought in this part of the country is primarily due to a lack of thunderstorm activity [4].

Meteorologists recognize four types of drought:

1. **Meteorological Drought**: A prolonged time period of below normal precipitation for a region.

2. **Hydrological Drought**: A reduction in ground water supply in rivers, lakes, streams and below-surface water.

3. **Agricultural Drought**: A reduction in topsoil moisture, which can impact the health of vegetation.

4. **Socioeconomic Drought**: A reduction in water supplies intended for human consumption or use.

Monitoring Drought

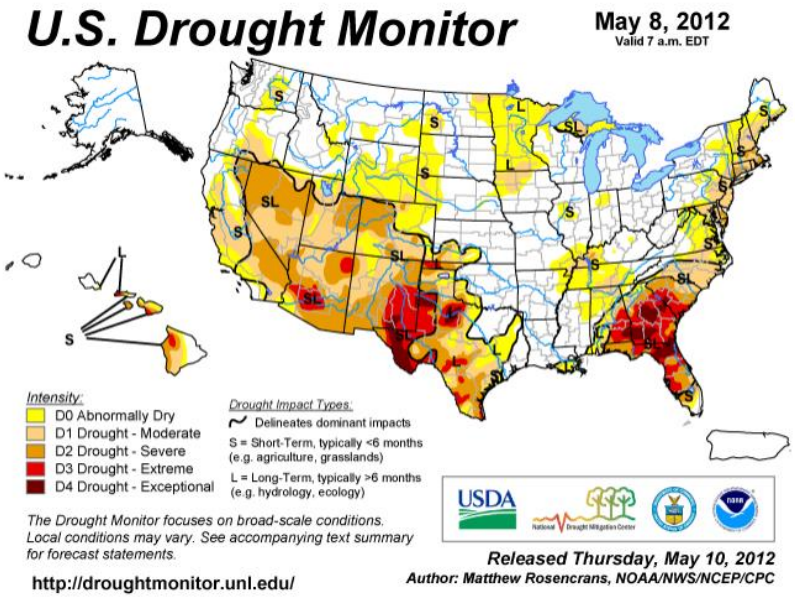


Figure 4. The U.S. Drought Monitor for May 8, 2012

Monitoring drought requires careful observation of four variables [4]:

1. **Ground water supply** (in aquifers and wells)
2. **Precipitation** (supplied by rain and snow)
3. **Surface evaporation rates** (how quickly/easily water evaporates from the soil)
4. **Water use and runoff** into streams or rivers (water that is transported away from an area)

To properly account for these for variables, the U.S. Department of Agriculture produces the "U.S. Drought Monitor" each month. Figure 4 shows regions around the U.S. that are currently experiencing drought [5]. The drought monitor is cumulative and therefore takes into account long-term drought conditions. For example, we can see that parts of Georgia are currently experiencing "exceptional" drought. If a massive thunderstorm were to provide rain to this area, it may help with the short-term problems but the long-term drought may still persist.

Drought is also monitored through a vast rain gauge network and Doppler radar [5]. Figure 5 (bottom) shows the two most commonly used instruments for monitoring precipitation. On the right is a tipping bucket rain gauge, which measures rainfall by filling a small container that tips every time 1/100 of a an inch of rain falls. On the left is a Doppler radar, which uses microwaves to remotely sense the intensity of the precipitation over an area. Data collected by these two instruments are compared the average annual rainfall amount (upper left) to see if a particular region is below normal on rainfall. For east central Illinois, we typically get 40" of rain a year so any less than that and we will begin to experience drought conditions.

