CLIMATE CHANGE *and* THE WATER CYCLE

A 10-Hour Curriculum Unit for 6-12 Grade Students

USDA Southwest Regional Climate Hub

Developed by the Asombro Institute for Science Education

CLIMATE CHANGE AND THE WATER CYCLE

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CLIMATE CHANGE AND THE WATER CYCLE

A 10-Hour Curriculum Unit for 6-12 Grade Students

Welcome! This unit was designed to introduce 6-12 grade students to climate change, the water cycle, and the effects of the changing climate on water resources. The activities in this guide are appropriate for both formal and informal education settings, and they can be modified to fit the needs of students. All activities are aligned to Common Core State Standards and Next Generation Science Standards when applicable.

This curriculum is organized as a 10-day (or 10-hour) unit, with each activity building on the last. The unit need not be completed in its entirety, however. All of the activities can be conducted individually as well. There are nine activities, and some span multiple days (or hours). The Unit Schedule outlines a proposed schedule of activity completion, assuming one-hour periods. Some days on the Unit Schedule contain several activities, and some activities are completed over multiple days. Days on the schedule can be converted to hours to better suit the time available. Each activity includes an estimated time for completion.

The materials required for the activities can generally be purchased at a household goods store, and some are items that many educators often have available. There are very few specialized supplies needed. Each activity includes a materials section that lists the items required to complete the activity, with provided resources, such as handouts and PowerPoint files, listed first. When viewing this guide electronically with an internet connection, the links within the materials section will navigate to each of the listed resources.

We hope that you and your students enjoy these activities! Please contact the editor with questions and feedback at s.haan-amato@asombro.org.

CLIMATE CHANGE AND THE WATER CYCLE

Unit Schedule

This unit is designed to be used over 10 days (or 10 hours). The unit need not be completed in its entirety, however. All of the activities can be conducted individually as well.

Day 1

INSULATING YOU, INSULATING EARTH
Examining the Enhanced Greenhouse Effect

Day 2

WEATHER OR CLIMATE?
You Decide!

UNDERSTANDING THE DIFFERENCE
Do the American Public and Media Know the Difference Between Weather and Climate?

EVAPORATION INVESTIGATION

Day 3

THE WATER CYCLE GAME

EVAPORATION INVESTIGATION
Measurements

Day 4

STREAMS AND STEAM
Effects of Climate Change on the Water Cycle

EVAPORATION INVESTIGATION
Measurements

Day 5

EVAPORATION INVESTIGATION
Conclusion

READY, SET, GROW
How Does Climate Change Affect Primary Producers?

Day 6

RAINOUT SHELTERS
How Does the Availability of Water Affect Plant Growth in the Desert?

Day 7-10

CLIMATE DATA JAM
Communicating Climate Data to Nonscientists

Examining the Enhanced

Greenhouse Effect

DESCRIPTION

To model the enhanced greenhouse effect, students conduct an experiment using their own body heat, thermometers, towels, and space blankets.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Make a prediction using prior knowledge and experience
- Model the greenhouse effect
- Synthesize the results of an experiment
- Use data and models to forecast the rate of climate change and impacts on Earth

TIME
1 HOUR

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

Grade 6 » Statistics & Probability
CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: CCSS.MATH.CONTENT.6.SP.B.5.C. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

NEXT GENERATION SCIENCE STANDARDS

Middle School
MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

High School
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

BACKGROUND

Earth is surrounded by an atmosphere of gases, which remains near the planet because of gravitational force. The atmosphere is composed mostly of nitrogen, oxygen, argon, and carbon dioxide, and it functions to moderate the climate of Earth.

The **greenhouse effect** describes the process by which the climate is regulated by greenhouse gases: carbon dioxide, water vapor, ozone, methane, nitrous oxide, and fluorinated gases. Electromagnetic radiation from the sun, mostly at short wavelengths in the form of light, is able to pass through the atmosphere and is absorbed by Earth. Electromagnetic radiation at longer wavelengths, often called infrared radiation or heat, is re-radiated from Earth up to space. Unlike solar radiation, most long-wave radiation is absorbed by greenhouse gases (or clouds) and re-emitted in all directions. The long-wave radiation re-emitted downward warms the surface. The greenhouse effect effectively traps heat near Earth and ensures that the planet is warm enough to sustain life.

Since the Industrial Revolution, humans have been emitting increasing amounts of greenhouse gases into the atmosphere, especially carbon dioxide, methane, and nitrous oxide, mostly through energy production, transportation, and industry. As additional greenhouse gases are released into the atmosphere, more of the re-radiated heat from Earth is re-emitted back to the planet instead of escaping into space. This **enhanced greenhouse effect** is causing average global temperatures to increase. With this increase in temperature, Earth is experiencing changes in weather, climate, and ocean systems. The effects include increased droughts in some areas, increased flooding in other areas, melting glaciers and ice, rising sea levels, altered timing of stream flows, and ocean acidification.

MATERIALS

- *Insulating You, Insulating Earth* handout [1 per student]
- PowerPoint presentation
- Computer and projector
- Binder clips, size small (¾″ wide) [1 per every four students]
- Calculators [1 per every four students or more if available]
- Hand towels (16″ x 26″ or larger) [1 per every four students]
  - If working with adults or older students, may also want a few small bath towels (27″ x 52″ or smaller)
- Mylar space/emergency blanket (Figure 1), cut into rectangles of approximately 20″ x 26″ or larger if needed [1 per every four students]
- Stopwatches [1 per every four students]
- Thermometers,* preferably ones with a probe and separate digital readout, such as the meat thermometer shown in Figure 2 [1 per every four students]

Figure 1. Example Mylar emergency/space blanket »

« Figure 2. Example meat thermometer with probe and digital readout

***Some notes about thermometers:** A thermometer without a probe and digital readout can be used. However, students will not be able to check the temperature readings every minute as instructed in this activity because, if so, they would have to lift the towel to read the thermometer, which would release the trapped heat. Instead, if using a thermometer without a probe, students should **only** read and record the temperature of the test subject's lap before placing the towel on top and after 5 minutes, immediately after removing the towel.

- If a different type of thermometer is used, an alternative method of fastening the thermometer to the clothing on students' laps may be needed.
- If a different type of thermometer is used, it is recommended that the educator try the experiment using their own lap several times before conducting the activity with students.

Another option is an indoor-outdoor thermometer with a digital readout and wired sensor (such as the one found here: http://www.taylorusa.com/digital-indoor-outdoor-thermometer-hygrometer.html). However, in our testing of an indoor-outdoor thermometer, it seemed slower to respond and register changes in temperature, and students may not see as large of a temperature difference.

PREPARATION

1. Plan to divide students into teams of four. If necessary, teams of three or five would also be acceptable, as activity tasks can be combined or divided.
2. Plan locations for the appropriate number of stations needed to accommodate the number of student teams in the group. Stations can be simple tables and chairs with enough space for three to five students, and no power source is needed.
3. Place a small binder clip, calculator, stopwatch, thermometer, towel, and rectangle of space blanket at each station.
4. Draw the "Whole Class" table from page 3 of the *Insulating You, Insulating Earth* handout on the board or prepare to show it with a document camera.
5. Set up a computer and projector and display the PowerPoint presentation.

PROCEDURES

Experimental Setup and Greenhouse Effect Introduction

1. Divide students into teams of four and place students at stations.
2. Pass out an *Insulating You, Insulating Earth* handout to each student.
3. Instruct students to read the team member roles on the front page of the handout and choose one role for each student in the group.

Figure 3. Meat thermometer set up

4. Display the "Setting Up the Experiment" slide in the PowerPoint presentation (Slide 2). The test subject will use a binder clip to attach the wire of the meat thermometer to the clothing on their lap. Instruct the student to point the metal probe toward their hip, and attach the binder clip approximately halfway down the length of their thigh (Figure 3). Ensure that the thermometer probe is contacting the student's thigh as much as possible. The probe should not be pointed sideways or hanging off of the student's lap.
5. The meat thermometer can take up to five minutes to accurately display the initial temperature of students' laps. Instruct students to watch the temperature casually and note whether it increases, decreases, or stays the same. Now that students have their thermometers in place, take some time to explain the experiment, have students make a prediction, and give a short introduction to the greenhouse effect.
6. Explain to the class that they will be conducting an experiment to determine which will insulate better: a single towel or a towel plus a space blanket on top. Tell students that they will first place a towel over the thermometer and perpendicular to their thighs while demonstrating with one of the towels. They will record the temperature every minute for five minutes. Then say that they will place the towel back on their lap and put a rectangle of space blanket on top while demonstrating with a towel and space blanket. Explain that the space blanket is made of Mylar, which is a good insulator (and also used for balloons), and it can be used as a blanket in emergencies.
7. Ask students to make a prediction about which trial will result in warmer temperatures and then fill in the blank of the prediction statement on the front page of the handout.
8. Give a short introduction to the greenhouse effect using the PowerPoint presentation.
   a. **Slide 3**: we have gases in our atmosphere that trap heat called greenhouse gases, and they are: carbon dioxide, water vapor, ozone, methane, nitrous oxide, and fluorinated gases.
   b. **Slide 4 (a)**: begin with the diagram on the left. The greenhouse effect ensures that Earth is warm enough for us to inhabit. Our atmosphere contains greenhouse gases, like carbon dioxide, methane, and nitrous oxide. Electromagnetic radiation from the sun, mostly at short wavelengths in the form of light, is able to pass through the atmosphere and is absorbed by Earth. Earth re-radiates some of this energy back toward space as heat, which is long-wave radiation. Most of the heat is able to pass through the atmosphere and escape into space, but some is absorbed by the atmosphere and then re-emitted back to Earth.
   c. **Slide 4 (b)**: now explain the diagram on the right. This is the enhanced greenhouse effect, which is caused by increased greenhouse gases in our atmosphere. As more greenhouse gases are released into the atmosphere, more of the re-radiated heat from Earth is re-emitted back to Earth instead of escaping to space. This is causing the average global temperature to increase.
   d. **Slide 5**: ask students which is the closest planet to the sun in our solar system [answer: Mercury]. Ask students which is the hottest planet in our solar system [answer: Venus]. Ask students if they know why Venus is the hottest planet even though it is not the closest to the sun. Venus has a very thick atmosphere, comprised mostly of carbon dioxide. Carbon dioxide is a greenhouse gas, which effectively traps the heat within the atmosphere

of Venus. High temperatures on the surface of Venus can reach almost 900°F. Venus serves as a natural experiment of the runaway greenhouse effect, demonstrating how high levels of greenhouse gases in the atmosphere result in high temperatures.

e. **Slide 6**: this pie chart shows the percentage of each of the greenhouse gases that humans emit through our activities. Carbon dioxide accounts for more than 75% of the greenhouse gases that we release.
f. **Slide 7**: humans emit carbon dioxide mostly through fossil fuel combustion, i.e. the burning of coal, natural gas, and oil, for the production of electricity and transportation. Many industrial processes rely on fossil fuel combustion as well, and the production of mineral products, such as cement, the production of metals, and the production of chemicals can all result in carbon dioxide emissions.
g. **Slide 8**: since 1958, scientists at Mauna Loa, on a Hawaiian island in the North Pacific, have been collecting atmospheric data. This graph shows the concentration of carbon dioxide in the atmosphere as measured at Mauna Loa. Ask students to describe the trend of this graph [answer: carbon dioxide is increasing]. Ask students why they think scientists would choose to take this measurement at Mauna Loa [answer: to minimize the effects of local surface CO_2 emissions and air pollution so that the measurement is representative of the global atmosphere.]
h. Stop the presentation here to conduct the experiment.

TOWEL TRIAL

1. Ask students to read the current temperature of their thermometers and tell you whether it has increased, decreased, or stayed the same since they clipped it to their clothing. The temperature should have increased initially and then mostly stabilized.
2. Once the temperature has stabilized, direct each team's data recorder to record the temperature in the lap row of the towel temp column. The data recorder is the team member who is responsible for writing down all of the data, but all students must complete the data table as well.
3. Instruct the materials manager to give the towel to the test subject. The test subject lays the towel over the thermometer and across their lap so that its long side is perpendicular to their thighs. Then they tuck the ends of the towel under their legs if possible; if it will not tuck under, just ensure that it is covering the thermometer.
4. As soon as the towel is in place, instruct the timer to press the start button on the stopwatch.
5. Explain to the timer that for each minute that passes, they are to call out the time to the data recorder.
6. Explain to the data recorder that when the timer calls out the time, they are to read the temperature on the thermometer, and record it in the corresponding row of the towel temp column.
7. Tell students to stop recording after 5 minutes. If you would like to extend the data collection time for this activity, have students continue to write temperature data on a separate piece of paper (see the Extensions section).
8. At the conclusion of the measurements, instruct the timer to reset the stopwatch.
9. Quickly ask the test subject to remove the towel from their lap but **leave the thermometer attached**. The goal is to return the thermometer to approximately the same temperature as the beginning lap temperature in the towel only trial. This can take 2-3 minutes. If it takes too long, you can instruct students to fan the metal probe with a piece of paper to speed up the cooling, but be cautious of fanning it for more than 20-30 seconds, which could result in the temperature decreasing too much.
10. While waiting for the thermometer to stabilize and return to the beginning lap temperature in the towel-only trial, ask students to complete the subtraction problem on the third page of the handout (in-between the tables). They fill in the blanks with the temperature of their final measurement (5 min., unless you choose to take measurements for longer) and the temperature of the test subject's lap at the beginning of the trial. They then calculate the difference by subtracting lap temperature from the 5 min. temperature.

TOWEL + SPACE BLANKET TRIAL

1. When the thermometer stabilizes at approximately the same as the beginning lap temperature in the towel trial, begin the second trial. Instruct the data recorder to record the beginning lap temperature in the towel and space blanket temp in the lap row.
2. Ask the materials manager to give the towel and then the space blanket rectangle to the test subject.
3. Instruct the test subject to, first, lay the towel over the thermometer and across their lap, and then place the space blanket rectangle on top. Both should be oriented so that the long side is perpendicular to their thighs. Have them tuck both the towel and the space blanket under their legs together if possible. If they will not tuck under, just ensure that they are covering the thermometer.
4. As soon as the towel and space blanket are in place, the timer starts the stopwatch.
5. Explain to the timer that for each minute that passes, they call out the time to the data recorder.
6. Explain to the data recorder that when the timer calls out the time, they read the temperature on the

thermometer, and record it in the corresponding row of the towel and space blanket temp column.
7. Tell students to stop recording after 5 minutes (unless you would like to extend the data collection time for this activity).
8. The test subject can remove the space blanket, towel, and thermometer.
9. Instruct students to calculate the difference in towel and space blanket temperature.
10. Ask students to report the temperature differences in the towel trial and the towel and space blanket trial to the class. Have students record their differences in the table on the board, or they can call them out to you while you write them on the board. Students must then record them in their "Whole Class" table on their handout and calculate the mean.

RESULTS AND CONCLUSIONS

1. Have students answer the results and conclusions questions.
2. If you would like to discuss evaluation question number 1 with students, return to the PowerPoint presentation.
    a. **Slide 9**: Quickly review the left and right sides of the diagram, explaining the natural greenhouse effect and the enhanced greenhouse effect.
        i. The experiment that students just conducted was a model of the natural greenhouse effect and the enhanced greenhouse effect.
        ii. Ask students to determine which item in the experiment modeled the earth and discuss how it is like the earth [answer: the student's lap modeled the earth because it emits heat].
        iii. Ask students to determine which item in the experiment modeled the atmosphere and discuss how it is like the atmosphere [answer: the towel modeled the atmosphere because the towel absorbed some of the heat and re-emitted it back toward the lap, effectively trapping it and keeping the lap warmer].
        iv. Ask students to determine which item in the experiment modeled the additional greenhouse gases and discuss how it is like additional greenhouse gases [answer: the space blanket because, once it was added, more of the heat from the lap was re-emitted back to the lap instead of escaping to into the room].
3. Use the PowerPoint presentation to explain the concept of climate change and wrap up the activity.
    a. **Slide 10**: the atmosphere influences our climate, and we conducted the experiment to model one aspect of how our climate is changing. Explain that climate is the description of the long-term pattern of weather in a particular area. Long-term usually means approximately 30 years. Make sure that students understand that in order to be considered climate, conditions must be averaged over a long time period. Today's weather in your area (or even this month's or this year's) is not the same as the climate.
    b. **Slide 11**: the climate of Earth is changing. Read the definition for climate change. Tell students that climate change includes global warming (the temperature of Earth is increasing), changes in precipitation patterns, and more severe storms.
    c. **Slide 12**: we have recorded data on Earth temperatures since 1880. Ask students to describe the trend of this graph [answer: temperature is increasing].
    d. **Slide 13**: remind students that you discussed carbon dioxide levels in the atmosphere earlier and that these are shown in the top graph. Temperature is shown in the bottom graph. Ask students to describe the relationship between CO_2 and global temperature [answer: as carbon dioxide increases, global temperature increases].
    e. **Slide 14**: our atmosphere acts like one blanket around the earth and keeps our planet warm enough for us to inhabit. However, when we add greenhouse gases to our atmosphere, we are putting on an additional blanket (click slide forward to display second blanket). This extra blanket results in temperatures that are too warm for species that are adapted for recent historic local temperatures, and is causing changes to atmospheric conditions and weather patterns, which will have large impacts on humans.
4. If you would like to discuss evaluation question numbers 2 – 4 with students, display slide 15.
    a. **Slide 15**: scientists used several models to predict global temperatures by the end of the century, in the year 2100. This graph displays three global temperature projections, shown by the colored lines. The three lines represent different scenarios for the amount of warming that will occur, which depends on the activities of humans. The amount that the temperature will increase depends greatly on human population growth and the amount of greenhouse gases emitted in this century.
    b. Direct students to look at evaluation question 2 and at the scenario with the warmest projected temperatures, shown by the top (red) line of the graph. Emphasize that they should only be considering the top line of the graph. Ask them to estimate the approximate number of degrees Fahrenheit by which the average temperature is projected to increase by 2100 in the warmest scenario [answer:

approximately 6 – 8 °F].

c. Direct students to look at evaluation question 3 and at the scenario with the lowest projected temperatures, shown by the bottom (blue) line of the graph. Emphasize that they should only be considering the bottom line of the graph. Ask them to estimate the approximate number of degrees Fahrenheit by which the average temperature is projected to increase by 2100 in the lowest temperature scenario [answer: approximately 2 – 4 °F].
d. Ask students to consider question 4 and solicit answers. Although temperature increases of 2 – 8 °F may not sound like much, the impacts are likely to be great. We will continue to experience increases in snow and glacial melt; increased sea levels; less rainfall in the Mediterranean, southwest North America, and southern Africa; and more precipitation in Alaska and other high latitudes of the Northern Hemisphere. These changes will impact humans through increased droughts and wildfires in some areas, increased severe storms and flooding in other areas, and reduction in food production.

EXTENSIONS

1. After students conduct the experiment as outlined, they may have ideas for further research. Students are often interested to investigate what happens under different scenarios. Here are some ideas for additional student-directed inquiry, but feel free to encourage your students to think of more:
    a. Conduct the experiment for a longer time period. The temperature differences are greater and there is a more pronounced difference between the two trials if you allow the experiment to continue for up to 15 minutes.
        i. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
    b. Add more layers of insulating materials, such as additional towels and space blankets, small blankets, jackets, etc., and conduct the experiment again.
        i. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
        ii. Ask students to reflect on how their extension experiment relates to the natural and enhanced greenhouse effect.
            1. For example, some additional insulating materials may not result in increased temperatures because they are not as efficient at insulating as space blankets. This is analogous to adding non-greenhouse gases, such as O_2, to the atmosphere.
    c. Carry out the experiment on an object that does not generate heat, such as a rock.
        i. Ask students to hypothesize about the temperature change [answer: insulating a rock will not change its temperature because the rock does not have an internal temperature source like a person does. The rock is in energy balance with the surrounding air.].
        ii. Record the results on a separate piece of paper. Ask students to determine which variables they will be measuring and how they need to construct their data table.
2. Have students research ways to reduce greenhouse gases and create an education campaign for their school or community.

ADDITIONAL RESOURCES

Website with helpful background information:

Environmental Protection Agency (EPA). Climate Change: Basic Information. Published 18 Mar. 2014. Web. Accessed 09 Oct. 2014. <http://www3.epa.gov/climatechange/basics/>.

Name ____ Date ________________

INSULATING YOU, INSULATING EARTH

Examining the Enhanced Greenhouse Effect

SETTING UP THE EXPERIMENT

1. Please work with your instructor to assemble into teams of 4.

2. Each team member will choose a role from the list of team member roles below.

TEAM MEMBER ROLES
Test subject
Materials manager
Timer
Data recorder

3. **As quickly as possible**, the team member who is the test subject will use a binder clip to attach the thermometer to the clothing on their lap. Attach the binder clip approximately halfway down the length of the thigh, and ensure that as much of the thermometer as possible is contacting the leg (Fig. 1).

4. Complete the prediction and follow the procedures.

Figure 1. Example thermometer set up

PREDICTION

I predict that the temperature of the ______________________________ trial will be **warmer**.

a. Towel

b. Towel + space blanket

c. Neither (they will be the same)

MATERIALS

- Thermometer
- Small binder clip
- Stopwatch
- Hand towel
- Rectangle of space blanket
- Calculator

PROCEDURES FOR TOWEL TRIAL

1. **Data recorder,** once the temperature reading of the test subject's lap has stabilized, record the temperature in the "Your Group" table. It can take several minutes for the temperature to stabilize. Enter the temperature under the "Towel Temp" column in the "Lap" row.
2. **Materials manager**, give the towel to the **test subject**. Test subject, lay the towel over the thermometer and across your lap so that its long side is perpendicular to your thighs, and tuck the ends of the towel under your legs if possible. **Timer**, press the start button on the stopwatch.
3. **Timer**, every time a minute passes on the stopwatch, call out the time to the data recorder. **Data recorder**, when the timer calls out the time, read the temperature on the thermometer and record it in the corresponding row of the "Towel Temp" column. Stop recording after 5 minutes. **Timer**, stop and reset the stopwatch.
4. **Test subject**, remove the towel from your lap and give it to the materials manager. **Leave the thermometer clipped to your lap.**
5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel temperature.

PROCEDURES FOR TOWEL + SPACE BLANKET TRIAL

1. Wait until the thermometer reads approximately the same as the beginning lap temperature in the towel trial.
2. **Data recorder**, record the beginning lap temperature under the "Towel + Space Blanket Temp" column in the "Lap" row.
3. **Materials manager**, first give the towel and then the space blanket rectangle to the test subject. **Test subject**, lay the towel over the thermometer and across your lap, and then place the space blanket rectangle on top. Both should be oriented so that the long side is perpendicular to your thighs. Tuck both the towel and the space blanket under your legs together if possible. **Timer**, press the start button on the stopwatch.
4. **Timer**, every time a minute passes on the stopwatch call out the time to the data recorder. **Data recorder**, when the timer calls out the time, read the temperature on the thermometer, and record it in the corresponding row of the "Towel + Space Blanket Temp" column. Stop recording after 5 minutes. **Timer**, stop and reset the stopwatch.
5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel + space blanket temperature.
6. Report the temperature differences in your towel trial and your towel + space blanket trial to the class. Record every group's differences, including your own, in the "whole class" table. Calculate the average differences. Answer the results and conclusions questions.

DATA & ANALYSIS

YOUR GROUP		
TIME	A. TOWEL TEMP	B. TOWEL + SPACE BLANKET TEMP
LAP	°F	°F
1 MINUTE	°F	°F
2 MINUTES	°F	°F
3 MINUTES	°F	°F
4 MINUTES	°F	°F
5 MINUTES	°F	°F

A. TOWEL DIFFERENCE

_______°F – _______°F = _______°F
5 min. Lap Difference

B. TOWEL + SPACE BLANKET DIFFERENCE

_______°F – _______°F = _______°F
5 min. Lap Difference

WHOLE CLASS		
GROUP	A. TOWEL DIFFERENCE	B. TOWEL + SPACE BLANKET DIFFERENCE
GROUP 1	°F	°F
GROUP 2	°F	°F
GROUP 3	°F	°F
GROUP 4	°F	°F
GROUP 5	°F	°F
GROUP 6	°F	°F
GROUP 7	°F	°F
GROUP 8	°F	°F
GROUP 9	°F	°F
MEAN		

RESULTS

1. In your group, which trial had the greater temperature difference? (Circle one.)
   a. Towel
   b. Towel + space blanket
   c. Same in both trials

2. In the whole class data, which trial had the greater mean difference? (Circle one.)
   a. Towel
   b. Towel + space blanket
   c. Same in both trials

CONCLUSIONS

1. Turn back to the first page and review your prediction. Was your prediction correct? Use the mean temperature differences from the "Whole Class" table to answer.

   Yes / No

2. Review your answer to the results question #2. Looking at the trial that you circled, why do you think that it had a greater difference in temperature, or if it was the same, why do you think that occurred?

EVALUATION

1. This experiment was a model of the greenhouse effect. Fill in the blanks below to indicate which component in this experiment was modeling the following components of the greenhouse effect. Read the excerpt below for help.

Earth was modeled by the ______________________.
Lap / Towel / Space Blanket

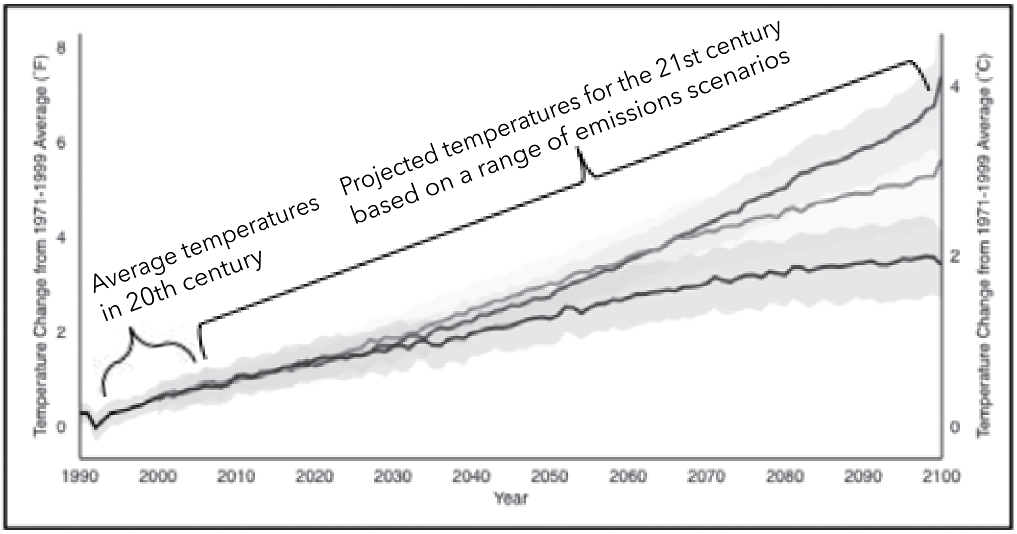
The atmosphere was modeled by the________________________.
Lap / Towel / Space Blanket

Additional carbon dioxide was modeled by the_______________________.
Lap / Towel / Space Blanket

> Think of yourself under a blanket in a cold room. You represent the earth, a warm body giving off energy, what we usually call "heat." The blanket represents the atmospheric layer of greenhouse gases.
>
> Among the earth's blanket of greenhouse gases, carbon dioxide is the one you probably hear about most often, because it is increasing in the atmosphere as we burn a great deal of coal, oil, and gas for energy.
>
> In our blanket analogy, this is like putting on another blanket, so there are more layers of blanket fibers for the energy to pass through to reach the top.
>
> Excerpted from: American Chemical Society – A Greenhouse Effect Analogy
> *http://www.acs.org/content/acs/en/climatescience/climatesciencenarratives/a-greenhouse-effect-analogy.html*

Figure 2. Global Temperature Projections. The graph shows the average of a set of temperature simulations for the 20th century (single line), followed by projected temperatures for the 21st century based on a range of emissions scenarios (three lines). The shaded areas around each line indicate the statistical spread (one standard deviation) provided by individual model runs.

Source: *www.climate.gov/news-features/understanding-climate/climate-change-global-temperature-projections*



Use the Global Temperatures Projections graph (Fig. 2) to answer the following questions.

2. Examine the scenario with the **warmest** projected temperatures (top line). In the scenario with the **warmest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

3. Examine the scenario with the **lowest** projected temperatures (bottom line). In the scenario with the **lowest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

4. How will increasing temperatures affect Earth systems?

ANSWER KEY

Examining the Enhanced

Greenhouse Effect

SETTING UP THE EXPERIMENT

1. Please work with your instructor to assemble into teams of 4.

2. Each team member will choose a role from the list of team member roles below.

TEAM MEMBER ROLES
Test subject
Materials manager
Timer
Data recorder

3. **As quickly as possible**, the team member who is the test subject will use a binder clip to attach the thermometer to the clothing on their lap. Attach the binder clip approximately halfway down the length of the thigh, and ensure that as much of the thermometer as possible is contacting the leg (Fig. 1).

4. Complete the prediction and follow the procedures.

Figure 1. Example thermometer set up

PREDICTION

I predict that the temperature of the ___*student answers will vary*___ trial will be **warmer**.

a. Towel

b. Towel + space blanket

c. Neither (they will be the same)

MATERIALS

- Thermometer
- Small binder clip
- Stopwatch
- Hand towel
- Rectangle of space blanket
- Calculator

PROCEDURES FOR TOWEL TRIAL

1. **Data recorder,** once the temperature reading of the test subject's lap has stabilized, record the temperature in the "Your Group" table. It can take several minutes for the temperature to stabilize. Enter the temperature under the "Towel Temp" column in the "Lap" row.
2. **Materials manager**, give the towel to the **test subject**. Test subject, lay the towel over the thermometer and across your lap so that its long side is perpendicular to your thighs, and tuck the ends of the towel under your legs if possible. **Timer**, press the start button on the stopwatch.
3. **Timer**, every time a minute passes on the stopwatch, call out the time to the data recorder. **Data recorder**, when the timer calls out the time, read the temperature on the thermometer and record it in the corresponding row of the "Towel Temp" column. Stop recording after 5 minutes. **Timer**, stop and reset the stopwatch.
4. **Test subject**, remove the towel from your lap and give it to the materials manager. **Leave the thermometer clipped to your lap.**
5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel temperature.

PROCEDURES FOR TOWEL + SPACE BLANKET TRIAL

1. Wait until the thermometer reads approximately the same as the beginning lap temperature in the towel trial.
2. **Data recorder**, record the beginning lap temperature under the "Towel + Space Blanket Temp" column in the "Lap" row.
3. **Materials manager**, first give the towel and then the space blanket rectangle to the test subject. **Test subject**, lay the towel over the thermometer and across your lap, and then place the space blanket rectangle on top. Both should be oriented so that the long side is perpendicular to your thighs. Tuck both the towel and the space blanket under your legs together if possible. **Timer**, press the start button on the stopwatch.
4. **Timer**, every time a minute passes on the stopwatch call out the time to the data recorder. **Data recorder**, when the timer calls out the time, read the temperature on the thermometer, and record it in the corresponding row of the "Towel + Space Blanket Temp" column. Stop recording after 5 minutes. **Timer**, stop and reset the stopwatch.
5. Everyone in the group will transfer these measurements onto their own data table. Using these data, calculate the difference in towel + space blanket temperature.
6. Report the temperature differences in your towel trial and your towel + space blanket trial to the class. Record every group's differences, including your own, in the "whole class" table. Calculate the average differences. Answer the results and conclusions questions.

DATA & ANALYSIS

YOUR GROUP		
TIME	A. TOWEL TEMP	B. TOWEL + SPACE BLANKET TEMP
LAP	°F	°F
1 MINUTE	°F	°F
2 MINUTES	°F	°F
3 MINUTES	°F	°F
4 MINUTES	°F	°F
5 MINUTES	°F	°F

student answers will vary

A. TOWEL DIFFERENCE

_______°F – _______°F = _______°F
5 min. Lap Difference

B. TOWEL + SPACE BLANKET DIFFERENCE

_______°F – _______°F = _______°F
5 min. Lap Difference

WHOLE CLASS		
GROUP	A. TOWEL DIFFERENCE	B. TOWEL + SPACE BLANKET DIFFERENCE
GROUP 1	°F	°F
GROUP 2	°F	°F
GROUP 3	°F	°F
GROUP 4	°F	°F
GROUP 5	°F	°F
GROUP 6	°F	°F
GROUP 7	°F	°F
GROUP 8	°F	°F
GROUP 9	°F	°F
MEAN		

student answers will vary

RESULTS

1. In your group, which trial had the greater temperature difference? (Circle one.)

   a. Towel

   b. Towel + space blanket ⟵ *this is usually the case*

   c. Same in both trials

2. In the whole class data, which trial had the greater mean difference? (Circle one.)

   a. Towel

   b. Towel + space blanket ⟵ *this is usually the case*

   c. Same in both trials

CONCLUSIONS

1. Turn back to the first page and review your prediction. Was your prediction correct? Use the mean temperature differences from the "Whole Class" table to answer.

   student answers will vary Yes / No

2. Review your answer to the results question #2. Looking at the trial that you circled, why do you think that it had a greater difference in temperature, or if it was the same, why do you think that occurred?

   The trial with the towel and the space blanket had a greater difference in temperature because adding the space blanket provided additional insulation, trapping more heat.

EVALUATION

1. This experiment was a model of the greenhouse effect. Fill in the blanks below to indicate which component in this experiment was modeling the following components of the greenhouse effect. Read the excerpt below for help.

   Earth was modeled by the ___*lap*___.
   Lap / Towel / Space Blanket

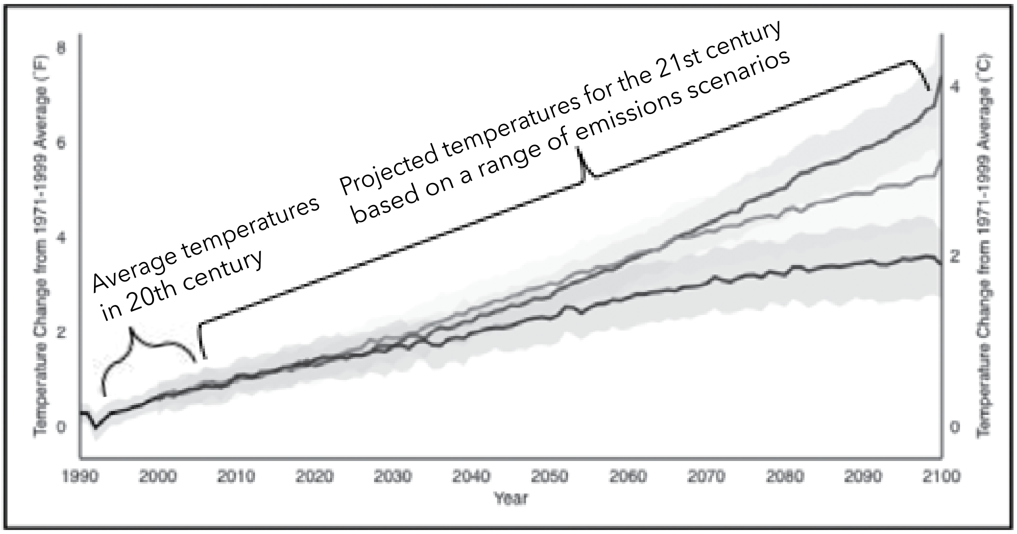
   The atmosphere was modeled by the ___*towel*___.
   Lap / Towel / Space Blanket

   Additional carbon dioxide was modeled by the ___*space blanket*___.
   Lap / Towel / Space Blanket

> Think of yourself under a blanket in a cold room. You represent the earth, a warm body giving off energy, what we usually call "heat." The blanket represents the atmospheric layer of greenhouse gases.
>
> Among the earth's blanket of greenhouse gases, carbon dioxide is the one you probably hear about most often, because it is increasing in the atmosphere as we burn a great deal of coal, oil, and gas for energy.
>
> In our blanket analogy, this is like putting on another blanket, so there are more layers of blanket fibers for the energy to pass through to reach the top.
>
> Excerpted from: American Chemical Society – A Greenhouse Effect Analogy
> *http://www.acs.org/content/acs/en/climatescience/climatesciencenarratives/a-greenhouse-effect-analogy.html*

Figure 2. Global Temperature Projections. The graph shows the average of a set of temperature simulations for the 20th century (single line), followed by projected temperatures for the 21st century based on a range of emissions scenarios (three lines). The shaded areas around each line indicate the statistical spread (one standard deviation) provided by individual model runs.

Source: *www.climate.gov/news-features/understanding-climate/climate-change-global-temperature-projections*



Use the Global Temperatures Projections graph (Fig. 2) to answer the following questions.

2. Examine the scenario with the **warmest** projected temperatures (top line). In the scenario with the **warmest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

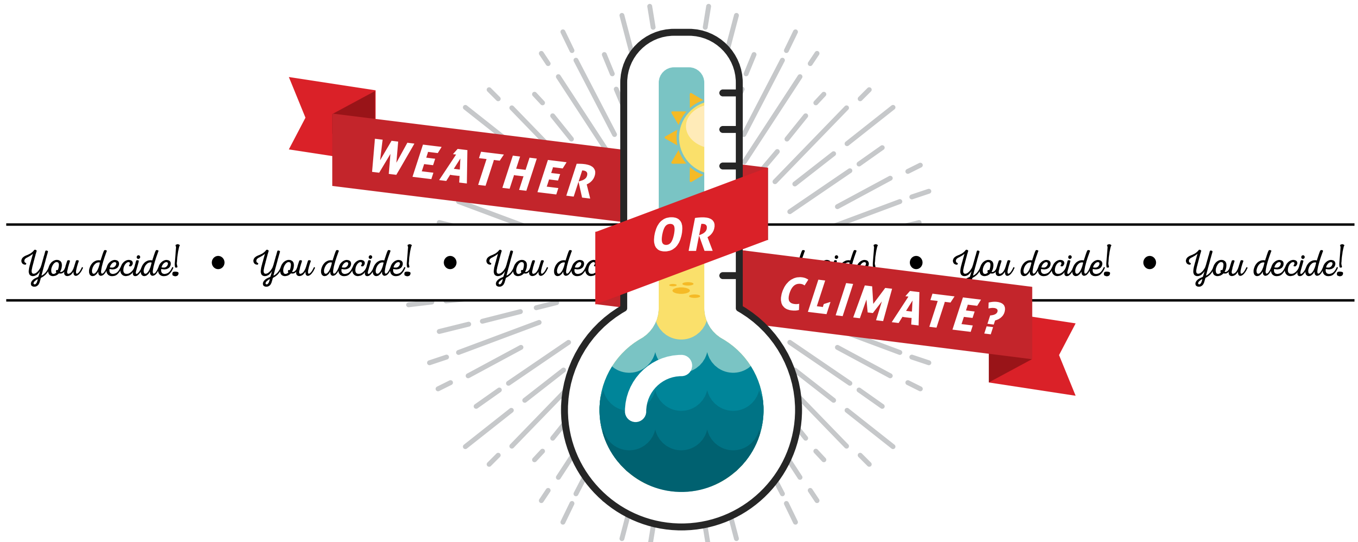
   Approximately 6 – 8 °F

3. Examine the scenario with the **lowest** projected temperatures (bottom line). In the scenario with the **lowest** projected temperatures, by approximately how many degrees Fahrenheit is the average temperature projected to increase over the 21st century, from the year 2000 to the year 2100?

   Approximately 2 – 4 °F

4. How will increasing temperatures affect Earth systems?

   Snow and glacial melt, increased sea levels, changes in precipitation patterns (flooding in some areas, drought in some areas), more severe storms



DESCRIPTION

Students use their understanding of the definitions of weather and climate to identify which of the two concepts is better represented by several figures that are presented during the activity.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Synthesize the definitions of weather and climate
- Apply their knowledge to identify whether figures better represent weather or climate

TIME
20 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7. 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).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

BACKGROUND

Members of the public and media often confuse the concepts of weather and climate. This common misconception can lead to inaccurate conclusions about climate change.

Weather is a description of short-term atmospheric conditions. It can include temperature, humidity, precipitation, cloudiness, visibility, wind, and atmospheric pressure. These observations are used to describe the conditions over a short time period, from minutes to months.

Climate is the long-term pattern of weather in an area. It describes the average weather for a region over a longer time period, often defined as approximately 20-30 years or more.

MATERIALS

- *Weather or Climate? You Decide!* handout [1 per student]
- PowerPoint presentation **OR** prints of activity figures [1 set per every 2-4 students]
- Computer and projector

PREPARATION

1. Set up a computer and projector to show the video and to show the PowerPoint presentation if using to display the figures in this activity.

PROCEDURES

1. As an overview of the difference between weather and climate, show the following National Geographic video with Neil deGrasse Tyson: https://www.youtube.com/watch?v=cBdxDFpDp_k
2. Pass out a *Weather or Climate? You Decide!* handout to each student.
3. Ask students to take a few minutes to read through the definitions of weather and climate in the box at the top of the handout.
4. Once it seems like most students have had enough time to read the definitions, ask students for a volunteer to verbally summarize the difference between weather and climate for the class [answer: weather refers to atmospheric conditions in the short term, and climate is a long-term average pattern of weather, usually over approximately 30 years].
5. Begin the PowerPoint presentation or pass out printed sets of the activity figures (1 for every 2-4 students).
6. Explain that students will view seven numbered figures. For each, ask students to examine the figure and determine whether the figure better represents the concept of weather or climate. They will then circle the answer on their worksheet.
   a. Figure 1: television forecaster who is giving a prediction of the conditions in Flagstaff, Arizona for a 4-day period [answer: weather].
   b. Figure 2: map that displays the average temperature in the continental United States from 1961-1990, a 30-year period [answer: climate].
   c. Figure 3: satellite images of Elephant Butte reservoir in New Mexico during a drought. The top photo was taken in 1994, and the bottom photo was taken in 2013, 19 years later [answer: climate. Reservoirs require climatic lengths of time to fill and empty.].
   d. Figure 4: photo of a rain gauge in Fort Collins, Colorado. The rain gauge has collected precipitation from a recent rain event [answer: weather].
   e. Figure 5: map that displays the average precipitation in the continental United States from 1961-1990, a 30-year period [answer: climate].
   f. Figure 6: photo of a person walking in a snowstorm [answer: weather].
   g. Figure 7: graph of the average surface temperature on Earth since 1880 [answer: climate].