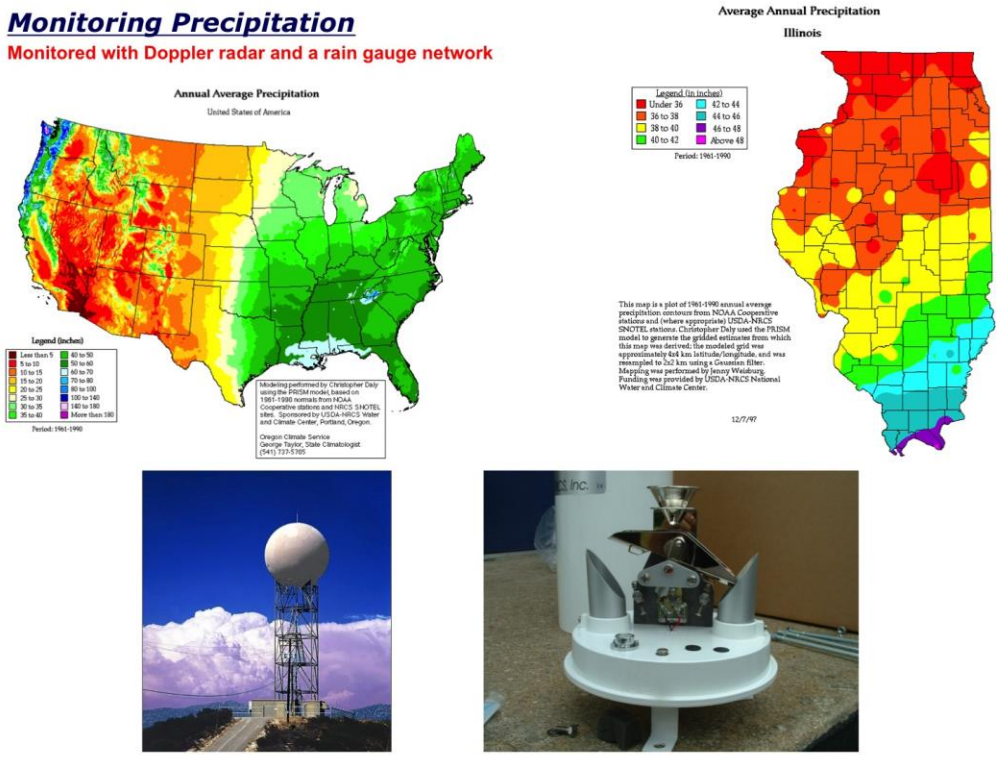


Figure 5. Top left – Average annual precipitation in the U.S. Top right – Average annual precipitation in Illinois. Bottom left - a Doppler radar. Bottom right – Tipping bucket rain gauge.

Historic Drought: Dustbowl of the 1930s

According to the journal "Weatherwise", the drought of the 1930s or "Dustbowl" as it came to be known as, was the worst weather event of the 20th century. The Dustbowl is an excellent example of a socioeconomic drought and it was brought on by a combination of human and meteorological events [5]. In the late 1800s/early 1900s, the population of the U.S. was pushing west. All across the Midwest, immigrants took advantage of the Homestead Act to gain land and make a living from farming. For the first part of the 20th century, farming was good and drought was not a major issue. With almost uncanny timing, the moment the stock market crashed in 1929, the rain stopped falling across the Midwest. Deficits in rainfall were recorded in almost every year during the 1930s (top right panel of Figure 6). Farmers, desperate to cling to any moisture left in their fields, made the fatal mistake of repeatedly plowing their fields. As a result, as the land dried, the repeated plowing granulized the dirt and made it ready to be picked up by the wind. Dust storms raged across the land for nearly a decade paralyzing the central U.S. Millions were forced to move and thousands died before the rains returned in the 1940s. For a summary presentation on this drought, check out this video!

Dustbowl (1:11)