EXTENSIONS

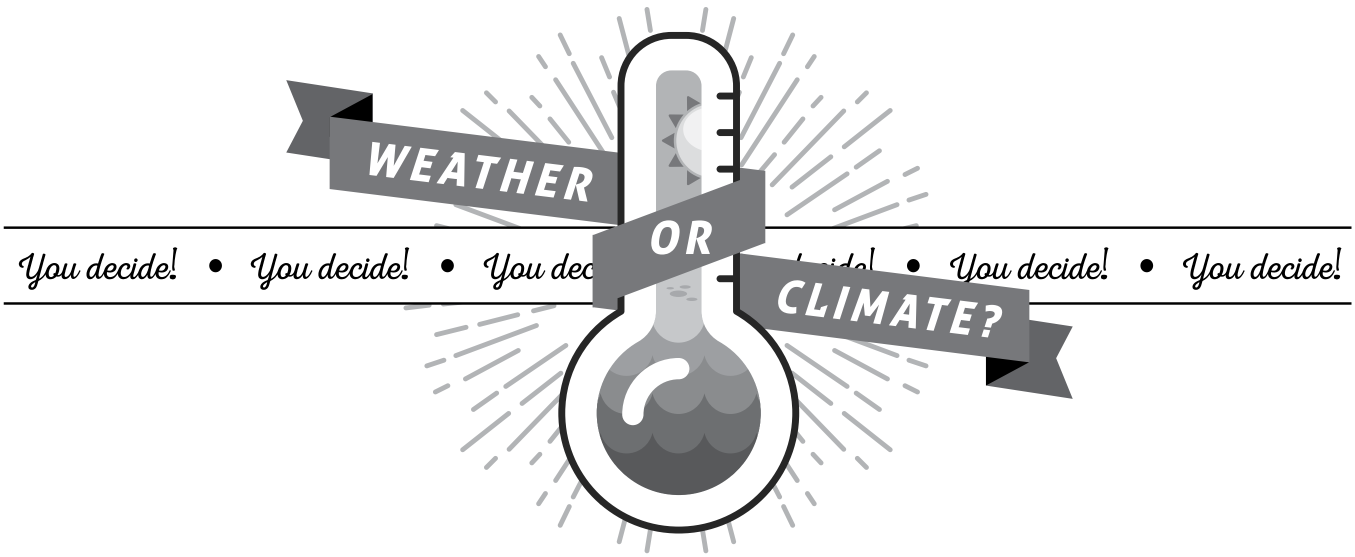
1. Ask students to bring in figures from books or magazines that represent the concepts of weather and climate.
2. Direct students to find figures that represent weather and climate online.

ADDITIONAL RESOURCES

Website with helpful explanation of the difference between weather and climate:

National Oceanic and Atmospheric Administration, National Ocean Service. What is the difference between weather and climate? Published 07 Apr. 2014. Web. 07 Jan. 2015. <http://oceanservice.noaa.gov/facts/weather_climate.html>.

Name ______________________________________ Date ________________



The words **weather** and **climate** are used sometimes interchangeably, but they shouldn't be! Weather and climate are not the same, and you are about to become an expert at understanding the difference.

Weather is basically the way the atmosphere is behaving, mainly with respect to its effects upon life and human activities. The difference between weather and climate is that weather consists of the short-term (minutes to months) changes in the atmosphere. Most people think of weather in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure.

Climate is the description of the long-term pattern of weather in a particular area. Some scientists define climate as the average weather for a particular region and time period, usually taken over [about] 30 years. It's really an average pattern of weather for a particular region.

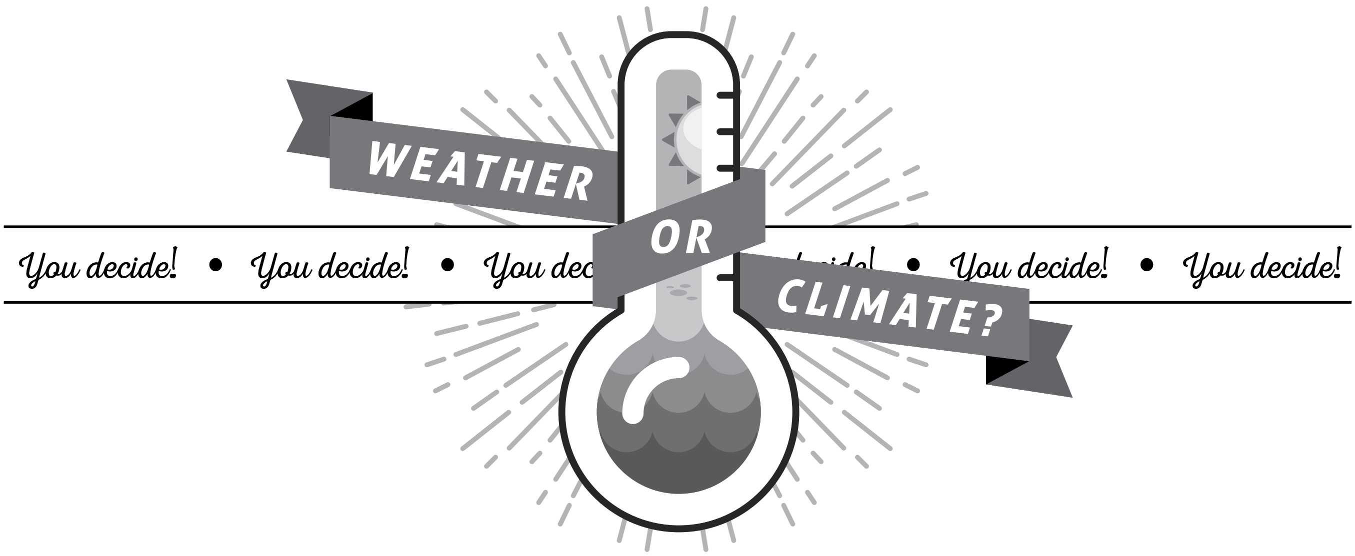
Excerpted from: NASA - What's the Difference Between Weather and Climate?
www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

DIRECTIONS

Please examine each of the numbered figures. Determine whether each figure better represents the concept of weather or climate, and circle the best answer below. Thank you.

FIGURE 1.	**WEATHER**	**CLIMATE**
FIGURE 2.	**WEATHER**	**CLIMATE**
FIGURE 3.	**WEATHER**	**CLIMATE**
FIGURE 4.	**WEATHER**	**CLIMATE**
FIGURE 5.	**WEATHER**	**CLIMATE**
FIGURE 6.	**WEATHER**	**CLIMATE**
FIGURE 7.	**WEATHER**	**CLIMATE**

ANSWER KEY



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Climate is the description of the long-term pattern of weather in a particular area. Some scientists define climate as the average weather for a particular region and time period, usually taken over [about] 30 years. It's really an average pattern of weather for a particular region.

Excerpted from: NASA - What's the Difference Between Weather and Climate?
www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

DIRECTIONS

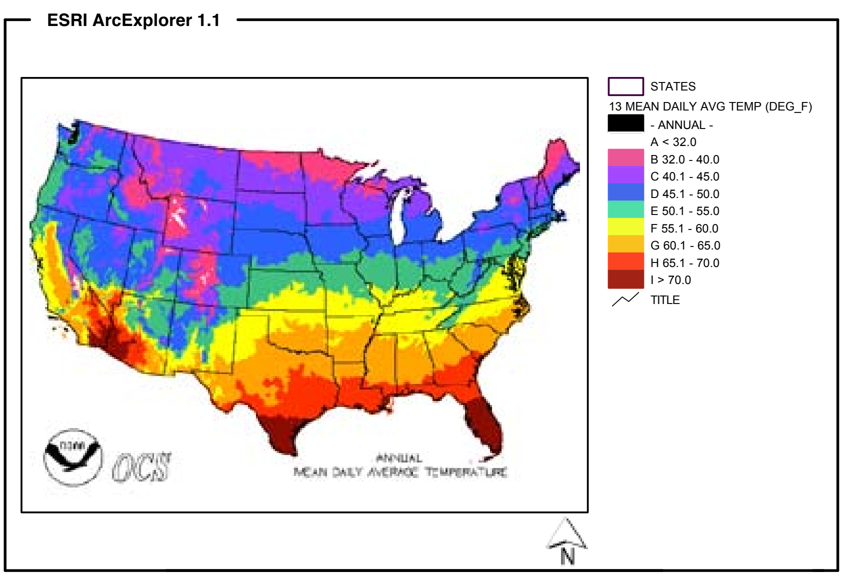
Please examine each of the numbered figures. Determine whether each figure better represents the concept of weather or climate, and circle the best answer below. Thank you.

FIGURE 1.	WEATHER	CLIMATE
FIGURE 2.	WEATHER	CLIMATE
FIGURE 3.	WEATHER	CLIMATE
FIGURE 4.	WEATHER	CLIMATE
FIGURE 5.	WEATHER	CLIMATE
FIGURE 6.	WEATHER	CLIMATE
FIGURE 7.	WEATHER	CLIMATE

Figure 1. Forecaster in Flagstaff, Arizona

Source: wn.com

Figure 2. Average daily temperature in the continental United States from 1961-1990



Source: cdo.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl

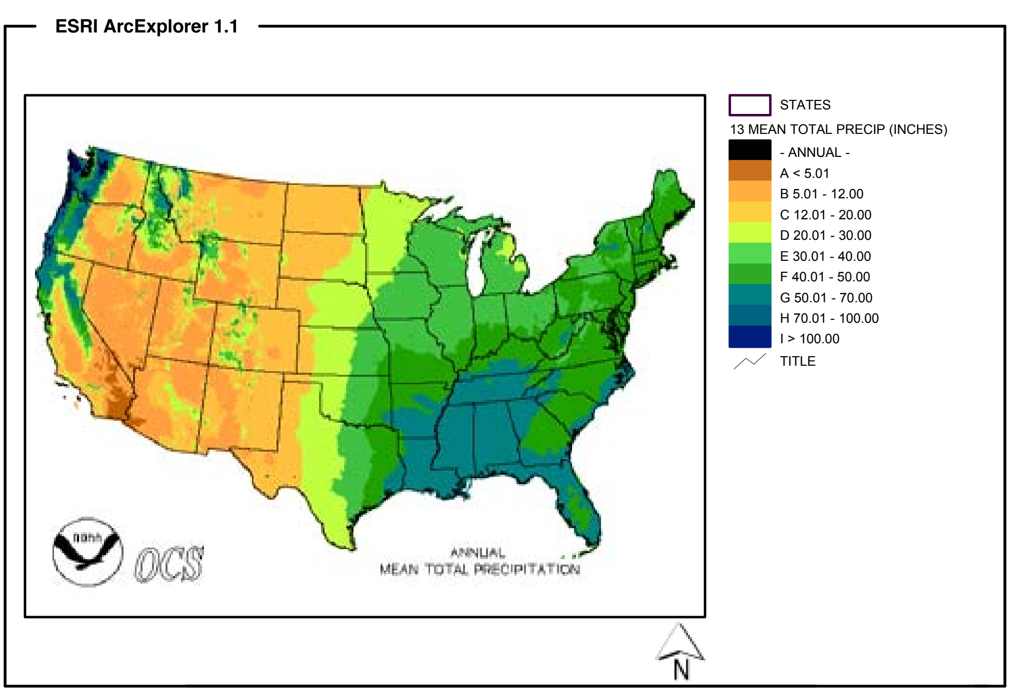
Figure 3. Lowered reservoir levels during drought, Elephant Butte, New Mexico

Source: earthobservatory.nasa.gov/IOTD/view.php?id=81714

Figure 4. Rain gauge in Fort Collins, Colorado

Source: pmm.nasa.gov/node/739

Figure 5. Average annual precipitation in the continental United States from 1961-1990

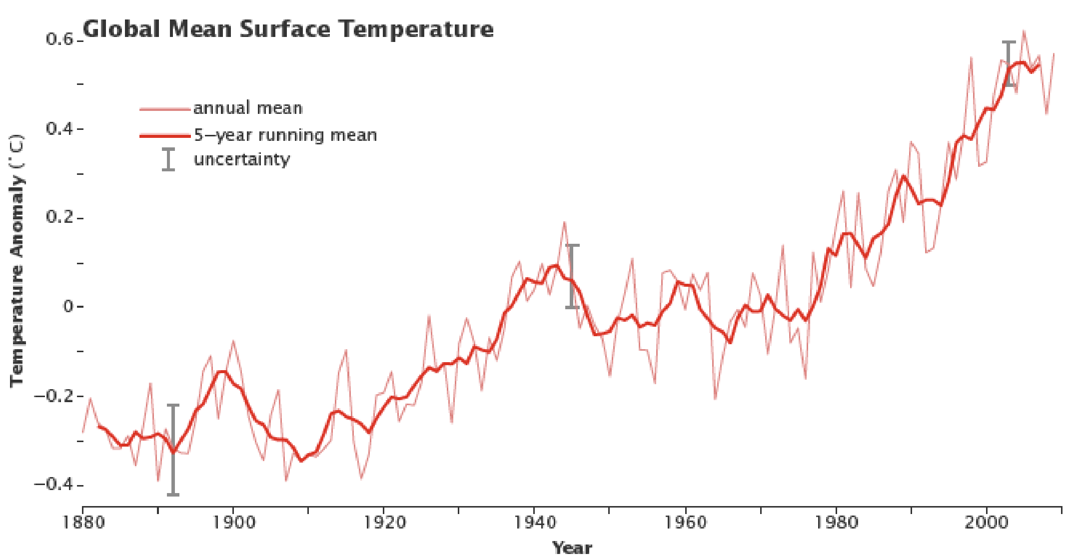


Source: cdo.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl

Figure 6. Snowstorm

Source: www.noaa.gov/features/monitoring_0209/coldwinds.html

Figure 7. Average global surface temperature



Source: earthobservatory.nasa.gov/Features/GlobalWarming/page2.php

Do the American Public and Media Understand Weather and Climate?

DESCRIPTION

Students read a short article and examine selections from the media to determine whether the American public and media tend to understand the difference between weather and climate.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Examine research findings
- Evaluate the portrayal of climate change in the media using two selections
- Formulate ideas about how to clarify the difference between weather and climate

TIME
20 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts.

CCSS.ELA-LITERACY.RST.6-8.8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.6. Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.

BACKGROUND

The public obtains most of its scientific information from the media (Boykoff and Rajan 2007), and therefore, the accuracy and reliability of the information conveyed is of utmost importance. However, portrayals of climate change in the media often demonstrate confusion between the concepts of weather and climate. This common misconception can lead to inaccurate conclusions about climate change.

Weather is a description of short-term atmospheric conditions. It can include temperature, humidity, precipitation, cloudiness, visibility, wind, and atmospheric pressure. These observations are used to describe the conditions over a short time period, from minutes to months.

Climate is the long-term pattern of weather in an area. It describes the average weather for a region over a longer time period, often defined as approximately 20-30 years or more.

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. This includes global warming, changes in precipitation patterns and length of seasons, and increased frequency of extreme weather events. Note that the media will often use the terms climate change and global warming interchangeably, and in fact, this is done in the article excerpt used for this activity. Global warming describes the current increasing average global temperature. Climate change is a broader term that encompasses global warming along with many other long-term changes in climate patterns that result from warmer temperatures.

MATERIALS

- *Understanding the Difference* handout [1 per student]

PREPARATION

None

PROCEDURES

1. Pass out an *Understanding the Difference* handout to each student.
2. Instruct students to read the short article excerpt in the box at the top of the handout and look at the graphics in the box at the bottom of the handout.
3. Once it seems like most students have had enough time to read the article excerpt and look at the graphics, ask them to answer the discussion questions on the handout.

PROCEDURE VARIATIONS

Students can answer the discussion questions using one or more methods. Choose one of the following options or combine them to approach the questions in a variety of ways.

1. Students can answer all of the questions on their own. Then lead a discussion of each of the questions after students have answered them.
2. Students can answer the questions as a whole group. Lead students in a discussion of each question, soliciting answers from students and talking about their answers.
3. Organize students in small groups and have each group work on one or two questions. In their groups, students should discuss the question, determine how they would like to answer it as a group, and choose one student to explain their answer to the whole class. Have one student from each group report to the class by reading the question and summarizing their group's answer. In a large class, it may be necessary to have more than one group answer each question.
4. With a group of students who do not yet know each other or with students who may be shy about their thoughts, try mixing up the handouts. First, students answer all of the questions on their own. Then mix up the handouts and pass them out to other students. Then call on a student to read the answer of a question from the other student's handout that they are holding (without revealing the name of the student). Finally, lead the class in a discussion of the answer and whether students agree with the answer. Repeat for each question on the handout.

EXTENSIONS

1. Ask students to research climate change in the media and create a project to communicate their findings. An example topic could be to investigate the media echo chambers and reinforcing spirals framework concepts found by Yale researchers and summarized on this webpage: http://environment.yale.edu/climate-communication/article/media-echo-chambers-and-climate-change
2. Have students examine public perceptions about climate change in your state, neighboring states, and/or across the US. The interactive Yale Climate Opinion Maps website provides survey data about climate change beliefs, risk perceptions, and policy support graphically by state, congressional district, or county. As an example activity, use the website to have students compare the percentage of adults who believe that global warming is caused mostly by human activities in their state and a neighboring state. Yale Climate Opinion Maps website: http://environment.yale.edu/poe/v2014/
3. Once students determine that the media can perpetuate misconceptions about climate change, they may be left wondering where people should seek information on the topic. Challenge students to find credible sources online. Discuss how to determine whether information found on a website is reliable (see reliable information website in Additional Resources section). The list of reliable websites in the Additional Resources section may be a helpful starting point. Ask students to take it a step further and brainstorm about ways that reliable information could be shared widely with the public and what outlets the average person would most likely see.

ADDITIONAL RESOURCES

1. Article with helpful background information about climate change in the media:
   Boykoff, MT, Rajan, SR. 2007. Signals and noise: mass media coverage of climate change in the USA and UK. EMBO Rep. 8(3): 207-211. Accessed online. 21 Apr. 2015. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1808044/>.
2. Website about finding reliable information online:
   Montecino, V. George Mason University. Criteria to Evaluate the Credibility of WWW Resources. Published Aug. 1998. Web. Accessed 28. Apr. 2015. <http://mason.gmu.edu/~montecin/web-eval-sites.htm>.
3. Websites with reliable climate change information:
   Environmental Protection Agency (EPA). Climate Change: Basic Information. Published 18 Mar. 2014. Web. Accessed 09 Oct. 2014. <http://www3.epa.gov/climatechange/basics/>.
   National Aeronautics and Space Administration (NASA). Global Climate Change: Vital Signs of the Planet. Updated 27 Apr. 2015. Web. Accessed 28 Apr. 2015. < http://climate.nasa.gov>.
   National Oceanic and Atmospheric Administration (NOAA). Climate.gov. Web. Accessed 28 Apr. 2015. <http://www.climate.gov>.
   National Oceanic and Atmospheric Administration (NOAA). Global Climate Change Indicators. Web. Accessed 28 Apr. 2015. <https://www.ncdc.noaa.gov/indicators/>.
   National Park Service (NPS). Climate Change and Your National Parks. Updated 24 Apr. 2015. Web. Accessed 28 Apr. 2015. <http://www.nps.gov/subjects/climatechange/index.htm>.
   Southwest Regional Climate Hub. Web. Accessed 28 Apr. 2015. <http://swclimatehub.info>.

Name ______________________________ Date ______________

UNDERSTANDING THE DIFFERENCE

Do the American Public and Media Understand Weather and Climate?

DIRECTIONS

Please read the short article excerpt and look at the graphics below. Then answer the discussion questions.

BELIEF IN GLOBAL WARMING DROPS AFTER COLD WINTER

After an especially cold winter across much of the United States, the American public was slightly less convinced that the planet is heating up, a new survey shows.

A majority of Americans, or 63 percent, still believe there is solid evidence that global warming is real, according to the latest poll from the National Surveys on Energy and Environment (NSEE). That number is down, however, from 67 percent who said the same in the fall.

"The fairly cold winter and slow arriving spring weather this year appears to have contributed to a slight decline in the number of Americans that think global warming is happening," said Chris Borick, director of the Muhlenberg Institute, which conducts the NSEE in partnership with the University of Michigan.

Previous research has shown that public opinion on climate change often shifts in response to weather events that seem to support or refute a warming trend.

Excerpted from: NBC News, 6/19/2013
www.nbcnews.com/id/52254197/ns/technology_and_science-science/t/belief-global-warming-drops-after-cold-winter/#.VA38SUve71q

'Where's global warming when you really need it?'

DISCUSSION QUESTIONS

1. Evaluate this sentence from the article:
   "After an especially cold winter across much of the United States, the American public was slightly less convinced that the planet is heating up, a new survey shows."

Which word or phrase best describes this sentence?

a. Fact
b. Reasoned judgment based on research findings
c. Speculation

2. Does a big winter storm better represent the concept of **weather** or **climate**?

a. Weather
b. Climate

3. Does cold weather in one area of the world mean that the global climate is **not** changing and, specifically, that the earth is **not** warming? Why or why not?

4. Based on the survey data from the article, do you think that, in general, people understand the difference between weather and climate? If not, what can be done to help people understand the difference?

5. Do you think that the media, such as the example news clip and cartoon, can influence the way people think? In general, are newscasters and cartoonists qualified to educate the public about science topics?

Image Credits:
Chattanooga Times Free Press, Dec. 2010
Fox News Television, Jan. 2014

ANSWER KEY

UNDERSTANDING THE DIFFERENCE

Do the American Public and Media Understand Weather and Climate?

DIRECTIONS

Please read the short article excerpt and look at the graphics below. Then answer the discussion questions.

BELIEF IN GLOBAL WARMING DROPS AFTER COLD WINTER

After an especially cold winter across much of the United States, the American public was slightly less convinced that the planet is heating up, a new survey shows.

A majority of Americans, or 63 percent, still believe there is solid evidence that global warming is real, according to the latest poll from the National Surveys on Energy and Environment (NSEE). That number is down, however, from 67 percent who said the same in the fall.

"The fairly cold winter and slow arriving spring weather this year appears to have contributed to a slight decline in the number of Americans that think global warming is happening," said Chris Borick, director of the Muhlenberg Institute, which conducts the NSEE in partnership with the University of Michigan.

Previous research has shown that public opinion on climate change often shifts in response to weather events that seem to support or refute a warming trend.

Excerpted from: NBC News, 6/19/2013
www.nbcnews.com/id/52254197/ns/technology_and_science-science/t/belief-global-warming-drops-after-cold-winter/#.VA38SUve71q

'Where's global warming when you really need it?'

DISCUSSION QUESTIONS

1. Evaluate this sentence from the article:
   "After an especially cold winter across much of the United States, the American public was slightly less convinced that the planet is heating up, a new survey shows."

Which word or phrase best describes this sentence?

- a. Fact
- b. Reasoned judgment based on research findings
- c. Speculation

The answer is B because the sentence is summarizing the findings from a research sample. We cannot call this a fact because the researchers did not survey everyone in the US. It is not speculation because the author(s) cite a reliable source for their statement.

2. Does a big winter storm better represent the concept of **weather** or **climate**?

- a. Weather
- b. Climate

The answer is A because a big winter storm is experienced over a short time period.

3. Does cold weather in one area of the world mean that the global climate is **not** changing and, specifically, that the earth is **not** warming? Why or why not?

No. Cold temperatures in one area in a short time period do not have a large effect on the average global temperature over time. Climate change includes a long-term increase in global temperatures, and a cold winter in one area refers to the weather in that place, which is short term.

4. Based on the survey data from the article, do you think that, in general, people understand the difference between weather and climate? If not, what can be done to help people understand the difference?

The change in acceptance of climate change after cold weather suggests that many people do not understand the difference between weather and climate. Often people rely on anecdotal evidence instead of empirical evidence to inform their ideas.Student answers will vary about what can be done to help people understand the difference.

5. Do you think that the media, such as the example news clip and cartoon, can influence the way people think? In general, are newscasters and cartoonists qualified to educate the public about science topics?

Student answers will vary, but the educator may want to bring up the following points. Because the public tends to obtain most of its science information from the media, the media can have a large impact on the way that people think. In general, newscasters and cartoonists do not have science credentials. In fact, journalistic standards, such as "balanced reporting," can skew scientific information such that it appears that there is less consensus among scientists than there is. In other words, journalists are trained to present both sides of an issue equally, giving as much weight to a few dissenting voices as the scientific consensus.

Image Credits:
Chattanooga Times Free Press, Dec. 2010
Fox News Television, Jan. 2014

DESCRIPTION

Students conduct an experiment to investigate the effects of various factors on the rate of evaporation.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:

- Make a prediction using prior knowledge and experience
- Model evaporation of water from soil under various environmental conditions
- Synthesize results of an experiment
- Apply understanding of experimental results to make further predictions about Earth's systems

TIME

1 HOUR TOTAL OVER 4 DAYS
DAY 1:20 MINUTES
DAY 2:10 MINUTES
DAY 3:10 MINUTES
DAY 4:20 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

Grade 6 » Statistics & Probability
CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: CCSS.MATH.CONTENT.6.SP.B.5.C. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

NEXT GENERATION SCIENCE STANDARDS

Middle School
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

High School
HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

BACKGROUND

With increasing temperatures and changing weather patterns, climate change will affect evaporation rates in many areas. Evaporation is a major part of the earth's water cycle. It is the process of water molecules gaining enough energy to escape the surface of a water layer. In the water cycle, water from lakes, ponds, rivers, streams, and oceans is heated by the sun and converted into water vapor. This vapor rises into the air and may result in the development of clouds.

Many factors can affect evaporation. Heat makes water evaporate more quickly because water molecules move faster when they are warm. Since the molecules are moving faster, more of them can leave the surface of the water at one time. Humidity, the amount of water vapor in the air, also affects evaporation rates. For evaporation to occur, the humidity of the atmosphere must be less than the evaporation surface. At 100% relative humidity, there is no evaporation. Additionally, wind increases the rate of evaporation by blowing away moist air from the water surface, thus bringing in less humid air with room for more water molecules.

MATERIALS

- *Evaporation Investigation* handout [1 per student]
- Small, sandwich-sized, clear plastic storage containers, approximately 6.5" x 6.5" [10 per class]
- Permanent markers [10]
- Masking tape
- Metric rulers [10]
- Soil, well mixed (from the schoolyard or other location or bagged potting soil)
- Trowels [1-4]
- 100-mL graduated cylinders [5-10]
- Metric scales (Figure 1) [2-10]
- Heat lamps, can be metal clamp lamps or desktop lamps (Figure 2) [2 per class]
- Heating pads (Figure 2) [2 per class]
- Small desktop fans (Figure 2) [2 per class]
- Dried Spanish moss [1-2 bags, approximately 2-L]
- Automatic timers [2-6 per class, depending on location of outlets]
- Power strips [2-6 per class, depending on location of outlets]
- Optional: extension cords (if needed)
- Optional: document camera and projector (if using for the "Class Mean Data Table")

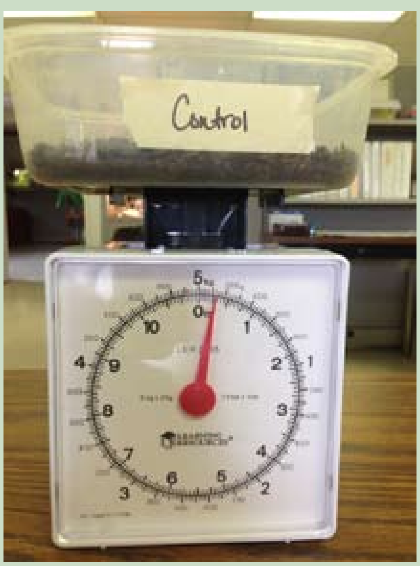


Figure 1. Example metric scale and container

Figure 2. Five experimental containers with treatment materials (left to right): heat lamp, heating pad, desktop fan, Spanish moss, and control

PREPARATION

1. Plan to divide the class into 10 groups. This allows for two replicates of each treatment (control, solar radiation, infrared ground radiation, wind, and ground cover). To save space, you can split each class into only five groups if you have more than one class conducting this experiment. Each class will share their data with other classes, thereby increasing replication.
2. Plan locations for five experimental treatments. Treatment locations can be simple surfaces, such as counters or tables, that are away from direct sunlight. Three locations should be near an outlet.
3. Set up supplies for each treatment. Ideally, the two replicates of each treatment will not be located right next to each other to avoid confounding the results with site-specific factors (e.g., a heating or cooling vent, etc.). However, space constraints may prevent placing the replicate containers far apart.
   a. **Control** (only soil and water): needs a surface away from direct sunlight.
   b. **Solar radiation** (heat lamp): needs a surface away from direct sunlight, near an outlet, and that can accommodate the heat lamp(s). Plug an automatic timer* into a nearby outlet, and program the timer to be on during the day and off during the times when classes are not in session. Plug a power strip and/or extension cord (if needed) into the timer. Set up the heat lamp(s), and plug them into the power strip that is connected to the timer.
   c. **Infrared ground radiation** (heating pad): needs a surface away from direct sunlight, near an outlet, and that can accommodate the heating pad(s). Plug an automatic timer* into a nearby outlet, and program the timer to be on during the day and off during the times when classes are not in session. Plug a power strip and/or extension cord (if needed) into the timer. Set up one or two heating pads; two small containers may fit on one heating pad, depending on the size of the containers and heating pad. Plug the heating pad(s) into the power strip that is connected to the timer.
   d. **Wind** (fan): needs a surface away from direct sunlight, near an outlet, and that can accommodate the fan(s). Plug an automatic timer* into a nearby outlet, and program the timer to be on during the day and off during the times when classes are not in session. Plug a power strip and/or extension cord (if needed) into the timer. Set up the fan(s), and plug into the power strip that is connected to the timer.
   e. **Ground cover** (moss): needs a surface away from direct sunlight. Place the bag of Spanish moss nearby.

   *Note: automatic timers can be shared among treatments, depending on the location of outlets and surface space, by using extension cords and/or power strips.
4. Place scales on level surfaces around the room that will be convenient for student access.
5. Place the container of soil in a central place that will be convenient for student access, and leave 1 – 4 trowels near the container.
6. Attach a small strip of masking or lab tape to the side of each container to be used as a label.
7. On the board or a large piece of paper, draw the "Class Mean Data Table" from page 3 of the handout, or prepare to show it with a document camera.

PROCEDURES

DAY 1

1. Divide the class into 10 groups.
2. Pass out an *Evaporation Investigation* handout to each student.
3. Explain that students will conduct an experiment to investigate evaporation because it is an important process in the water cycle. As the climate changes and temperature increases, evaporation will occur at a greater rate. In this experiment, we will examine some of the factors that affect evaporation and hypothesize about how the results relate to climate change.
4. Inform students that they will be determining which variable results in the most water loss through evaporation. Their experiment will examine the effects of the following variables on water loss from a container of soil: control (nothing is added), solar radiation (under a heat lamp), infrared ground radiation (on top of a heating pad), wind (in front of a fan), and ground cover (with moss on top).
5. Instruct students to complete the prediction at the top of page 1 of the handout.
6. Give each group a plastic container, a permanent marker, and a ruler, and have them measure 2 cm from the bottom of the container and place a mark with the marker.
7. Assign each group to one of the treatments: control, solar radiation, infrared ground radiation, wind, or ground cover. Assign two groups to each treatment. The first group assigned to the control treatment will be group 1 and the second will be group 2. If you are conducting the experiment with more than one class, assign sequential numbers (3, 4, etc.) to groups in subsequent classes.
8. Instruct students to write their treatment name and group number on page 3 of the handout and on the masking tape on their container.
9. Have each group fill the container with dry soil to the 2 cm mark. Tell them not to pat down the soil. They will then take the mass of the container with the dry soil and record the mass on page 3 of the handout.
   a. Soil for the entire class should

be very well mixed in a large container. Groups should not collect their own soil because it may differ considerably in texture.

10. Ask each group to measure 100 mL of water in a graduated cylinder and carefully sprinkle the water on top of the soil in the container. Tell students to make sure that water is sprinkled evenly across the top and not poured into one area of the container.
11. Instruct each group to take the mass of the container immediately after sprinkling the water. Students will record the mass on page 3 of the handout.
    a. The mass of 100 mL of water is 100 g. A quick check of student handouts should show that the mass of the container after sprinkling water is 100 g more than the mass of the container with dry soil.
12. Explain to each group how to set up their container.
    a. **Control**: do not add any other variables.
    b. **Solar radiation** (heat lamp): place the container under the heat lamp, approximately 3-6 inches away. Rotate the container 180° daily. The lamp simulates radiation from the sun.
    c. **Infrared ground radiation** (heating pad): place the container on top of the heating pad. Rotate the container daily. The heating pad simulates ground surface radiation.
    d. **Wind** (fan): set the container in front of the fan, and position the fan so that it blows level with the container. Put the fan on the lowest setting. Make sure that no other containers are in the line of the fan. Rotate the container daily. The fan simulates the wind.
    e. **Ground cover** (moss): place moss on top of the soil in patches. Do not cover the soil completely. Make sure all containers have the same percentage of the surface covered. The moss simulates plants covering the soil surface.

DAYS 2 - 4

1. On a daily basis for the following three days, instruct students to take the mass of the container and record it in "Your Group's Data Table" on page 3 of the handout. If possible, take the mass at the same time each day.
2. Direct students to calculate the amount of water lost by subtracting the current day's mass from the previous day's mass.

DAY 4

1. At the end of the experiment, have students calculate the total mass of water lost in the table on page 3 of the handout by adding the water lost on days two, three, and four.
2. Collect the total mass of water loss for each group in the "Class Mean Data Table" on the board (or displayed on the document camera). Either direct students to write their data on the displayed table themselves, or ask each group for their total verbally, and write it in the table.
3. Instruct students to write the class data in the "Class Mean Data Table" on page 3 of the handout and calculate the mean mass of water loss for each treatment.
4. Have students make a bar graph of the mean mass of water loss for each treatment in the graph on page 4 of the handout.
5. Students draw conclusions from the "Class Mean Data Table" and bar graph and use them to answer the conclusion questions on page 5 of the handout. It may be helpful to lead a discussion of experiment conclusions using the following questions and direct students to use some of the answers to write their own conclusions for conclusion question 2.
    a. Which treatments had the most evaporation?
    b. Which treatments had the least evaporation?
    c. Do the results support your prediction? (This is conclusion question 1.)
    d. What may be the reasons that some treatments had more evaporation than others?
    e. What might be the result of two or more of these variables acting at the same time in an ecosystem?
    f. Why is it important to replicate the experiment (i.e., to have more than one container for each treatment)?
6. After students answer conclusion question 3, discuss how increased evaporation rates affect the water cycle under climate change conditions. Earth is experiencing global warming, and the average global surface temperature is increasing. In this experiment, global warming is equivalent to turning up the heat on the heating pad. As temperatures increase around the world, more areas are experiencing increased evaporation rates, and there is more water in the atmosphere. More water in the atmosphere results in changes to precipitation patterns; some areas receive more precipitation and some receive less. It also results in increased frequency of extreme weather events, such as severe storms. In addition, water vapor is a greenhouse gas and further enhances the greenhouse effect.

EXTENSIONS

1. For older or advanced students, conduct this activity as a student-directed experiment instead of providing students with the procedures. Present the following question to students, "Which factor has the greatest impact on the rate of evaporation?" Explain the available materials, and ask students to develop a hypothesis and design an experiment that will test it. Have students design the needed data tables and determine how to analyze their results if possible.
2. Challenge students to think of at least one more variable that may affect the rate of evaporation and design and conduct an experiment to test its effects.

ADDITIONAL RESOURCES

Website with information about the effects of climate change on the processes of the water cycle:

Environmental Protection Agency (EPA), Climate Change and Water. Water Impacts of Climate Change. Updated 13 Mar. 2014. Web. Accessed 26 May 2015. <http://water.epa.gov/scitech/climatechange/Water-Impacts-of-Climate-Change.cfm>.

Name ______________________________ Date ______________

PREDICTION

I predict that the amount of evaporation from the __________________________ treatment will be the **highest** (i.e., this treatment will lose the **most** water).

a. Control
b. Solar radiation (heat lamp)
c. Infrared ground radiation (heating pad)
d. Wind (fan)
e. Ground cover (moss)
f. None (they will be the same)

MATERIALS

- Small plastic container
- Permanent marker
- Ruler
- Soil
- Graduated cylinder
- Scale

PROCEDURES

1. Measure 2 cm from the bottom of the plastic container, and place a mark with the permanent marker.
2. Your group will be assigned a treatment and a group number. Write your treatment and group number on the tape on your container and on page 3 of this handout.
3. Fill the container with dry soil to the 2 cm mark. Do not pat down the soil. Take the mass of the container with the dry soil and record the mass on page 3 of this handout.
4. Measure 100 mL of water in a graduated cylinder and carefully sprinkle the water on top of the soil in the container. Make sure the water is sprinkled evenly across the top and not poured into one area of the container.
5. Take the mass of the container immediately after sprinkling the water and record it on page 3 of this handout.
6. You have been assigned to one of the following treatments. Follow the directions for your treatment.
   a. **Control**: do not add any other variables.
   b. **Solar radiation** (heat lamp): place the container under the heat lamp, approximately 3-6 inches away. Rotate the container 180° daily. The lamp simulates radiation from the sun.

   c. **Infrared ground radiation** (heating pad): place the container on top of the heating pad. Rotate the container daily. The heating pad simulates ground surface radiation.
   d. **Wind** (fan): set the container in front of the fan, and position the fan so that it blows level with the container. Put the fan on the lowest setting. Make sure that no other containers are in the line of the fan. Rotate the container daily. The fan simulates the wind.
   e. **Ground cover** (moss): place moss on top of the soil in patches. Do not cover the soil completely. Make sure all containers have the same percentage of the surface covered. The moss simulates plants covering the soil surface.
7. Put the containers in an area that will not be disturbed and that will not allow other variables to affect them (e.g., keep them away from direct sunlight).
8. On a daily basis for the following three days, take the mass of the container and record it in the table on page 3 of this handout. If possible, take the mass at the same time each day.
9. Obtain data from other groups and record these data on the class mean data table on page 3 of this handout. Calculate the mean mass of water loss for each treatment.
10. Make a bar graph of the mean mass of water loss for each treatment on page 4 of this handout.

DATA & ANALYSIS

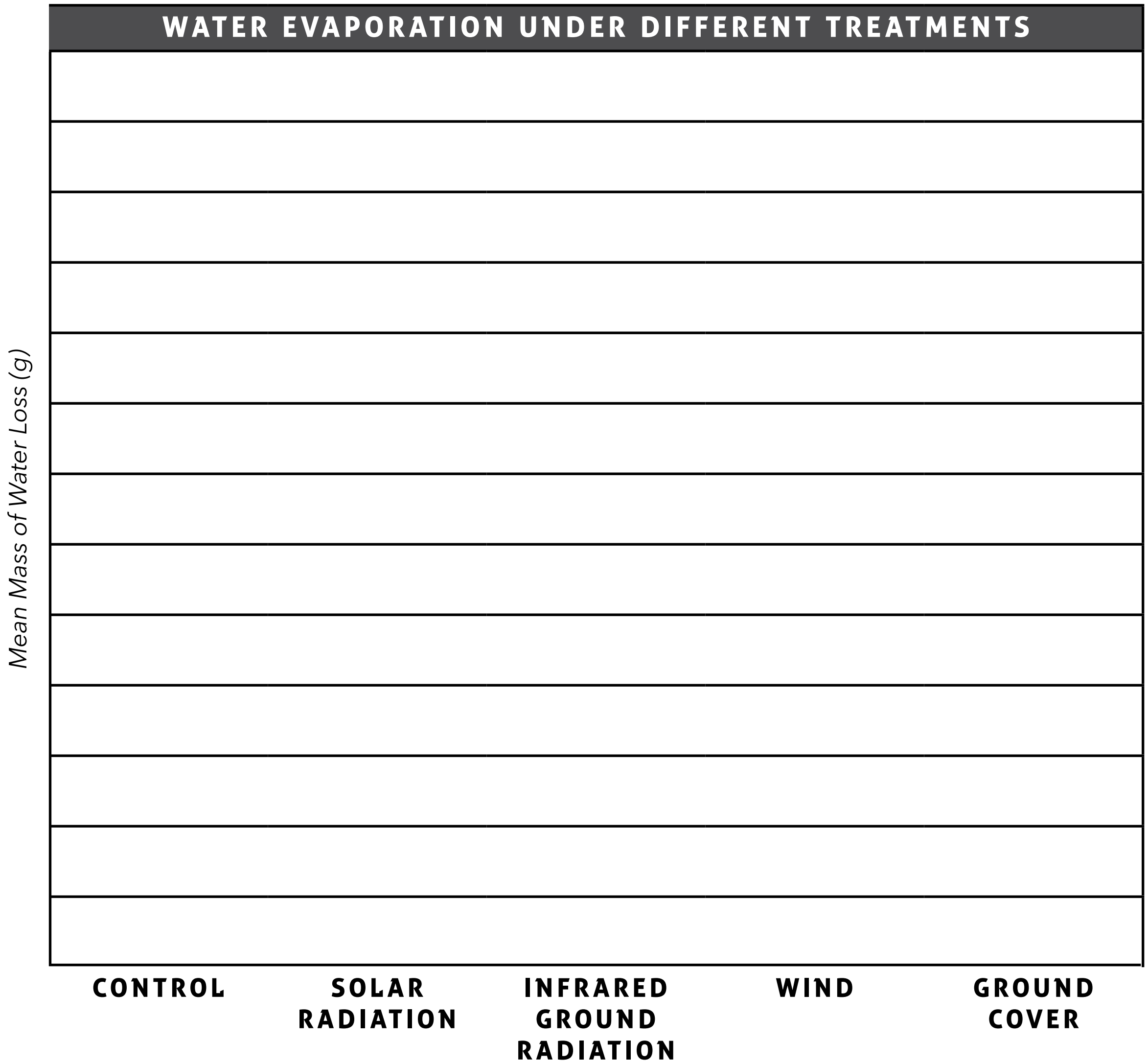
Group number: ________________ Treatment: ____________________

Mass of container with dry soil: ________________ Mass of container after sprinkling water: ________________

YOUR GROUP'S DATA TABLE		
	MASS (G)	DAILY WATER LOSS (previous day's mass minus current day's mass)
DAY ONE		
DAY TWO		
DAY THREE		
DAY FOUR		
TOTAL WATER LOSS (G)		

CLASS MEAN DATA TABLE					
TOTAL MASS OF WATER LOSS (G)					
GROUP/ REPLICATE	CONTROL	SOLAR RADIATION	INFRARED GROUND RADIATION	WIND	GROUND COVER
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
MEAN					

BAR GRAPH OF CLASS MEAN DATA



RESULTS

1. Looking at the class mean data table and bar graph, which treatment had the highest mean water loss? (Circle one.)

a. Control

b. Solar radiation

c. Infrared ground radiation

d. Wind

e. Ground cover

f. None (they were the same)

CONCLUSIONS

1. Turn back to the first page and review your prediction. Was your prediction correct? Use the mean mass of water loss from the class mean data table and bar graph to answer.

   Yes / No

2. After examining the results, summarize your conclusions about this experiment.

3. Use what you found in this experiment regarding the effects of several factors on the rate of evaporation and your knowledge of the climate change, the water cycle, and evaporation to answer these questions.

   a. What effect(s) does climate change have on the rate of evaporation from Earth?

   b. How do you think the effect(s) of climate change on the rate of evaporation (from question a. above) is changing the water cycle?