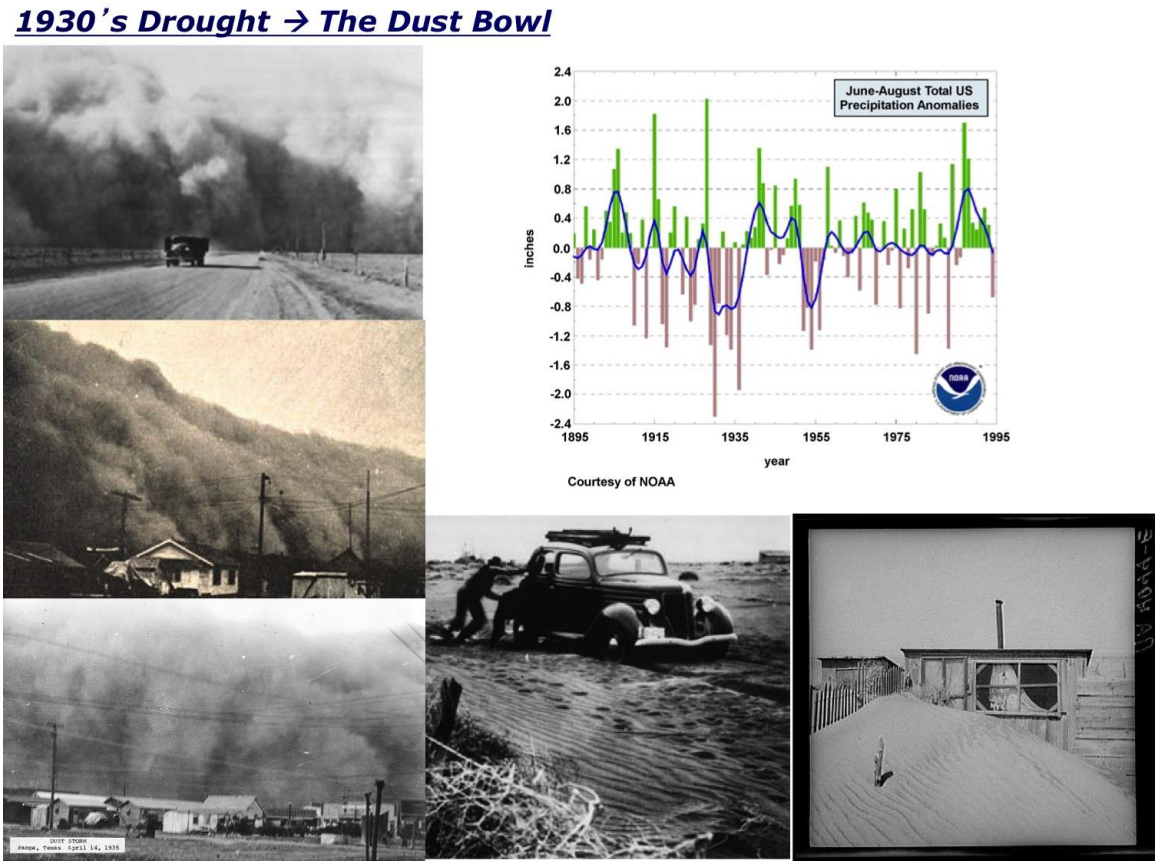


Figure 6. Several pictures from the Dustbowl and a chart of precipitation anomalies for the U.S. from 1895 – 1995 [5].

Heat Waves & Humidity

Heat waves often accompany a drought and combine for one of the deadliest forms of weather. Although heat waves may only last a few days, the livelihood of millions of people are at risk. To understand the power of a heat wave, let's investigate a recent deadly heat wave in the U.S. During July 1995, the air temperature in Chicago, IL rose to over 100°F for 4 straight days. As the air temperature rose, so did the dewpoint temperatures and relative humidity. The human body can efficiently cool itself by conduction, radiation, convection, and evaporation when the air temperature is below 95°F, but above 95°F the only efficient method of keeping cool is by the evaporation of sweat. With high relative humidity, the air contains close to the maximum amount of water vapor causing the perspiration on our skin to not evaporate as readily, and therefore not cool efficiently. Because of this relationship, the National Weather Service developed the Heat Index (see Figure 7). The **Heat Index** uses the air temperature and the relative humidity to find a "feels like" temperature. On this chart, as temperature and relative humidity rise, so does the heat index. To learn more about heat waves and the heat index, watch the following video:

Heat Waves (9:24)

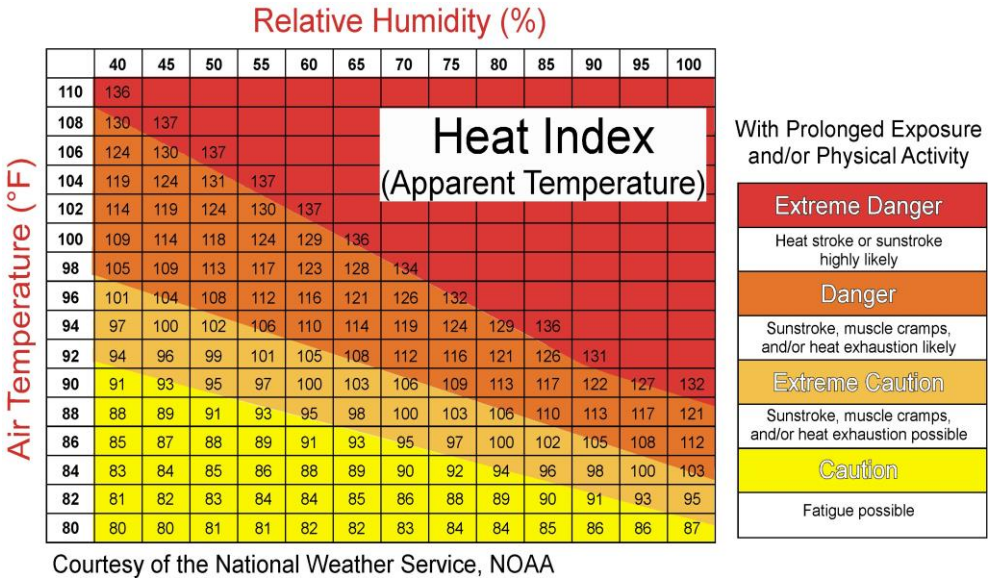


Figure 7. The Heat Index chart
Source

Urban Heat Island

Large cities are especially vulnerable to heat waves because of the Urban Heat Island Effect. An **urban heat island** is caused by the differences between building materials and vegetation. For a large city, concrete, asphalt, metal, glass, roadways, trains, cars, and buses have replaced vegetation. Building materials are very good at absorbing and storing the Sun's energy, whereas vegetation is good at using the sun's energy for photosynthesis or to evaporate water from its leaves [6].

The build up of the sun's energy in the city can produce air temperatures that are several degrees warmer than the surrounding countryside (see Figure 8). In Chicago, the urban heat island contributed to intense daytime temperatures and smothering nighttime temperatures as the heat stored in the city was released at night. When the heat wave had finally ended in Chicago, over 1,000 people had died in 4 days, mostly the elderly on the south side of the city. What was truly tragic was that Chicago's heat emergency plan was not put into action because so many city officials, including the mayor, were on summer vacation. Even greater than this disaster was the heat wave that gripped much of Europe during the summer of 2003. When that disaster finally abated, nearly 50,000 people had died from the heat wave!

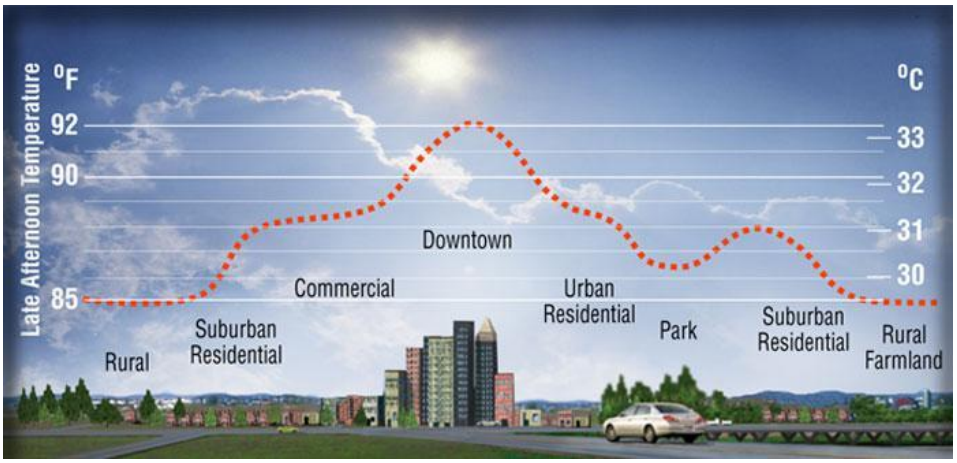


Figure 8. The "urban heat island" temperature profile shown in red.
Source

Heat Safety

As you have learned, heat can be extremely dangerous and causes the most fatalities per year than any other weather event. Particularly vulnerable groups include the elderly, young children, and those with asthma or chronic illness. These groups are especially susceptible to heat-related illness. Health impacts include fever, headaches, heat cramps, exhaustion, and heat stroke (Figure 9).

HEAT DISORDER	SYMPTOMS	FIRST AID*
SUNBURN	Redness and pain. In severe cases swelling of skin, blisters, fever, headaches.	Ointments for mild cases if blisters appear and do not break. If breaking occurs, apply dry sterile dressing. Serious, extensive cases should be seen by physician.
HEAT CRAMPS	Painful spasms usually in muscles of legs and abdomen possible. Heavy sweating.	Firm pressure on cramping muscles, or gentle massage to relieve spasm. Give sips of water. If nausea occurs, discontinue use.
HEAT EXHAUSTION	Heavy sweating, weakness, skin cold, pale and clammy. Pulse thready. Normal temperature possible. Fainting and vomiting.	Get victim out of sun. Lay down and loosen clothing. Apply cool, wet cloths. Fan or move victim to air conditioned room. Sips of water. If nausea occurs, discontinue use. If vomiting continues, seek immediate medical attention.
HEAT STROKE (or sunstroke)	High body temperature (106° F. or higher). Hot dry skin. Rapid and strong pulse. Possible unconsciousness.	HEAT STROKE IS A SEVERE MEDICAL EMERGENCY. SUMMON EMERGENCY MEDICAL ASSISTANCE OR GET THE VICTIM TO A HOSPITAL IMMEDIATELY. DELAY CAN BE FATAL. Move the victim to a cooler environment Reduce body temperature with cold bath or sponging. Use extreme caution. Remove clothing, use fans and air conditioners. If temperature rises again, repeat process. Do not give fluids.