ANSWER KEY

PREDICTION

I predict that the amount of evaporation from the _student answers will vary_ treatment will be the **highest** (i.e., this treatment will lose the **most** water).

a. Control
b. Solar radiation (heat lamp)
c. Infrared ground radiation (heating pad)
d. Wind (fan)
e. Ground cover (moss)
f. None (they will be the same)

MATERIALS

- Small plastic container
- Permanent marker
- Ruler
- Soil
- Graduated cylinder
- Scale

PROCEDURES

1. Measure 2 cm from the bottom of the plastic container, and place a mark with the permanent marker.
2. Your group will be assigned a treatment and a group number. Write your treatment and group number on the tape on your container and on page 3 of this handout.
3. Fill the container with dry soil to the 2 cm mark. Do not pat down the soil. Take the mass of the container with the dry soil and record the mass on page 3 of this handout.
4. Measure 100 mL of water in a graduated cylinder and carefully sprinkle the water on top of the soil in the container. Make sure the water is sprinkled evenly across the top and not poured into one area of the container.
5. Take the mass of the container immediately after sprinkling the water and record it on page 3 of this handout.
6. You have been assigned to one of the following treatments. Follow the directions for your treatment.
   a. **Control**: do not add any other variables.
   b. **Solar radiation** (heat lamp): place the container under the heat lamp, approximately 3-6 inches away. Rotate the container 180° daily. The lamp simulates radiation from the sun.

c. **Infrared ground radiation** (heating pad): place the container on top of the heating pad. Rotate the container daily. The heating pad simulates ground surface radiation.
d. **Wind** (fan): set the container in front of the fan, and position the fan so that it blows level with the container. Put the fan on the lowest setting. Make sure that no other containers are in the line of the fan. Rotate the container daily. The fan simulates the wind.
e. **Ground cover** (moss): place moss on top of the soil in patches. Do not cover the soil completely. Make sure all containers have the same percentage of the surface covered. The moss simulates plants covering the soil surface.

7. Put the containers in an area that will not be disturbed and that will not allow other variables to affect them (e.g., keep them away from direct sunlight).
8. On a daily basis for the following three days, take the mass of the container and record it in the table on page 3 of this handout. If possible, take the mass at the same time each day.
9. Obtain data from other groups and record these data on the class mean data table on page 3 of this handout. Calculate the mean mass of water loss for each treatment.
10. Make a bar graph of the mean mass of water loss for each treatment on page 4 of this handout.

DATA & ANALYSIS

Group number: ________________ Treatment: ____________________

Mass of container with dry soil: ________________ Mass of container after sprinkling water: ________________

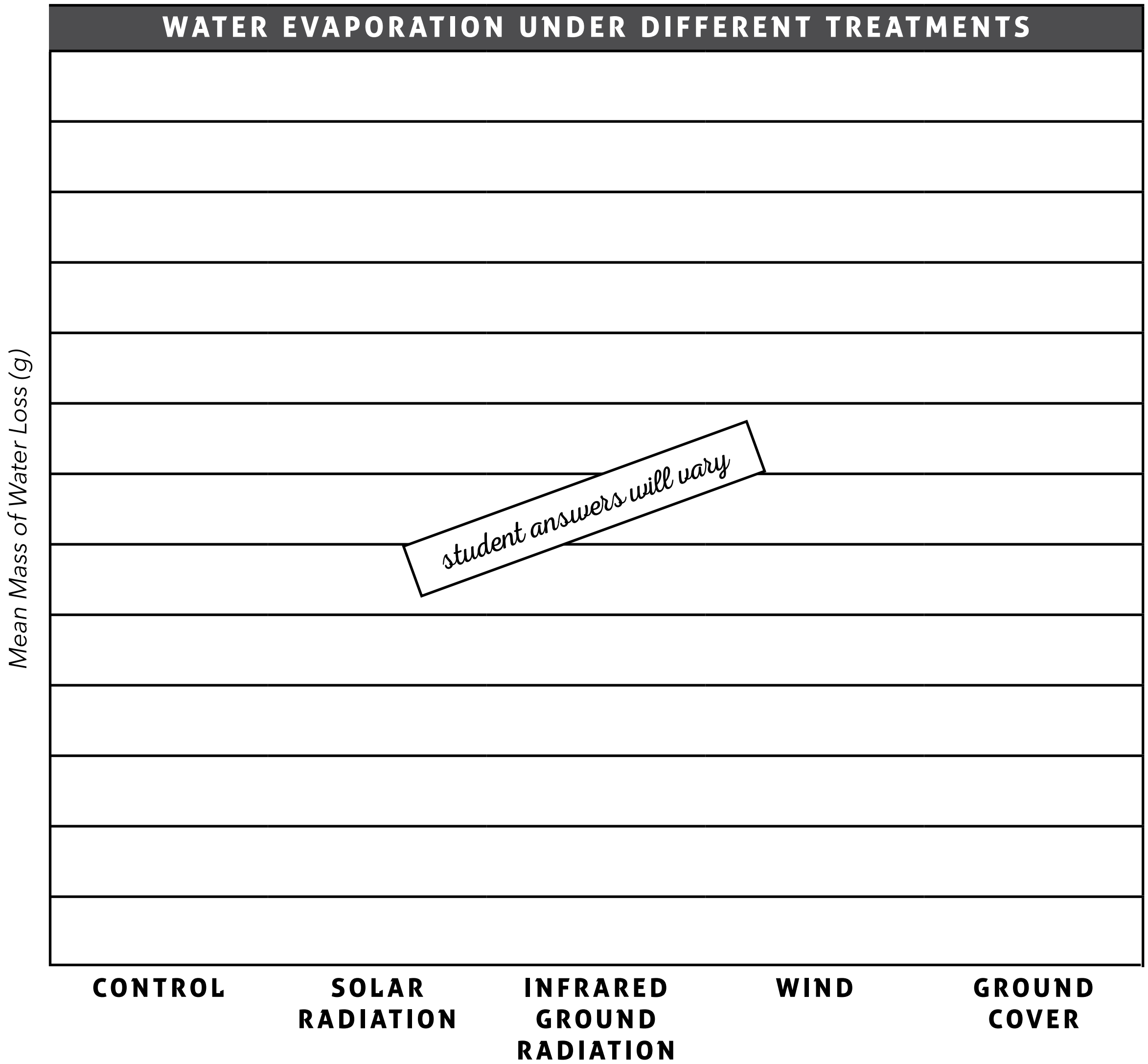
YOUR GROUP'S DATA TABLE		
	MASS (G)	DAILY WATER LOSS (previous day's mass minus current day's mass)
DAY ONE		
DAY TWO		
DAY THREE		
DAY FOUR		
TOTAL WATER LOSS (G)		

student answers will vary

CLASS MEAN DATA TABLE					
TOTAL MASS OF WATER LOSS (G)					
GROUP/ REPLICATE	CONTROL	SOLAR RADIATION	INFRARED GROUND RADIATION	WIND	GROUND COVER
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
MEAN					

student answers will vary

BAR GRAPH OF CLASS MEAN DATA



RESULTS

1. Looking at the class mean data table and bar graph, which treatment had the highest mean water loss? (Circle one.)

student answers will vary

a. Control	Wind
b. Solar radiation	e. Ground cover
c. Infrared ground radiation	f. None (they were the same)

CONCLUSIONS

1. Turn back to the first page and review your prediction. Was your prediction correct? Use the mean mass of water loss from the class mean data table and bar graph to answer.

   student answers will vary Yes / No

2. After examining the results, summarize your conclusions about this experiment.

   student answers will vary

3. Use what you found in this experiment regarding the effects of several factors on the rate of evaporation and your knowledge of the climate change, the water cycle, and evaporation to answer these questions.

   a. What effect(s) does climate change have on the rate of evaporation from Earth?

   Student answers will vary but may include:
   When heat was applied in this experiment, the rate of evaporation increased. The solar radiation and infrared ground radiation treatments lost more mass than the control. As Earth continues to get warmer, evaporation rates will increase and more water will evaporate into the atmosphere.

   b. How do you think the effect(s) of climate change on the rate of evaporation (from question a. above) is changing the water cycle?

   Student answers will vary but may include:

   - *Increased evaporation results in more water in the atmosphere, which leads to increased precipitation and flooding in some areas.*
   - *More water in the atmosphere results in increased frequency of extreme weather events, such as severe storms.*
   - *More water in the atmosphere enhances the greenhouse effect because water vapor is a greenhouse gas.*
   - *In this experiment, ground cover reduced the rate of evaporation. The ground cover treatment lost less mass than the control. However, in conjunction with increased global temperatures, we may experience an increase in evaporation, even in areas with ground cover. Increased evaporation from the soil will leave less water for plants, which may lead to a decline in plant ground cover. If plant ground cover decreases, even more water will evaporate into the atmosphere.*

THE WATER CYCLE GAME

DESCRIPTION

Students play the roles of reservoirs and hydrologic processes to illustrate the movement of water in the water cycle.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Interpret a diagram of the water cycle
- Plan the movement of water from one reservoir to another
- Describe water cycle processes

TIME
30 – 50 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7. 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).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

CCSS.ELA-LITERACY.RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

NEXT GENERATION SCIENCE STANDARDS

Middle School
MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

BACKGROUND

As climate change intensifies, climate scientists predict that many areas of the world, including the southwestern United States, will experience more frequent and prolonged periods of drought. As water becomes scarcer, it becomes increasingly important. Knowledge of the water cycle is necessary to understand how climate change impacts our water resources.

Water continuously moves around through the living and non-living parts of Earth. The **water cycle** is the movement of water on, in, and above Earth. During the cycle, water changes state between liquid, vapor, and ice. The processes by which water moves through the water cycle are defined below.

GLOSSARY

- **Evaporation**: process by which water changes from a liquid to a gas or vapor, most often driven by heat from the sun
- **Groundwater Flow**: flow of groundwater towards streams, the ocean, or deeper into the ground
- **Infiltration**: process of water seeping through soil and rock
- **Precipitation**: water released from clouds, can be in the form of rain, freezing rain, hail, snow, or sleet
- **Plant Uptake**: process by which the roots of plants take up water from the soil and move it to their leaves
- **Reservoir**: place that water is stored for some period of time
- **Snowmelt Runoff**: movement of water from melted snow and ice
- **Streamflow**: amount of water flowing in a river or stream channel
- **Transpiration**: process by which plants release water to the atmosphere

MATERIALS

- *Water Cycle* diagram, in black and white or color [1 per every 2-4 students]
    - Optional: extra set of black and white *Water Cycle* diagrams [1 per student]
- Bin labels, in black and white or color [1 set]
- PowerPoint presentation
- Computer and projector
- Six clean medium storage bins (approximately 16” h x 20” l x 17” w or similar size) or small trash cans (Figure 1)
- 72 wadded-up pieces of scrap paper wrapped with masking tape (masking tape is optional; it is best to wrap masking tape around the paper wads for durability if the game will be played multiple times, and it gives them a bit more weight for tossing)

Figure 1. Reservoir bin example, storage bin with bin label attached

PREPARATION

1. Make six reservoir bins by taping the bin labels to the outside of the storage bins or trash cans (Figure 1).
2. Plan to divide students into six groups. Plan to spread the groups around the space as much as possible. Clear a small space on the floor next to each group for the reservoir bin.
3. Place 12 paper wads into each reservoir bin.
   a. The paper wads represent water. For simplicity the game is started with equal amounts of water in each reservoir. In reality, Earth's reservoirs do not contain the same amounts of water (Table 1). For accuracy, you may want to plan to explain the relative distribution of water among Earth's reservoirs before you play the game.

Table 1. The hydrologic cycle by the numbers, an estimate of the amount of water in selected reservoirs

RESERVOIR	AMOUNT (KM^3)
OCEAN	1,338,000,000
ICE CAPS, GLACIERS, AND PERMANENT SNOW	24,064,000
GROUNDWATER	23,400,000
LAKES	176,400
ATMOSPHERE	12,900

Source: water.usgs.gov/edu/earthwherewater.html

PROCEDURES

1. Give an introduction to the water cycle using the PowerPoint presentation.
   a. **Slide 2**: small amounts of water are lost and gained through geologic processes and space, but basically we have a fixed amount of water on Earth. This water is continuously moved around through the living and non-living parts of Earth in the water cycle. The water cycle is the movement of water on, in, and above Earth. During the cycle, water changes state between liquid, vapor, and solid (ice and snow).
   b. **Slide 3**: this diagram shows the water cycle. The arrows show the movement of water from one location to another. For example, because of heat from the sun, water evaporates from the ocean and condenses to form clouds in the sky; then it falls from the clouds as precipitation. Places that water is stored for some period of time are called reservoirs, and flows or pathways (denoted by arrows) are the routes that water takes between reservoirs.
   c. **Slide 4**: As a further overview of the water cycle, show the following National Oceanic and Atmospheric Administration (NOAA) video: http://oceanexplorer.noaa.gov/edu/learning/player/lesson07.html
2. Divide students into six groups.
3. Pass out copies of the *Water Cycle* diagram and show it using the PowerPoint presentation (slide 5). Give a quick overview of the diagram, showing how the arrows indicate the movement of water from one location to another. Point out that the arrows are labeled with the processes by which water moves. Explain that the thickness of the arrows indicates the relative amount of water. In other words, the thicker the arrow, the more water that is moving to that location.
4. Assign each of the six groups a water cycle reservoir: atmosphere, groundwater, lakes and streams, land ice and snow, ocean, or plants.
5. Explain that each group is a reservoir for water, and they will move water to another reservoir by using one of the processes indicated on the diagram.
6. Tell students that they will be given an allotment of water in the form of 12 paper wads, and each group will receive a reservoir bin.
   a. You might want to take a moment to explain that water is not actually evenly distributed among Earth's reservoirs. The large majority of water is in the oceans. A large amount is also found in ice/glaciers/snow and ground water (Table 1).
7. Explain that as a group, students must plan where they could move their water, and water will be moved by tossing paper wads into a reservoir bin in at least one correct location.
8. Explain that they must determine the number of water drops that they could move to each reservoir based on the thickness of the arrows in the diagram.
   a. Students can move **two water drops into reservoirs connected to their own reservoir with thin arrows and five water drops into reservoirs connected to their own reservoir with thick arrows.**
   b. Students must state the process by which water is moving from their reservoir to the other.
   c. You may want to write these rules on the board as you discuss them.
      i. Thin lines = 2 water drops (paper wads)
      ii. Thick lines = 5 water drops (paper wads)
      iii. State process by which water is moving
9. Have students look at their *Water Cycle* diagrams and have

a discussion in their group to decide where they could move their water.

10. Optional: on the extra black and white set of *Water Cycle* diagrams, direct students to write the number of water drops they can move to each reservoir next to the arrows.
11. These are the possibilities for the movement of water.
    a. The ocean can give five water drops to the atmosphere through evaporation.
    b. The atmosphere can give five water drops to the ocean through precipitation and two water drops each through precipitation to land ice and snow, lakes and streams, and groundwater.
    c. Land ice and snow can give two water drops to lakes and streams through snowmelt runoff.
    d. Lakes and streams can give two water drops to the ocean through streamflow, two water drops to groundwater through infiltration, and two water drops to the atmosphere through evaporation.
    e. Groundwater can give two water drops to the ocean through groundwater flow and two drops to plants through plant uptake.
    f. Plants can give two water drops to the atmosphere through transpiration.
12. Once students have come up with a plan for the movement of their water, you can begin the game. Spread the groups around the space as much as possible. Clear a small space on the floor next to each group for the reservoir bin.
13. Give each group a reservoir bin with 12 paper wads inside. Place the reservoir bin on the floor near the group.
14. Instruct students to pick **one** reservoir on their diagram where they can move their water.
15. Have each group take a turn to send members of their group over the **one** reservoir where they have chosen to move their water. Instruct students to state the process by which the water is moving from their reservoir to this one.
16. Tell the whole class that if it is not their group's turn to move water, their job is to ensure that water is being moved correctly. They must check the other groups by consulting their *Water Cycle* diagram. If the current group tries to incorrectly move water to the wrong reservoir or with the incorrect number of water drops, the other groups must "buzz" them by making a buzzer noise.
17. Choose *one* group to go first, and direct that group to remove the number of water drops they will need from their reservoir bin to move their water drops to their one chosen reservoir.
18. To move water, students must first state by which process the water is moving from their reservoir to this one. Then students stand 3-5 feet away from the reservoir bin and shoot each of the allotted water drops into the reservoir bin. For management purposes, they should not stand further away.
19. After each group moves their water drops, discuss the process that led to that movement with the whole class and be sure that students understand how and why the group moved their water drops to that reservoir.
20. Next, choose a second group to move their water drops to **one** reservoir on the *Water Cycle* diagram.
21. The second group then moves their water to their chosen reservoir's bin after stating the process by which the water is moving.
22. Continue by choosing groups to move their water until each group has had a turn.
23. Complete as many rounds of the game as time allows or until water has been moved by each process shown on the diagram.
24. If there is time remaining, quiz students on the processes that result in the movement of water from one reservoir to another. Instruct students to turn over their diagrams on the desk (or collect them). Go through the *Water Cycle* diagram, and ask them by which process water moves for every arrow on the diagram.

EXTENSIONS

1. Challenge students to create their own model of the water cycle.
2. Have students research the water cycle and add missing processes to the *Water Cycle* diagram. Instruct students to describe the added processes in their own words.
3. Ask students to research and write a paragraph about how the water cycle is driven by energy from the sun and the force of gravity.

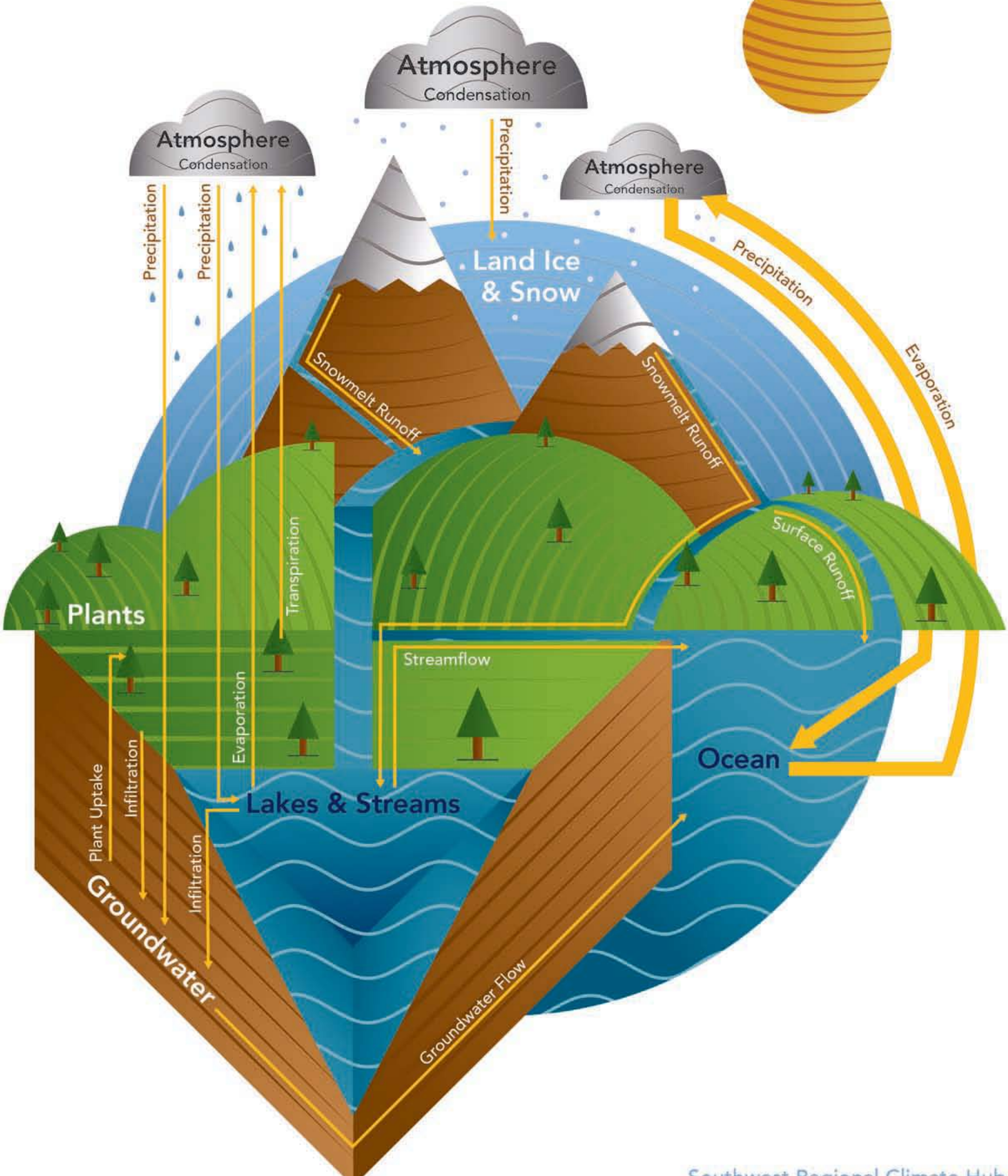
ADDITIONAL RESOURCES

Websites with background information about the water cycle:

United States Geological Survey. The Water Cycle – UGSC Water Science School. Modified 18 Mar. 2014. Web. Accessed 30 Apr. 2015. <http://water.usgs.gov/edu/watercycle.html>.

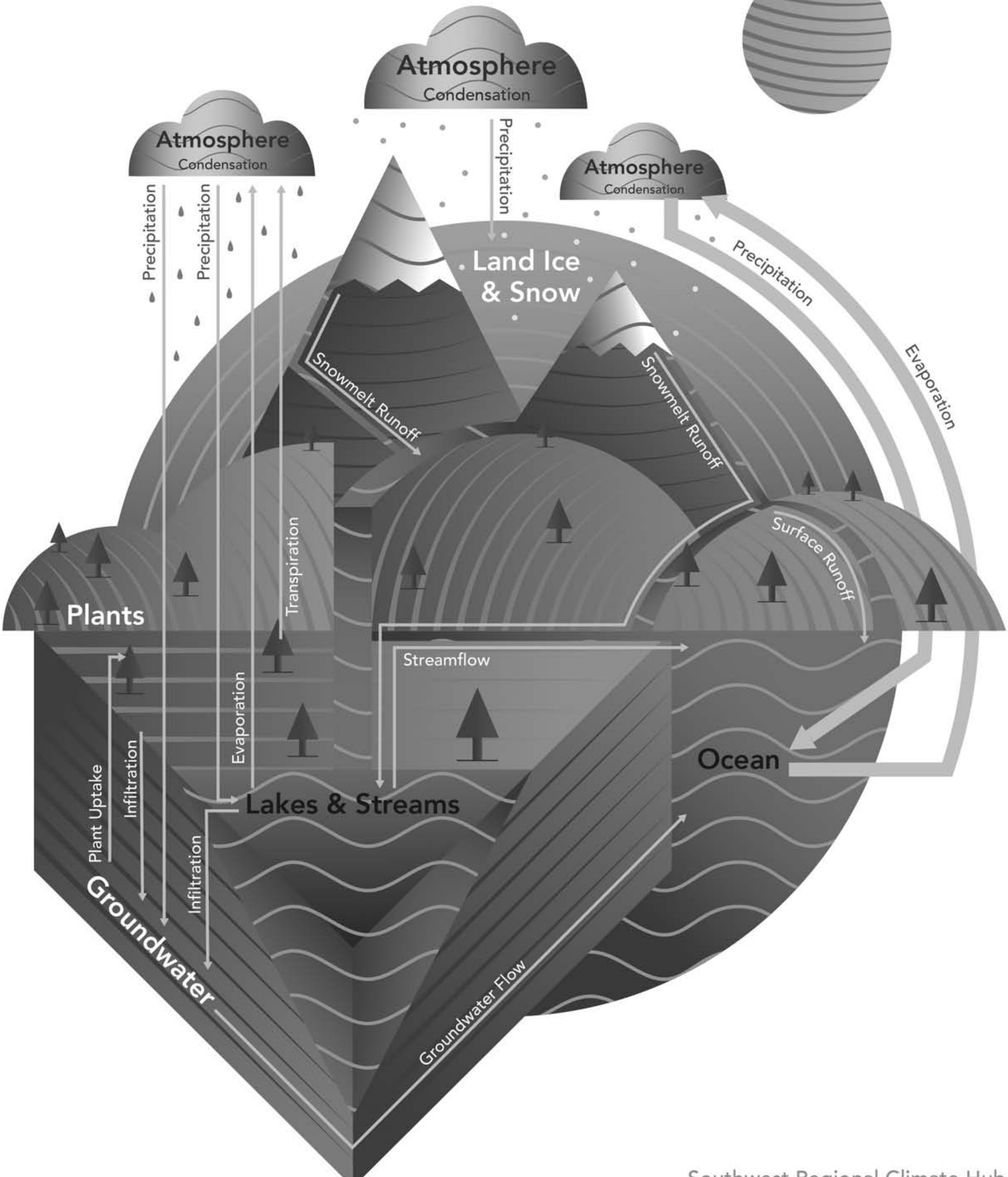
University Corporation for Atmospheric Research (UCAR), Center for Science Education. The Water Cycle. Published 2011. Web. Accessed 28 Apr. 2015. <http://scied.ucar.edu/longcontent/water-cycle>.

THE WATER CYCLE
(The Hydrologic Cycle)



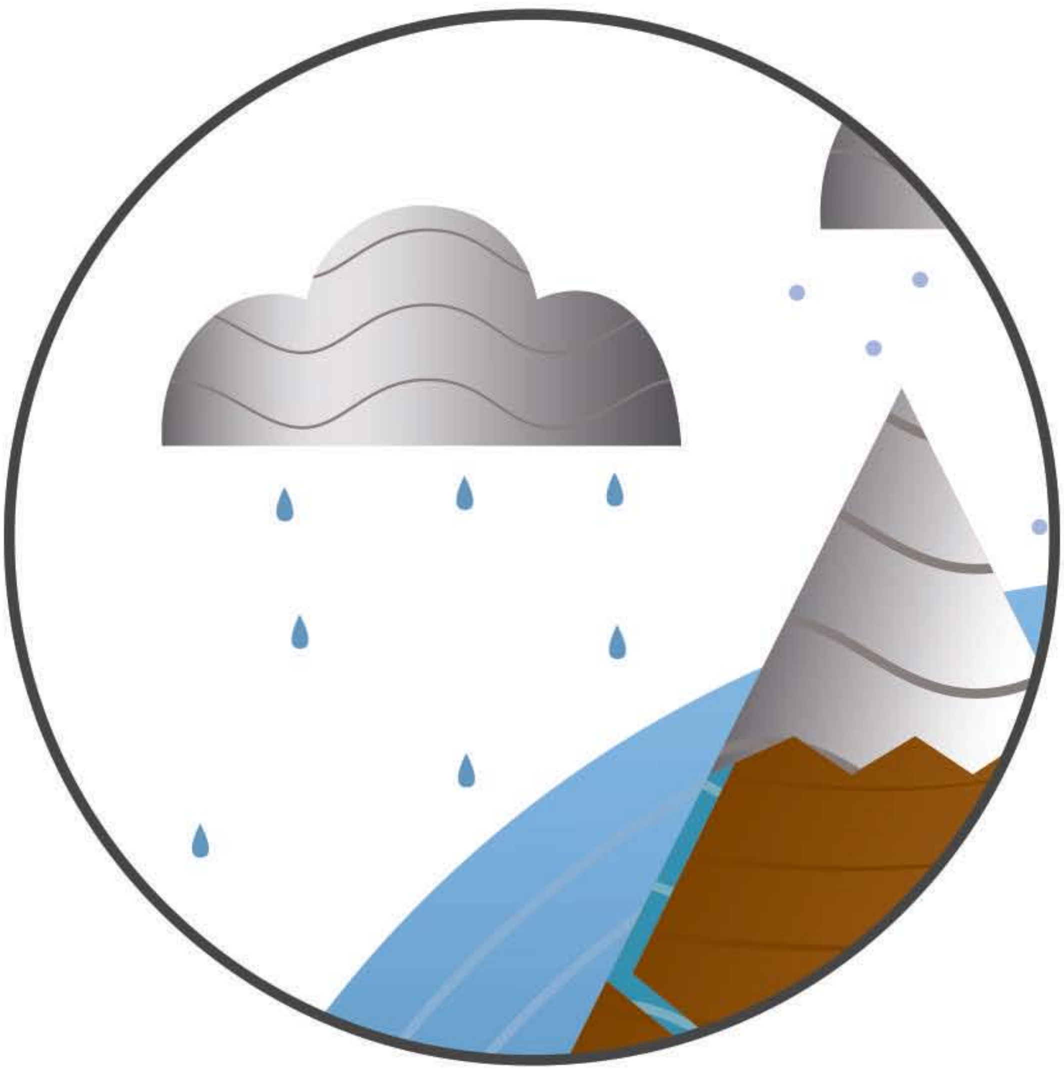
Southwest Regional Climate Hub

THE WATER CYCLE
(The Hydrologic Cycle)