Figure 9. Heat-related Illnesses Source

The National Weather Service (NWS) has implemented a warning system to protect against loss of life during extreme heat events. A **heat advisory** is issued if the following conditions are met:

1. Maximum heat index of 105 – 110^{o}F
2. Minimum heat index of 75^{o}F for 2 or more consecutive days

An **excessive heat warning** is issued if the following criteria are met:

1. Three or more consecutive days with a maximum heat index of 100 - 105^{o}F with at least (a) 85% sunshine on two of the days or (b) heat index of 75^{o}F or higher each day
2. One day with a maximum heat index greater than 110^{o}F

If the NWS issues either one of these warnings, you should reduce heat exposure by staying indoors, eliminate strenuous physical activity, and drink plenty of water. You should also check on the vulnerable groups mentioned above to ensure they have the resources necessary to stay cool such as air conditioning and water.

Pre-Class Activity 1, 3, 5

Instructions: Before teaching about heat waves and drought, have the students answer the questions below, followed by a scenario question for in-class discussion between you and your students.

1. Which of the following is not a type of drought?
    a. Socioeconomic drought
    b. Agricultural drought
    c. Desert drought
    d. Hydrological drought
    e. Meteorological drought

2. Droughts and heat waves are most frequently associated with
    a. persistent low pressure systems.
    b. persistent high pressure systems.
    c. persistent cold fronts.
    d. stationary fronts.

3. All of the following variables except which are used to monitor drought?
    a. Cloud cover
    b. Ground water supply
    c. Precipitation
    d. Surface evaporation rates
    e. Water use

4. Precipitation is monitored using which of the following?
    a. Thermometer
    b. Doppler radar
    c. Rain gauges
    d. a & b
    e. b & c

5. Which weather variable reduces our body's ability to cool down efficiently?
    a. Increasing temperature
    b. Decreasing temperature
    c. Increasing relative humidity
    d. Decreasing relative humidity
    e. Increasing precipitation

Discussion Question: There has been an Excessive Heat Warning issued for your area. What steps should you take to ensure you and your family's safety? What are some risks associated with prolonged periods of extreme heat exposure?

In-Class Activity

Instructions: In this project, your group will forecast and prepare for a major drought and heat wave in the U.S. Each group member will choose one of the following roles and complete the tasks written at the end of each section.

1. Meteorologist
2. Chicago citizen
3. Mayor of Chicago
4. Wal-Mart Store Owner

Real World Scenario: Meteorologist [5]

Task #1 The surface reports below were obtained from stations affected by a summer heat wave. In each case, estimate the Heat Index using the table provided.

	Temperature	Relative Humidity	Heat Index
a)	90°F	55%	_____
b)	103°F	45%	_____
c)	86°F	75%	_____
d)	80°F	45%	_____
e)	95°F	70%	_____

Relative Humidity (%)

Air Temperature (°F)

	40	45	50	55	60	65	70	75	80	85	90	95	100
110	136												
108	130	137											
106	124	130	137										
104	119	124	131	137									
102	114	119	124	130	137								
100	109	114	118	124	129	136							
98	105	109	113	117	123	128	134						
96	101	104	108	112	116	121	126	132					
94	97	100	102	106	110	114	119	124	129	136			
92	94	96	99	101	105	108	112	116	121	126	131		
90	91	93	95	97	100	103	106	109	113	117	122	127	132
88	88	89	91	93	95	98	100	103	106	110	113	117	121
86	85	87	88	89	91	93	95	97	100	102	105	108	112
84	83	84	85	86	88	89	90	92	94	96	98	100	103
82	81	82	83	84	84	85	86	88	89	90	91	93	95
80	80	80	81	81	82	82	83	84	84	85	86	86	87

Heat Index
(Apparent Temperature)

Courtesy of the National Weather Service, NOAA

Task #2 On the map below, build a composite map that shows the locations in the U.S. where significant drought is occurring and where flooding is occurring. To do this, examine the latest drought monitor map, linked below, and shade in on the map below all locations experiencing "moderate" to "exceptional" drought (use the legend in the lower right). Then examine the annual percent of normal precipitation map for the U.S. These maps are created using Doppler radar data and one can quickly identify locations of abundant precipitation, as well as regions of drought. Use the drop down menus at the bottom of the webpage (linked below) to select 'Yearly', 'Full Year', and 'Percent of Normal'. Then outline all areas that are currently experiencing at least 150% of their total rainfall (scale on right-hand side of map).

USDA Drought Monitor **http://droughtmonitor.unl.edu/**
NWS Precipitation Map **http://water.weather.gov/precip/**

Task #3 As a meteorologist, it is important that you learn to properly convey weather information to the general public. Your task is to create a 5-minute weather broadcast, like you might see on the Weather Channel, about droughts and heat waves. Remember that your classmates will not know much about what you have just learned so be sure to address the following topics in your broadcast:

1. Convey statistics about droughts and heat waves in the U.S. (fatalities, numbers, etc.)
2. Discuss drought formation in the central U.S.
3. Explain the drought monitor and how precipitation is monitor.
4. Explain how the urban heat island works.
5. Discuss the heat index.
6. Talk about recent drought in the U.S. or historical droughts that have had a major impact on the U.S.

Build this weather broadcast using presentation software (like PowerPoint) and be sure to supplement everything you discuss with images and videos. Your teacher has access to several videos and pictures of drought so make sure to use your teacher as a resource as well as the Internet. Be sure both informative and entertaining!

Real World Application: Chicago Citizen

In the last 10 years, deaths from heat waves have been by far the deadliest weather phenomenon in the United States. Channel 5 News in Chicago, IL has just announced that a weeklong heat wave is expected to hit your area with heat index values climbing above 120^{o}F for 7 days. You must work with your family to create an evacuation plan so you are prepared and survive the heat wave.

Task #1

Each question discusses different situations people find themselves in during a heat wave. Answer the following questions to help each group prepare for and survive a heat wave. Be detailed, these answers will help you create an evacuation plan in part two!

1. An elderly grandparent with a heat aggravated illness (like asthma) lives with your family.
    a. What window coverings could you use to minimize the amount of heat exposure? Remember *reflective surfaces* will redirect sunrays away from the house.
    b. What level of the house should they be on? Remember *heat rises*!
    c. What items should you prepare to help keep them cool?
    d. If they suddenly become ill, who should you call? Where can you take them?

2. You are a single mom with young children in your house.
    a. How do you keep your children entertained? What will you need to prepare for keeping them occupied?
    b. What should you give your children to keep them hydrated? Remember *sugars dehydrate* the body, so no soda!
    c. What food should they be kept away from? Remember *salt dehydrates*!
    d. What clothing should they be dressed in? Should it be tight or lose, why? Remember *light colors* reflect heat and sunlight.

3. Your neighborhood experiences a blackout and you lose electricity.
    a. Where could you seek out air conditioning?
    b. How would you get there?
    c. What do you need to bring with you?
    d. Your refrigerator and freezer won't work anymore- what food will you save and what will perish? Think about what will last the longest and help keep the body cool.

Task #2

Using your answers to the previous questions, create a one-page survival guide and evacuation plan to help someone prepare and survive a heat wave. This guide must include evacuation route in the event that your home becomes too unbearable to live in.

Here are some questions you can try to answer if you are not sure where to start:

1. How to prepare for a heat wave?
    a. What items may you need to buy?
    b. What can you do to help insulate the house from heat?
    c. Who may you need to check on? Do you have any elderly grandparents?
    d. Health effects to take into consideration?

2. How can you prepare now for things that may happen during a heat wave?
    a. Who will you call if an emergency arises?
    b. Where can you go if the electricity goes out?
    c. What risks will you face during a heat wave?

Real World Scenario: Mayor of Chicago, IL

You are the mayor of Chicago, one the largest cities in the United States. As mayor, you are responsible for the well being of millions, and any decisions you make can have large impacts on many lives.

Imagine now that a devastating heat wave has just struck your city! This heat wave lasts for seven days, and during this time, heat index values climb to more than 120 degrees Fahrenheit. As temperatures continue to rise, more and more lives are in danger. To complicate the situation even further, Chicago is a major city; urban areas like this one are in even more danger during heat waves since this type of environment allows for absorption of heat, causing maximum damage. Your job as the mayor of Chicago is to develop a plan of action that ensures the fewest hospitalizations and fatalities as possible.

Task

Designate one of your group members as a TV news reporter and have them conduct an interview with the student who will play the role of the mayor of Chicago. Use the questions below in your interview.

1. When should you begin issuing warnings? When should you use your heat-emergency plan?

2. How will you inform citizens of the dangers and how to stay safe?

3. What will you do to help at-risk populations such as poorer people without air-conditioning? What about older citizens who are at a higher risk for heat illnesses? People who live alone?
    a. Will you establish cooling centers and transportation to them?
    b. Will you implement a phone-calling system to check in on these citizens?

4. Providing resources to aid the at-risk populations requires some extra considerations. What kind of issues do you think now pop up as a result of offering them?
    a. How will you stock cooling centers with food and water?
    b. Who will work the phone centers?

5. How will you adjust hospitals, fire departments, ambulances, etc. to accommodate for the extra patients?
    a. Will additional resources and workers be necessary?
    b. What about citizen volunteers?

6. Fatalities and hospitalizations aren't the only thing to worry about during this heat wave. Power outages are often another consequence of events like this, and the results can be devastating. As mayor, it's crucial that you monitor the city's power grid and restore power in the event of an outage.
    a. What steps can you take to prevent a power outage from occurring?
    b. What about dealing with one if it does occur? Who will you remain in contact with?