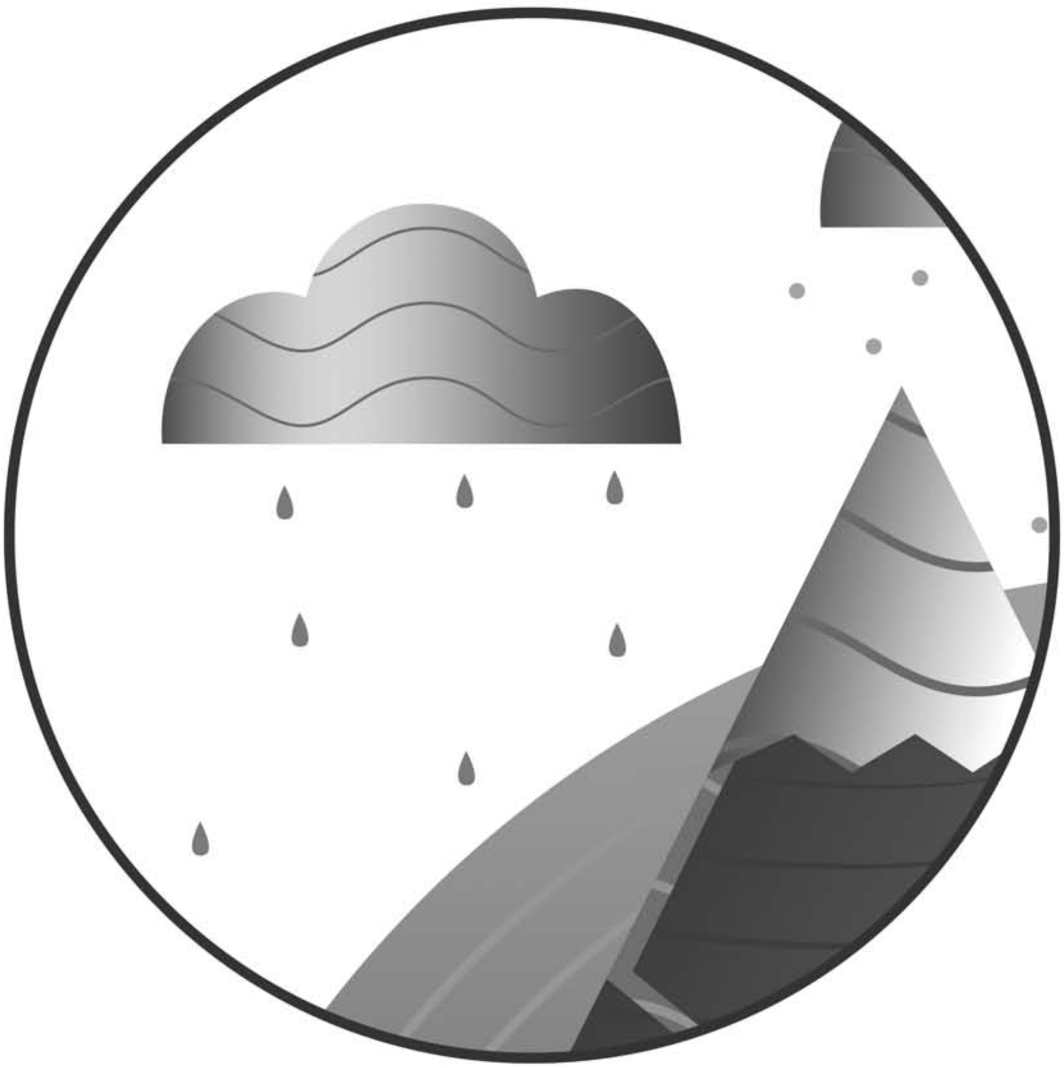


Southwest Regional Climate Hub

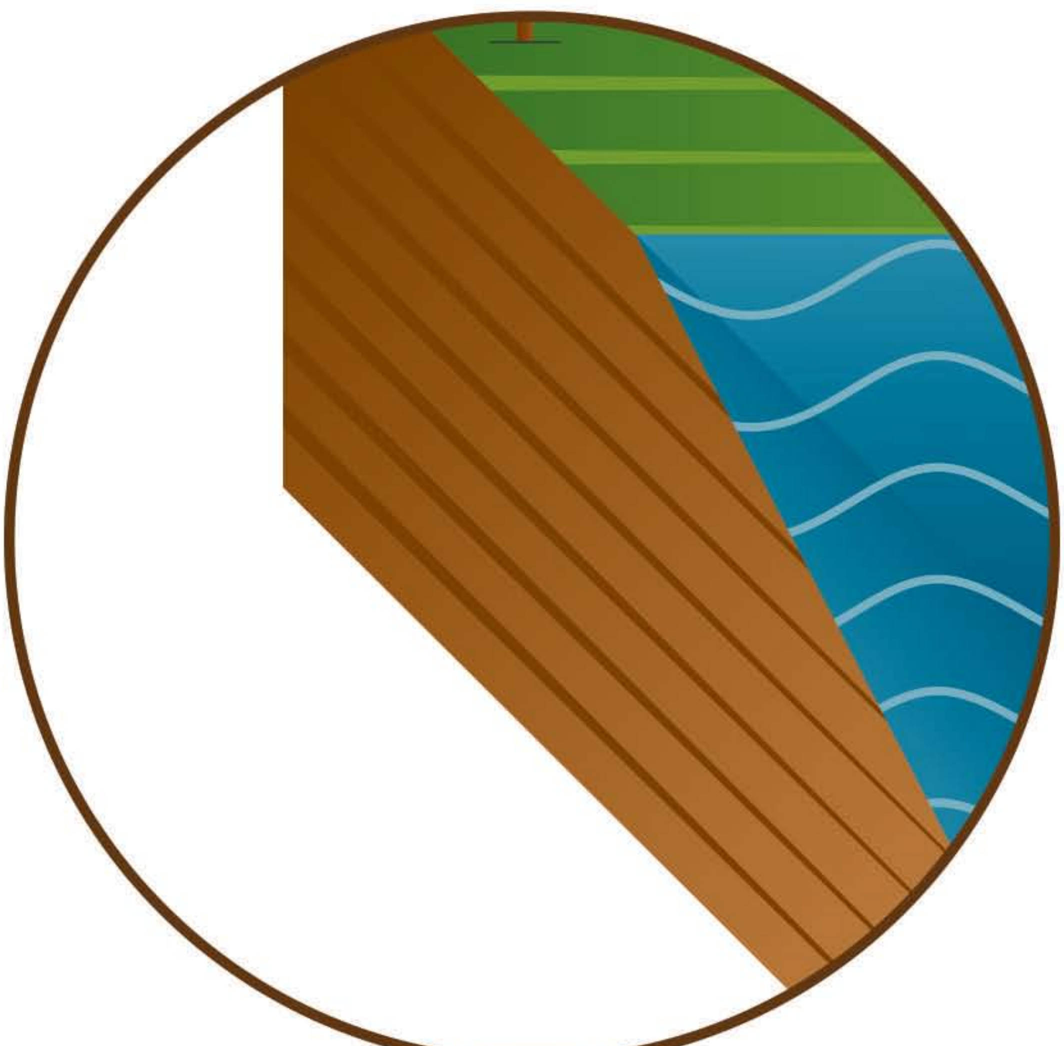
ATMOSPHERE



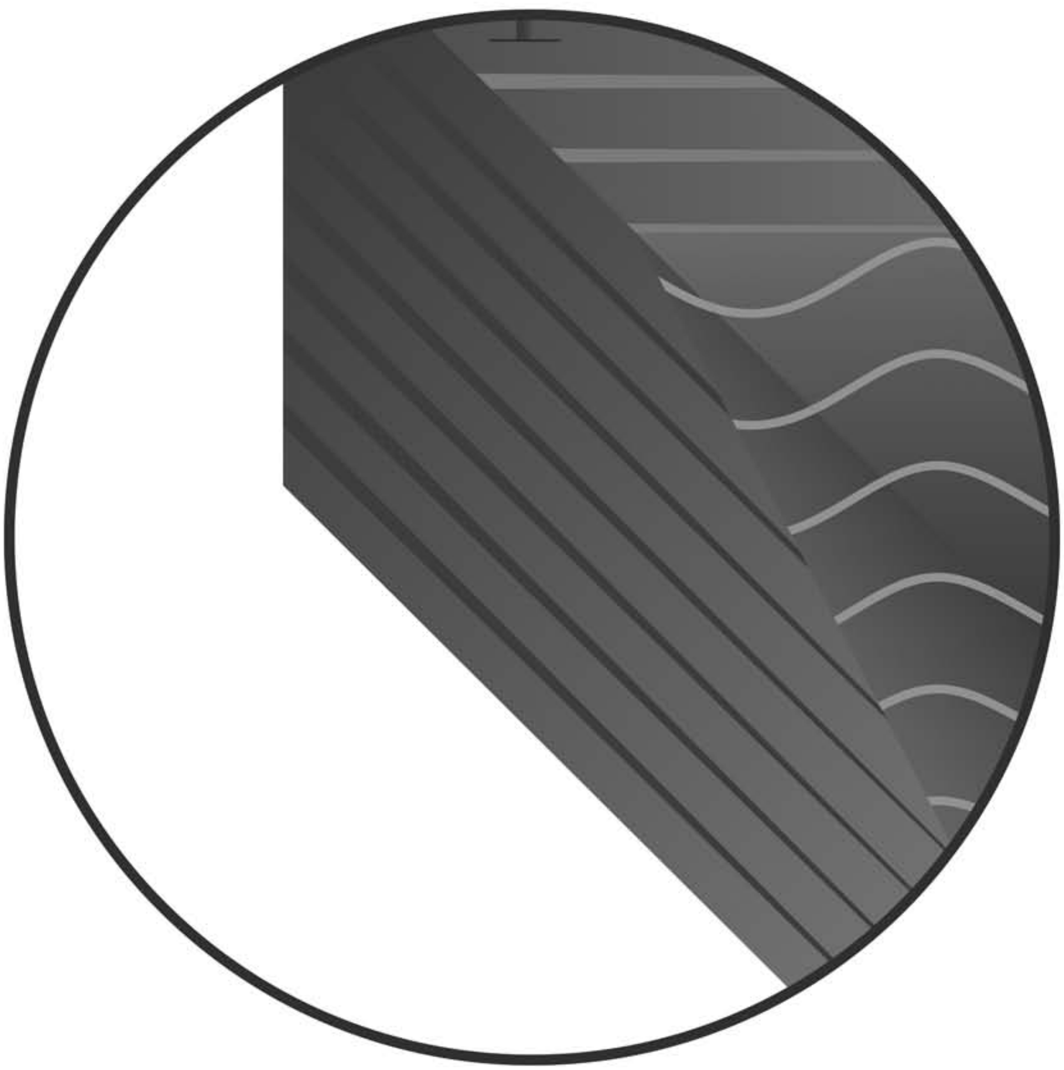
ATMOSPHERE



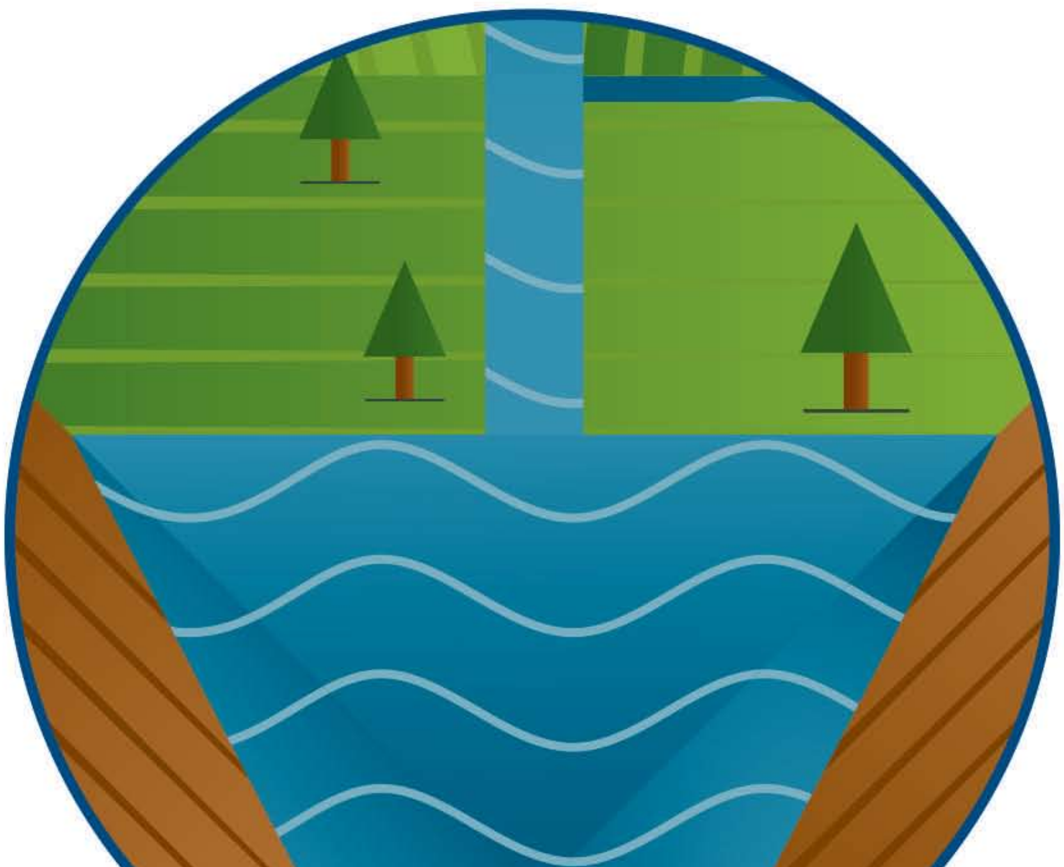
GROUNDWATER



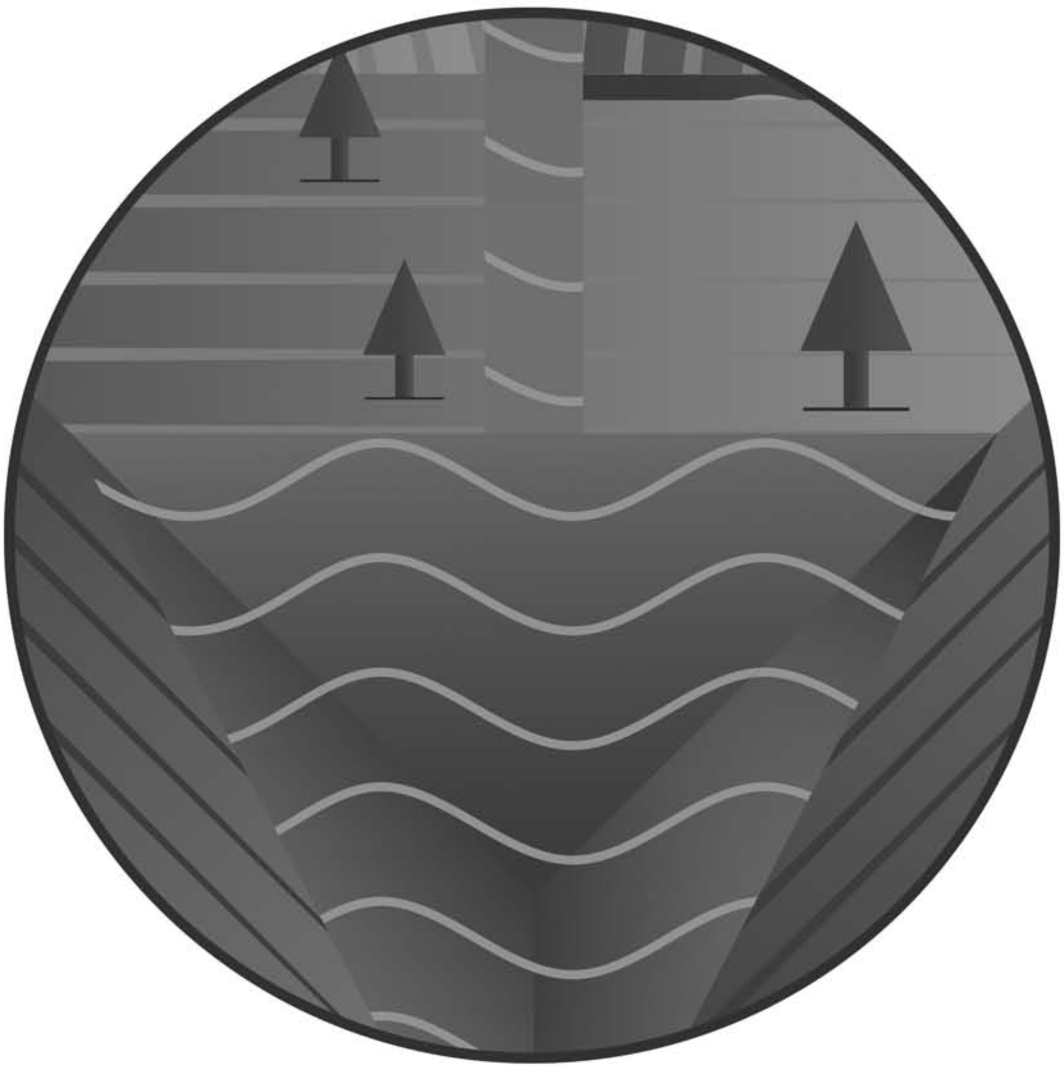
GROUNDWATER



LAKES & STREAMS



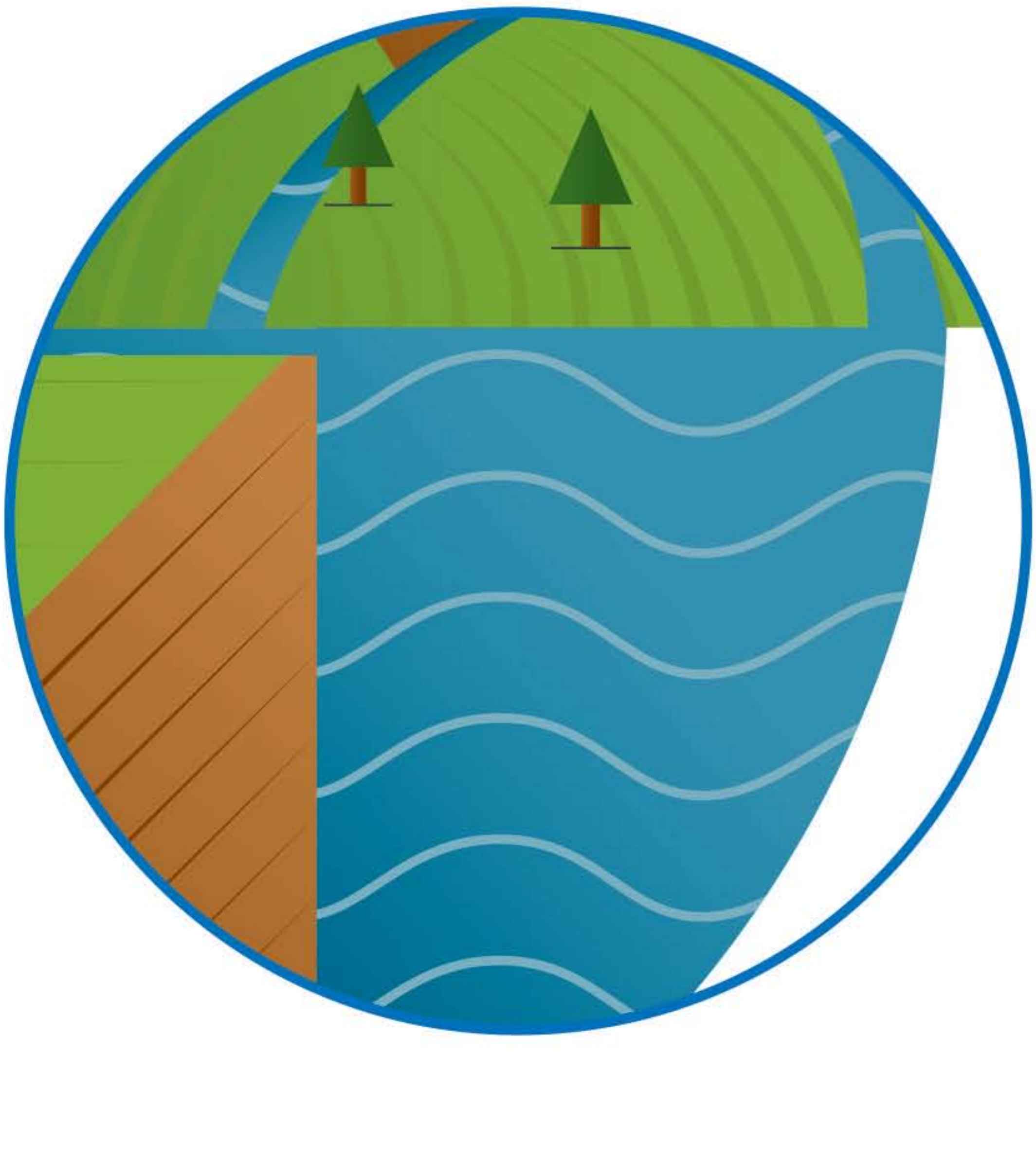
LAKES & STREAMS



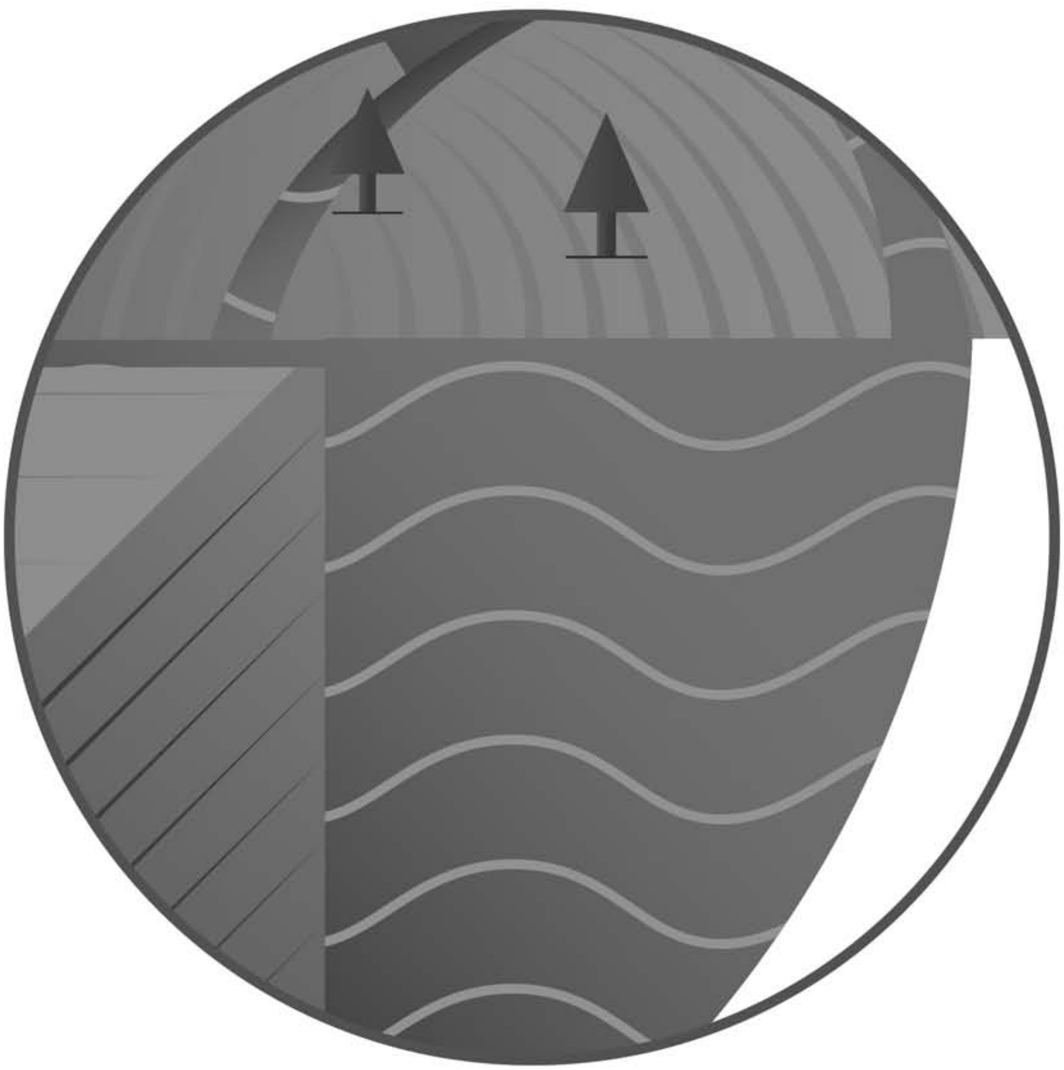
LAND ICE & SNOW

LAND ICE & SNOW

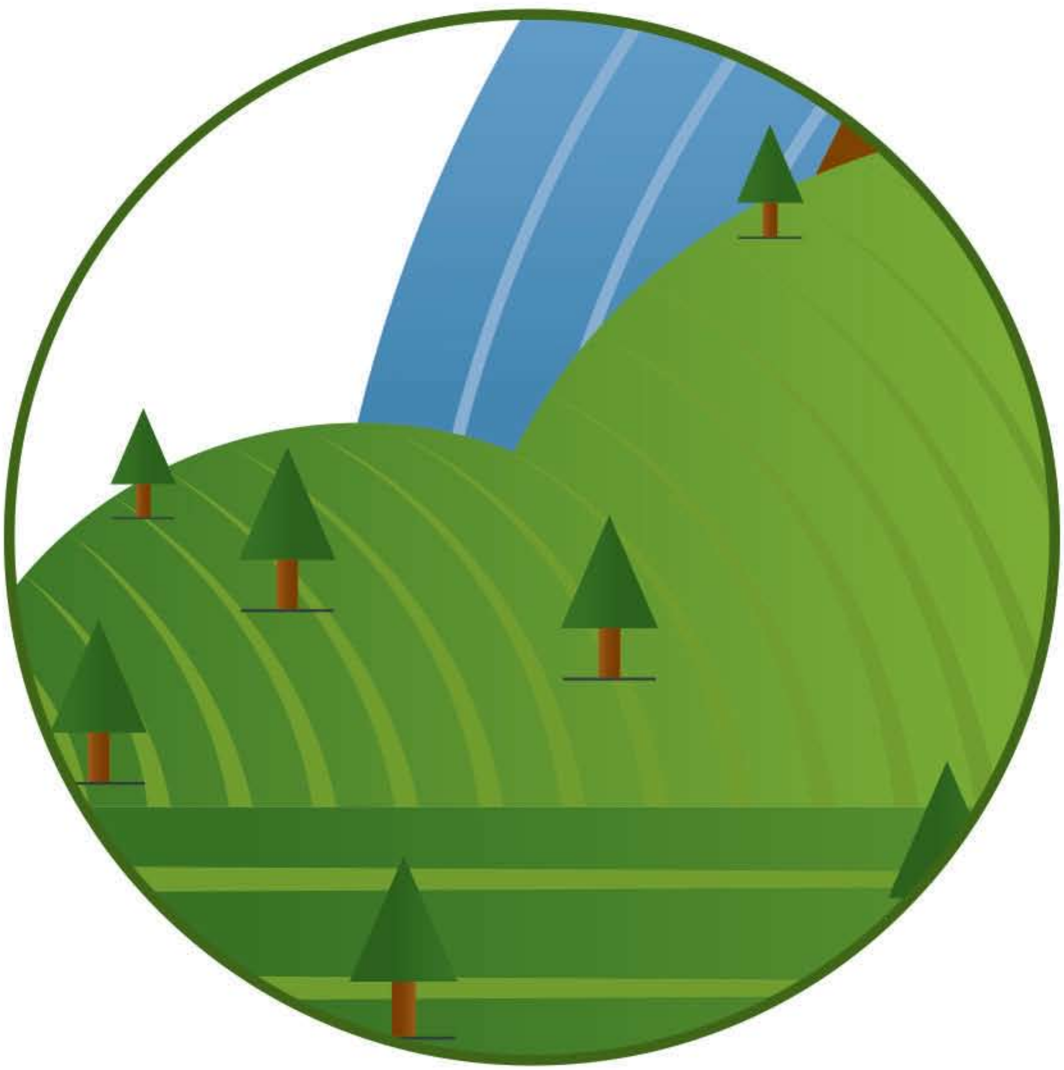
OCEAN



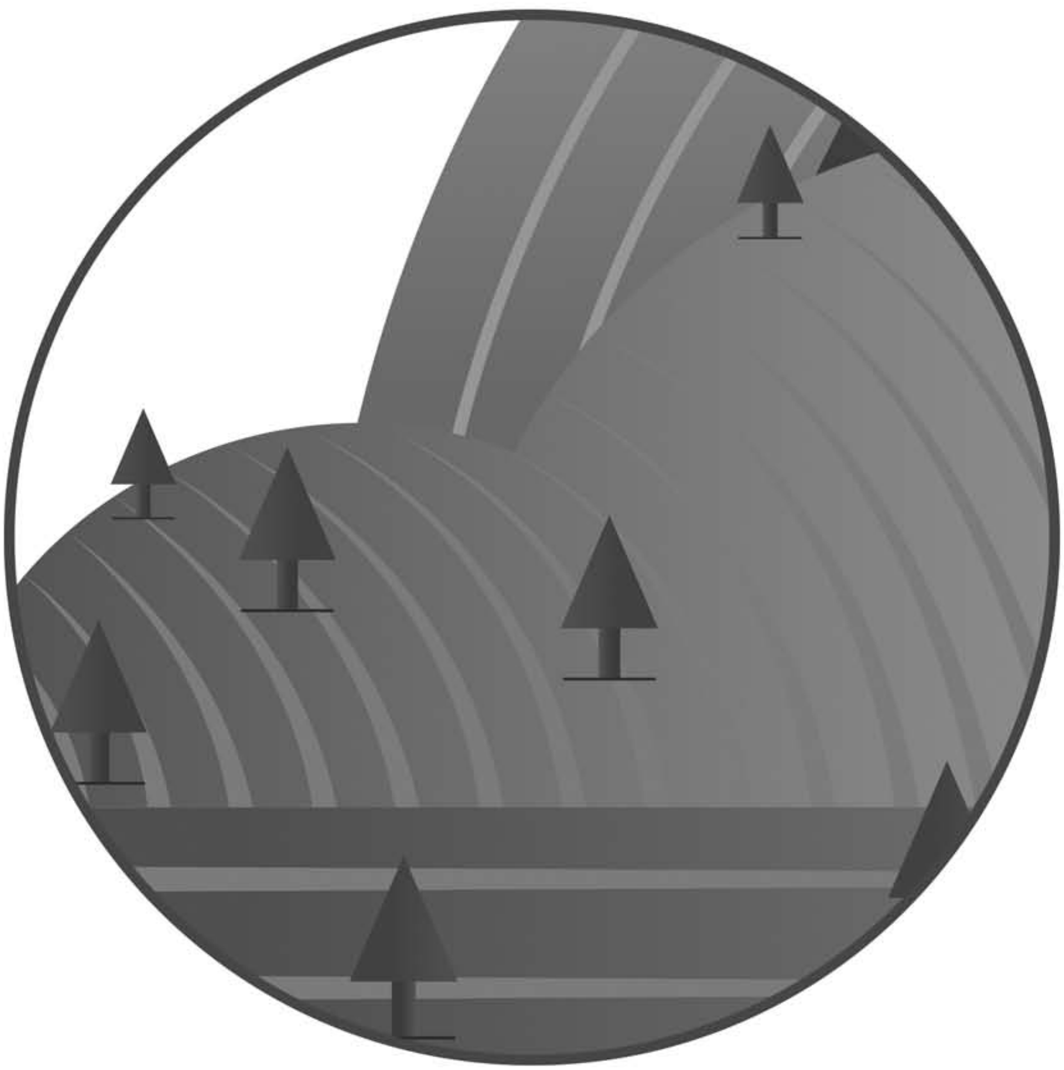
OCEAN



PLANTS



PLANTS



STREAMS AND STEAM

Effects of Climate Change on the Water Cycle

DESCRIPTION

Students play a Chutes-and-Ladders-style board game to understand the effects of climate change on the water cycle.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Predict how increasing temperatures on Earth will affect the water cycle
- Synthesize information about the effects of climate change on the water cycle
- Explain how changes in the water cycle affect humans

TIME
50 MINUTES – 1 HOUR

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts. [Extension Activity]

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7. 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).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. [Extension Activity]

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.1. Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. [Extension Activity]

CCSS.ELA-LITERACY.RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

NEXT GENERATION SCIENCE STANDARDS

Middle School
MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

High School
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

BACKGROUND

The availability of water resources for humans, our crops, and our livestock is changing because of the enhanced greenhouse effect and resulting global warming and climate change.

The greenhouse effect ensures that Earth is warm enough to sustain life. Electromagnetic radiation from the sun, mostly at short wavelengths in the form of light, is able to pass through the atmosphere and is absorbed by Earth. Earth re-radiates some of this energy back toward space as heat, more of which was able to pass through the atmosphere and escape into space historically. We are currently experiencing the enhanced greenhouse effect, however, which is caused by increased greenhouse gases in our atmosphere. As higher levels of greenhouse gases are released into the atmosphere, more of the re-radiated heat from Earth is re-emitted back to Earth instead of escaping to space. This is causing the average global temperature to increase. The increasing temperature of Earth is called **global warming**.

Global warming is leading to additional changes to our climate, such as increased frequency of extreme weather events and changing precipitation patterns, wind patterns, and length of seasons. These long-term changes in measures of climate are called **climate change**.

The **water cycle** is the movement of water on, in, and above Earth, and it is largely driven by energy from short-wave electromagnetic radiation (sunlight) absorbed by Earth's surface. The effects of climate change on the water cycle are numerous because of how warmer temperatures affect water cycle processes. Warmer water evaporates more readily, and warmer air has the capacity to hold more water vapor. As a result, in some areas, the frequency of intense precipitation events will increase, and other areas will experience more drought. Also, because of higher temperatures, more precipitation is falling as rain instead of snow. In parts of the Northern Hemisphere, early arrival of warm spring season temperatures results in earlier snowmelt and altered streamflows.

MATERIALS

- *What Is Happening to Our Water?* handout [1 per student]
- *Streams and Steam* handout [1 per student]
- *Streams and Steam* game board, in black and white or color [1 per every 4 students]
- Optional: *Water Cycle* diagram, in black and white or color [1 per every 1-4 students]
- PowerPoint presentation
- Computer and projector
- Four unique coins, e.g. penny, nickel, dime, and quarter [1 set per every four students]
- Die [1 per every four students]

PREPARATION

1. Plan to divide students into groups of four. If necessary, smaller groups are also acceptable.
2. Make the *Streams and Steam* game boards. Trim the bottom edge of the top half of the *Streams and Steam* game board, cutting away the white and blue/grey edges. Trim the top edge of the bottom half of the Streams and Steam game board, cutting away the white and blue/grey edges. Place the two halves together, align the game squares at the border, and tape the halves together.
3. Set up a computer and projector and display the PowerPoint presentation.

PROCEDURES

1. Pass out a *What is Happening to Our Water?* handout to each student.
2. Instruct students to read the excerpt at the top of the handout.
3. Once most students have had enough time to read the excerpt, introduce the activity with the PowerPoint presentation.
   a. **Slide 2**: Earth is getting warmer because of the enhanced greenhouse effect. Increased greenhouse gases in the atmosphere have resulted in global warming, which includes higher global surface temperatures and also higher air and water temperatures. (Review the greenhouse effect and global warming if needed.)
   b. Optional: pass out copies of the *Water Cycle* diagram.
   c. Ask students to draw on their understanding of the water cycle to predict the effects of warmer air and water temperatures on the processes of the water cycle; direct them to write their predictions on the handout. Students can use the *Water Cycle* diagram (if they have a copy) and the excerpt at the top of the handout.
4. Divide students into groups of four.
5. Pass out a *Streams and Steam* handout to each student.
6. Pass out a completed *Streams and Steam* game board to each group.
7. Use the PowerPoint presentation to explain the game.

a. **Slide 3**: this is the Streams and Steam game board. The game is played like Chutes and Ladders.
b. **Slide 4**: rules of the game:
   i. Roll the die to determine who starts the game.
   ii. The player who rolls the highest number goes first.
   iii. Players follow in turn from left to right.
   iv. All players begin with their coin on the start space.
   v. Roll the die and move the coin the number of spaces indicated.
   vi. When a player lands on a space that is at the top of a stream, they will "raft" down the stream by moving their coin to the square at the bottom of the stream.
      1. Move in the direction of the arrows, from the smaller to larger end of the stream.
   vii. When a player lands on a space that is at the bottom of a column of steam, they will rise up the column of steam by moving their coin up to the square at the top of the steam column.
      1. Move in the direction of the arrows, from smaller to larger puffs of steam.
   viii. The squares without pictures do not require any further action. The player will rest there until their next turn.
   ix. Two or more players may stop at the same square together.
   x. The first player to cross into the finish space wins the game. An exact roll of the die is not required to win.