Real World Scenario: Wal-Mart Store Owner

You are a business owner in downtown Chicago, IL. You are the owner and manager of a Wal-Mart Superstore in the city, and your store is open 24 hours a day**.**

A heat wave hits Chicago! Temperatures have skyrocketed, and the heat index indicates dangerous conditions outdoors. More and more people are exhausted from the heat, and many have to be hospitalized for heat stroke. A large number of Chicago citizens do not have air conditioning in their residencies, and as a result, thousands of people are flocking to your Wal-Mart Superstore in order to be in the air conditioning that your store provides 24 hours a day. Your store is now facing troubles due to constant overcrowding!

1. How do you handle the overwhelming surge of people? Do you stick to the required maximum number of people that your space can handle, or do you let in as many people as you can in order to give them relief from the heat?

2. You are facing a huge problem with people who are loitering, or lingering in your store without purchasing anything. Do you kick these people out because they are not paying customers? Or do you let them stay in your store for the air-conditioning?

3. Soon the bathrooms in your Wal-Mart are being used much more than usual; the bathrooms become unclean, and you don't have enough supplies. What do you do?

4. Parking becomes an issue. Your Wal-Mart customers want to shop in your store, but they can't find a parking space because your lot is always full. What action do you take?

5. Eventually, your Wal-Mart employees are tired of doing the extra work it takes to handle the crowds. What action do you take? Do you pay your employees more? Do you hire more workers? Explain your decision.

6. After thinking about all these issues that come up if your store is overcrowded, will you consider shutting down your store for a few hours a day, in order to clear the crowds out? Or will you still keep your Wal-Mart open 24 hours a day to provide air conditioning for everyone? Explain your decision.

7. Many business managers keep an informational manual or poster in their offices, with instructions on how to handle overcrowding in their stores if a heat wave occurs. What kind of helpful tips would you put on an informational poster for a business owner to follow during a heat wave?

Task

Address the classroom as if they were employees at Wal-Mart by answering and discussing the questions listed above.

Take Home Assignment

Part 1. Multiple Choice (Circle one) [1]

1. The heat index chart takes which two weather variables into account?
    a. Temperature and precipitation
    b. Temperature and relative humidity
    c. Temperature and wind speed
    d. Temperature and pressure
    e. Temperature and drought

2. Drought in the central and eastern United States begins in which season?
    a. Winter
    b. Spring
    c. Summer
    d. a & b
    e. b & c

3. What is the name of the infamous drought that occurred in the 1930s?
    a. The Dusty Drought
    b. The 1930s Drought
    c. The Dustbowl
    d. The Midwest Dryout

4. The urban heat island effect results from
    a. drought on islands
    b. drought in urban areas
    c. absorption of heat by city buildings
    d. nighttime heating of building surfaces
    e. a lack of precipitation

5. The extreme deterioration of land in arid and dry areas due to loss of vegetation and soil moisture can be described as
    a. Desertification
    b. Droughtification
    c. Deterioration
    d. Heat wave

Part 2. Matching 1, 2, 5, 7

Instructions: Match the type of drought to the description given. Give an example of how a person or object would be greatly affected by the type of drought.

1. A reduction in topsoil moisture, which can impact the health of vegetation.

   Drought Type _____
   Effect:

2. A reduction in ground water supply in rivers, lakes, streams, and ground water.

   Drought Type _____
   Effect:

3. A prolonged time period of below normal precipitation for a region.

   Drought Type _____
   Effect:

4. A reduction in water supplies intended for human consumption or use.

   Drought Type _____
   Effect:

Now, view the current Drought Monitor map by clicking the link and answer the questions below.

Drought Monitor

5. Where in the U.S. is extreme/exceptional drought occurring (western, central, eastern U.S.)?

6. In this particular region of the U.S., what causes drought?

7. What are the four variables that require careful observation when monitoring a drought?

    1. _____

    2. _____

    3. _____

    4. _____

8. Name two commonly used instruments to monitor precipitation and drought?

    1. _____

    2. _____

Part 3. Heat Waves [7]

Instructions: Calculate the heat index for 3 days in Chicago, IL and answer the following questions.

Day 1: T = 102°F, RH = 40% Heat Index _____

Day 2: T = 100°F RH = 45% Heat Index _____

Day 3: T = 117°F, RH = 55% Heat Index _____

1. Based on these heat index values, which would you issue: a heat advisory or an excessive heat warning to the city of Chicago?

2. List 3 health impacts are people likely to encounter if exposed to this extreme heat?

Student Evaluation 1, 4, 5, 9

Instructions: After completing the lesson on heat waves and drought, please have the students answer the following questions below.

1. Based on a 10-year average, how many people die from heat each year?
    a. 40
    b. 50
    c. 100
    d. 115
    e. 200

2. Which of the following groups is not especially vulnerable to extreme heat exposure?
    a. Children
    b. Elderly persons
    c. People with asthma
    d. People with seasonal allergies
    e. People with chronic illnesses

3. How does a drought begin in the western United States?
    a. Insufficient rainfall
    b. Insufficient snowpack
    c. Above average temperatures
    d. Lack of thunderstorms

4. The drought monitor takes into account
    a. relative humidity
    b. temperature
    c. short-term conditions
    d. long-term conditions
    e. thunderstorms

5. Below 95^{o}F, the human body can efficiently cool itself by
    a. conduction
    b. convection
    c. radiation
    d. evaporation
    e. all of the above

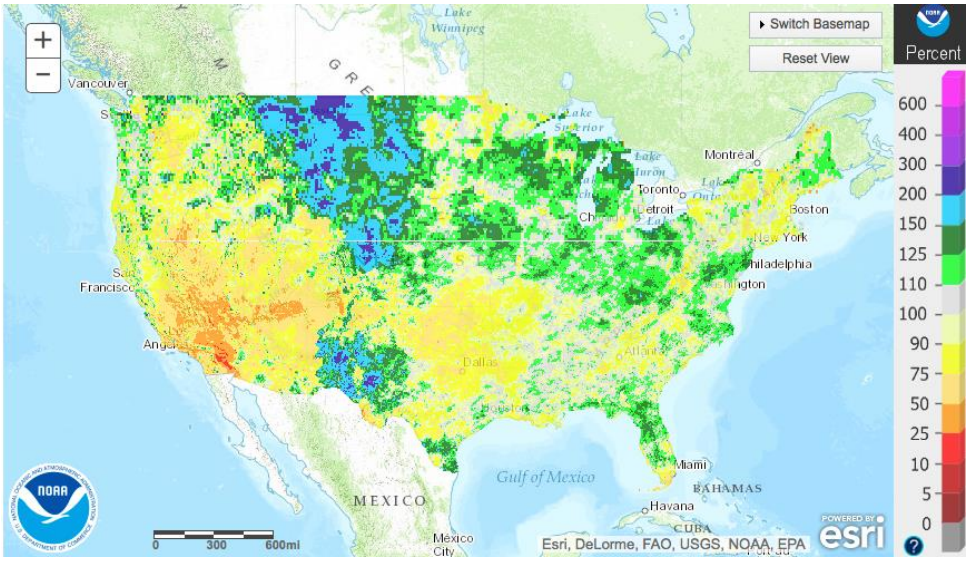
6. Heat waves and drought are the deadliest forms of weather. T F

7. Drought is associated with persistent low pressure systems. T F

8. Drought has caused famine, war, and widespread poverty. T F

9. The Heat Index accounts for how moisture in the atmosphere affects how efficiently your body can cool. Briefly explain why high humidity makes you feel hotter.

10. The map below shows the annual precipitation (percent of average). If the shading is more than 100%, the annual precipitation is above average. The average annual precipitation for Chicago, IL is 52 inches. If Chicago has experienced 130% of their annual average precipitation to date, how much precipitation has fallen so far this year?
    a. 40 inches
    b. 52 inches
    c. 67.6 inches
    d. 104 inches



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. **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; Pre-Class Activity; Take Home Activity: Part 1 & 2; Student Evaluation

2. **NGSS.MS-ESS3-2**

MS-ESS3-2. Human Impacts
Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
Lecture: Implications of Drought; Take Home Activity: Part 2

3. **NGSS.MS-ESS2.5**

MS-ESS2-5. Weather and Climate
Provide evidence for air pressure systems and resulting weather conditions.
Lecture: Drought Formation; Pre-Class Activity

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

MS-ESS2-4. Earth's Systems
Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
Lecture: Drought Formation, Monitoring Drought; Student Evaluation

5. **NGSS.MS-ESS3-3**

MS-ESS3-3. Human Impacts
Apply scientific principles to design a method for monitoring and minimizing human impact on the environment.
Lecture: Monitoring Drought, Historic Drought; Pre-Class Activity; In-Class Activity: Meteorologist; Take Home Activity: Part 2; Student Evaluation

6. **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: Urban Heat Island

7. **CCSS.ELA-LITERACY.RST.6-8.3**

Grade 6-8: Science and Technical Subjects
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
Take Home Activity: Part 2 & 3

8. **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

9. **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.
Student Evaluation