8. In the table in question #1 on the handout, instruct students to list all of the causes and effects that each student from their group lands on during the game. On the game board, causes are written in the beginning stream or steam square, and effects are listed in the square where the stream or steam ends. Example, cause: increased evaporation; effect: more water in the atmosphere.
   a. Instruct students to only write each pair of causes and effects **once** if they are landed on multiple times.
9. Pass out a set of four unique coins and a die to each group. Ask students to give each player one coin and begin playing.
10. Play as many rounds of the game as time permits. One round of the game takes approximately 10 – 15 minutes.
11. Ask students to volunteer to summarize the effects of climate change on the water cycle that they learned from playing *Streams and Steam*. Return to the PowerPoint presentation to review the effects summarized by students and to wrap up the activity.
   a. **Slide 5**: Review some of the important effects of climate change on the water cycle.
      i. Because surface, air, and water temperatures on Earth are increasing, there is a higher rate of evaporation of water into the atmosphere. Warmer air holds more water, which changes precipitation patterns. Also, water vapor is a greenhouse gas, so more water in the atmosphere further enhances the greenhouse effect and changes the climate.
      ii. We will experience more severe drought in some areas. As climate change intensifies, climate scientists predict less rainfall in the Mediterranean, southwest North America, and southern Africa.
      iii. Earth will receive increased precipitation in some areas. More precipitation is predicted in Alaska and other high latitudes of the Northern Hemisphere and near the equator.
      iv. As global surface temperatures continue to increase, most areas on Earth will have warmer winter temperatures.
         1. Warmer winter temperatures mean that more precipitation falls as rain instead of snow. Snowpack will be reduced, and there will be less water stored in snow to supply watersheds.
         2. With warmer winters and spring-like temperatures coming earlier, snow is melting earlier, altering the timing of streamflow. The increased temperature in springtime increases evaporation from surface water bodies, reducing overall streamflow. This generally means that less water is available during late spring and summer months when demand is highest for crops, livestock, and general public use.
12. Ask students to explain how these changes to the water cycle will affect humans [possible answers: less water available for crops, livestock, and general public use; less food available because of decreased water supply for crops and livestock and increased water temperatures in fisheries; loss of life and property due to flooding and more extreme weather events; increased soil erosion due to flooding and drought; less snow for recreation; changes in ability to produce hydroelectric power because of changes in streamflow].

EXTENSIONS

1. Students read the National Public Radio (NPR) article, "There's a Big Leak in America's Water Tower," and answer the associated questions.
2. Have students take action to conserve water by developing and implementing a water education campaign for their community, a water conservation plan for their home or school, or a similar action project of their choice.

ADDITIONAL RESOURCES

1. Websites with background information about the effects of climate change on the water cycle:
   Environmental Protection Agency (EPA), Water Resources. Climate Impacts on Water Resources. Updated 25 Mar. 2015. Web. Accessed 11 May 2015. <http://www3.epa.gov/climatechange/impacts/water.html>.
   National Aeronautics and Space Administration (NASA), Earth Observatory. The Water Cycle and Climate Change. Web. Accessed 7 May 2015. <http://earthobservatory.nasa.gov/Features/Water/page3.php>.
2. Online quiz about the effects of global warming on the water cycle for students:
   National Oceanic and Atmospheric Administration (NOAA), Ocean Explorer. Global Warming and the Water Cycle. Modified 12 Feb. 2013. Web. Accessed 30 Apr. 2015. <http://oceanexplorer.noaa.gov/edu/learning/7_water_cycle/activities/global_warming.html>.

Name ______________________________ Date ______________

What's Happening to Our Water?

Effects of Climate Change on the Water Cycle

DIRECTIONS

Please read the excerpt below and use your knowledge of the water cycle to make predictions about the effects of climate change on the water cycle.

> The water cycle is a delicate balance of precipitation, evaporation, and all of the steps in between. Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water.
>
> Increased evaporation may dry out some areas and fall as excess precipitation on other areas. Over the past 50 years, the amount of rain falling during the most intense 1% of storms increased by almost 20%.
>
> Warming winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year. This alters the timing of streamflow in rivers that have their sources in mountainous areas.
>
> Excerpted from: EPA - Climate Impacts on Water Resources
> *www.epa.gov/climatechange/impacts-adaptation/water.html#watercycles*

PREDICTIONS

Using the excerpt above and your knowledge of the water cycle and processes like evaporation, what do you think some of the effects of climate change are on the water cycle?

ANSWER KEY

Effects of Climate Change on the Water Cycle

DIRECTIONS

Please read the excerpt below and use your knowledge of the water cycle to make predictions about the effects of climate change on the water cycle.

> The water cycle is a delicate balance of precipitation, evaporation, and all of the steps in between. Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water.
>
> Increased evaporation may dry out some areas and fall as excess precipitation on other areas. Over the past 50 years, the amount of rain falling during the most intense 1% of storms increased by almost 20%.
>
> Warming winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year. This alters the timing of streamflow in rivers that have their sources in mountainous areas.
>
> Excerpted from: EPA - Climate Impacts on Water Resources
> *www.epa.gov/climatechange/impacts-adaptation/water.html#watercycles*

PREDICTIONS

Using the excerpt above and your knowledge of the water cycle and processes like evaporation, what do you think some of the effects of climate change are on the water cycle?

Student answers will vary but may include some of the following:

- *Higher rate of evaporation of water into the atmosphere because of warmer surface, air, and water temperatures*
- *Changing precipitation patterns – more precipitation in some areas and less in others, more severe storms*
- *More precipitation falls as rain instead of snow because of warmer winter temperatures*
- *Snow is melting earlier, which alters the timing of streamflow and reduces the availability of water during the late spring and summer months when demand is highest*
- *Sea level rise because of increased water temperatures and melting glaciers and ice*

Name ____ Date ________________

Effects of Climate Change *on the Water Cycle*

DIRECTIONS

Please follow the rules below to play a round of Streams and Steam with your group, and answer the questions.

RULES OF PLAY

1. Roll the die to determine who starts the game.
2. Player who rolls the highest number plays first.
3. Players follow in turn from left to right.
4. All players begin with their coin on the start space.
5. Roll die and move the coin the number of spaces indicated.
6. When a player lands on a square at the TOP of a stream, the player will "raft" down the stream by moving their coin down to the square at the bottom of the stream.
7. When a player lands on a square at the BOTTOM of a column of steam, the player will rise up the steam column by moving their coin up to the square at the top of the steam column.
8. The squares without pictures are regular squares and do not require any further action.
9. Two or more players may stop at the same square together.
10. The first player to cross into the finish space wins the game; an exact roll of the die is not required to win.

QUESTIONS

1. List all of the causes and effects that you and your group members land on when you go down a stream and/or up a column of steam while playing Streams and Steam. Only write each pair of causes and effects **once** if it is landed on multiple times.

CAUSE	EFFECT

2. Choose one of the effects from question #1. Explain how this change to the water cycle affects humans.

ANSWER KEY

Effects of Climate Change *on the Water Cycle*

DIRECTIONS

Please follow the rules below to play a round of Streams and Steam with your group, and answer the questions.

RULES OF PLAY

1. Roll the die to determine who starts the game.
2. Player who rolls the highest number plays first.
3. Players follow in turn from left to right.
4. All players begin with their coin on the start space.
5. Roll die and move the coin the number of spaces indicated.
6. When a player lands on a square at the TOP of a stream, the player will "raft" down the stream by moving their coin down to the square at the bottom of the stream.
7. When a player lands on a square at the BOTTOM of a column of steam, the player will rise up the steam column by moving their coin up to the square at the top of the steam column.
8. The squares without pictures are regular squares and do not require any further action.
9. Two or more players may stop at the same square together.
10. The first player to cross into the finish space wins the game; an exact roll of the die is not required to win.

QUESTIONS

1. List all of the causes and effects that you ... when you go down a stream and/or up a column of steam ... each pair of causes and effects **once** if it is landed on multiple ...

Student answers will vary but may include any or all of these answers

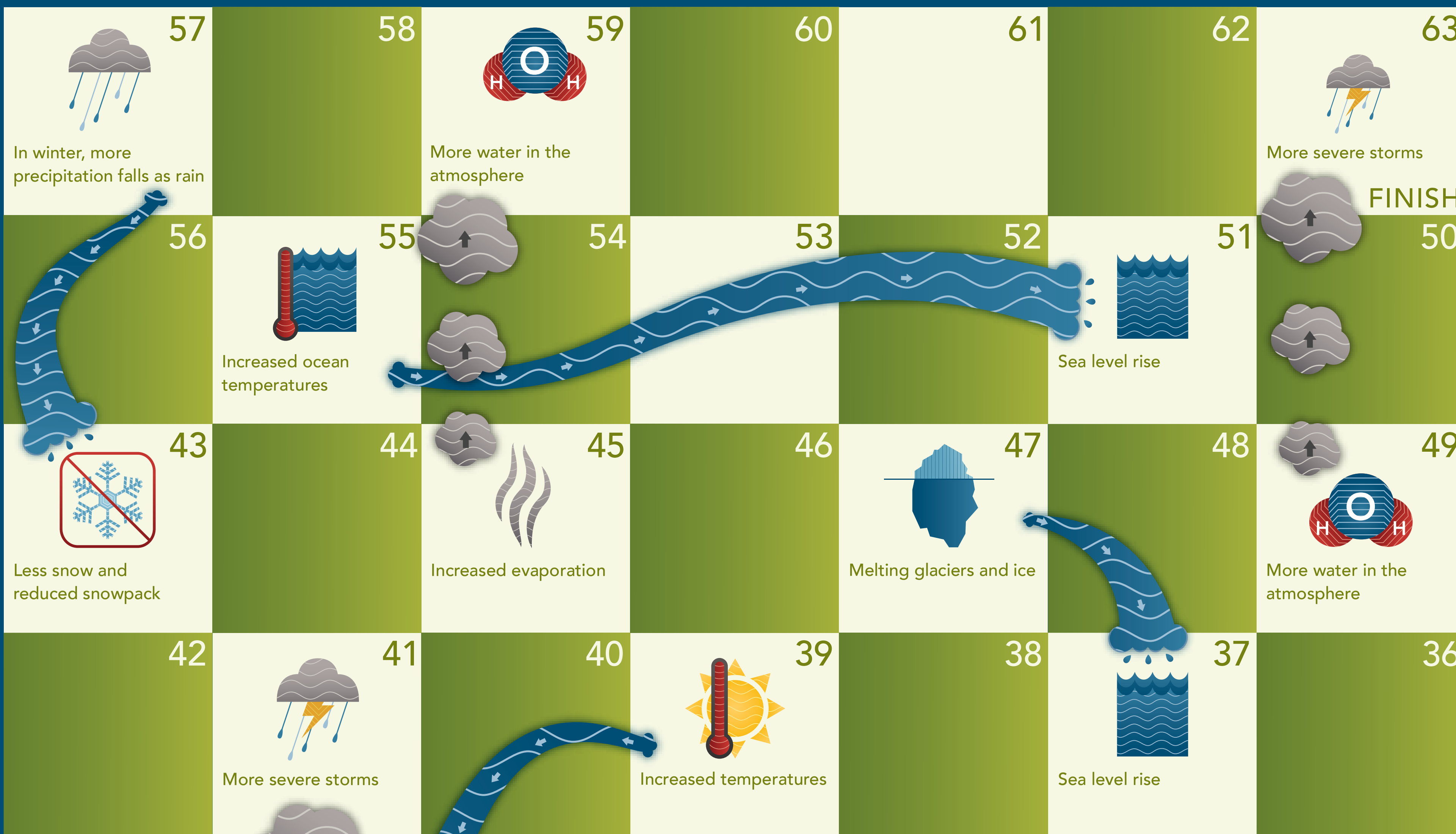
CAUSE	EFFECT
Increased evaporation	*More severe drought in some areas*
Increased evapotranspiration	*More water in the atmosphere*
Increased ocean temperatures	*More severe storms*
Reduced precipitation and decreased soil moisture in some areas	*Reduced groundwater availability*
More intense precipitation in some areas	*Flooding in some areas*
Decreased precipitation in spring	*More severe drought in some areas*
Increased temperatures	*Decreased soil moisture because of evaporation*
Increased evaporation	*More water in the atmosphere*
Melting glaciers and ice	*Sea level rise*
More water in the atmosphere	*More severe storms*
Increased ocean temperatures	*Sea level rise*
In winter, more precipitation falls as rain	*Less snow and reduced snowpack*

2. Choose one of the effects from question #1. Explain how this change to the water cycle affects humans.

- *More severe drought in some areas: less water available for crops, livestock, and general public use*
- *More water in the atmosphere: will lead to increased precipitation and flooding in some areas, which could result in property damage and human health effects; also, water vapor is a greenhouse gas, so more water in the atmosphere further enhances the greenhouse effect and changes the climate*
- *More severe storms: property damage, human health effects, loss of life*
- *Reduced groundwater availability: less water available for crops, livestock, and general public use*
- *Flooding in some areas: property damage, human health effects, loss of life*
- *Decreased soil moisture because of evaporation: less water available for crops, increased soil erosion, which could result in fewer nutrients available for crops*
- *Sea level rise: erosion of beach sand and reduction of recreation opportunities and impact to the tourism economy, property damage, displacement of waterfront and island property owners, loss of life*
- *Less snow and reduced snowpack: less water stored in snow to supply watersheds (so less water available for crops, livestock, and general public use), reduction of recreational opportunities and impact to the tourism economy*

STREAMS AND STEAM

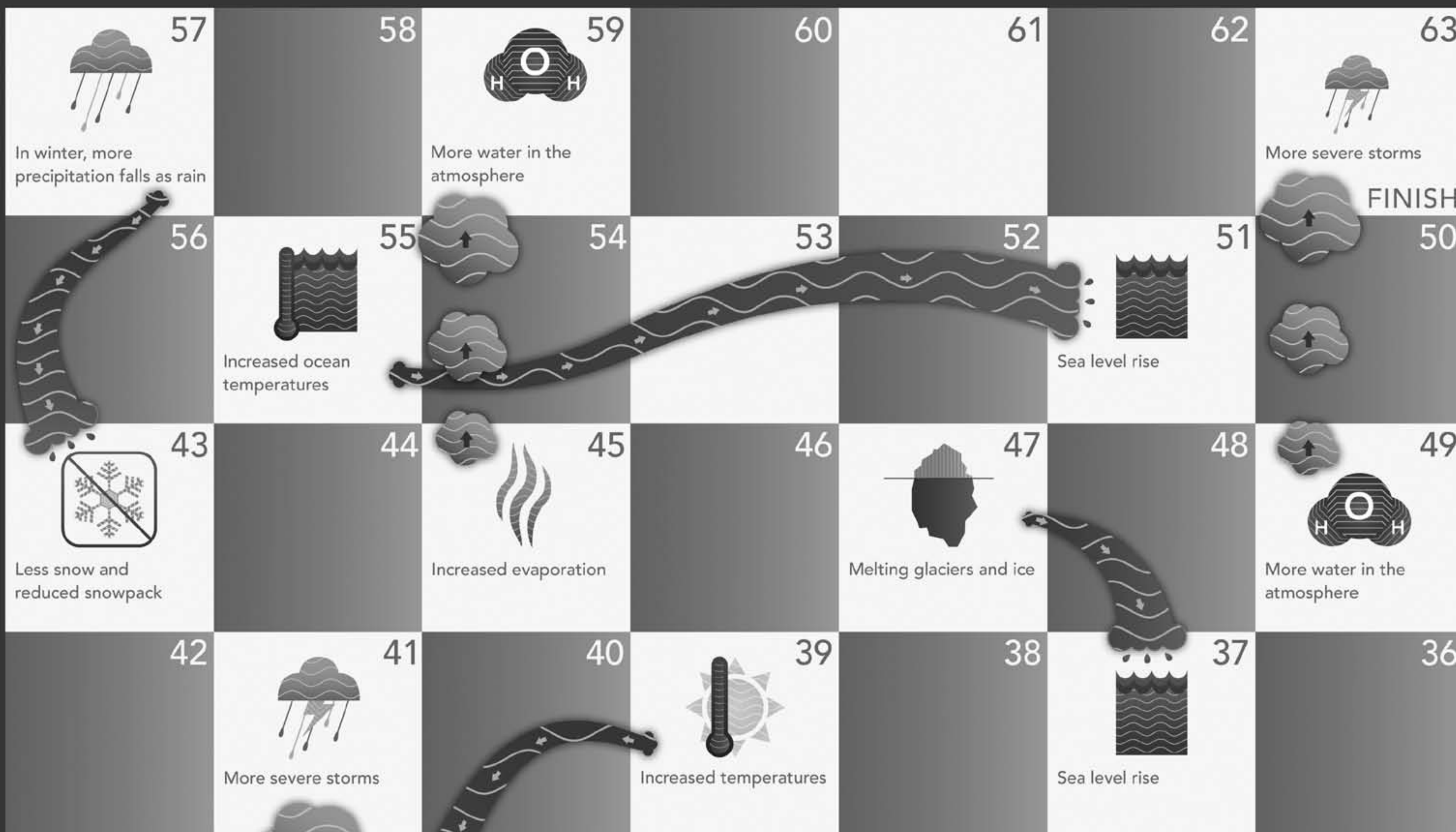
EFFECTS OF CLIMATE CHANGE ON THE WATER CYCLE




29
Decreased soil moisture becasue of evaporation
30
31
More severe drought in some areas
32
33
Decreased precipitation in spring
34
35
H O H
More water in the atmosphere
28
27
Snow melts earlier
26
25
More intense precipitation in some areas
24
23
Flooding in some areas
22
15
Increased ocean temperatures
16
17
Reduced precipitation and decreased soil moisture in some areas
18
19
20
21
14
13
Altered timing of streamflow
12
11
10
9
More severe drought in some areas
8
1
START
2
3
Increased evaporation
4
5
Reduced groundwater availability
6
7
Increased evapotranspiration
Southwest Regional Climate Hub

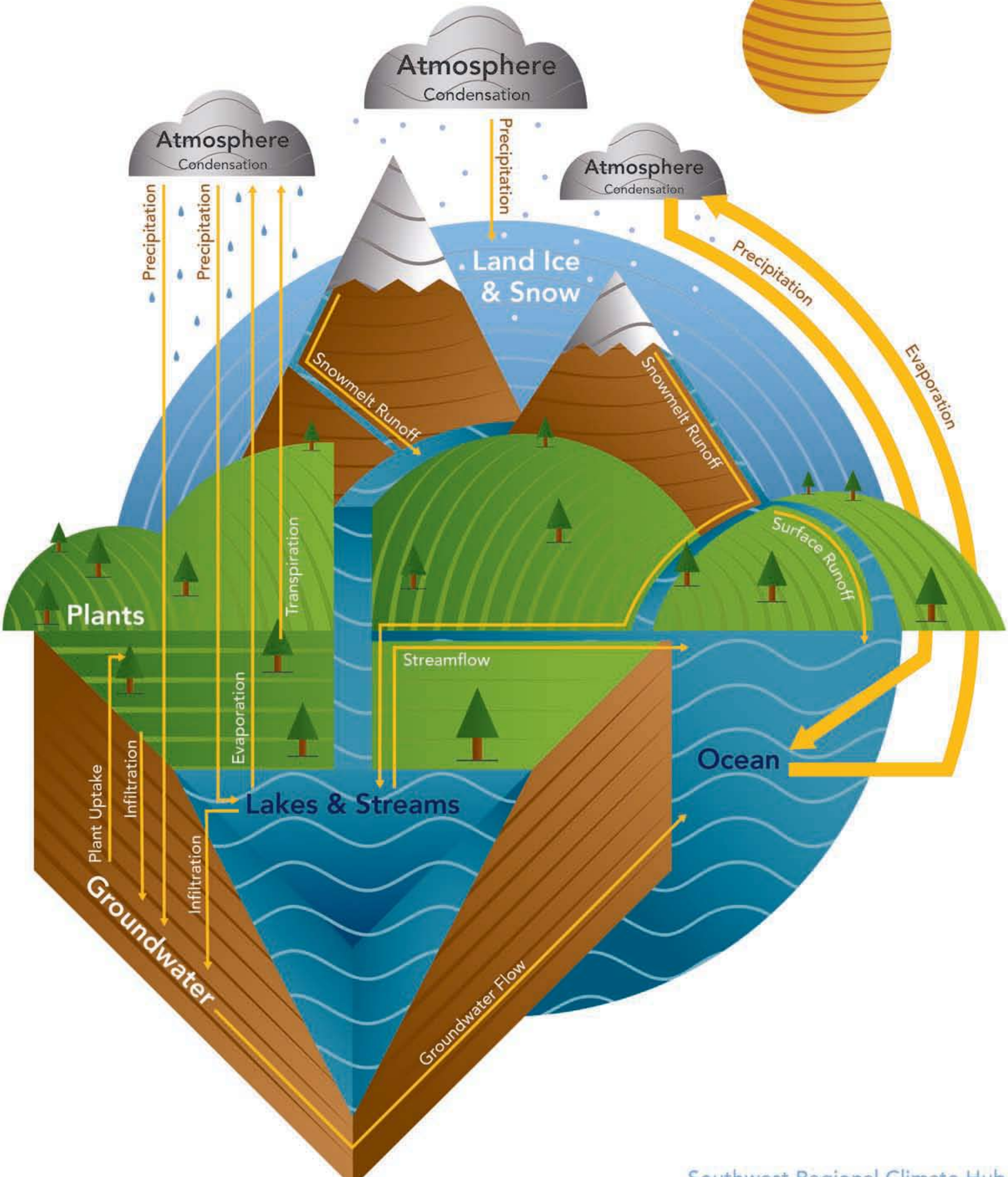
STREAMS AND STEAM

EFFECTS OF CLIMATE CHANGE ON THE WATER CYCLE



Southwest Regional Climate Hub

THE WATER CYCLE
(The Hydrologic Cycle)



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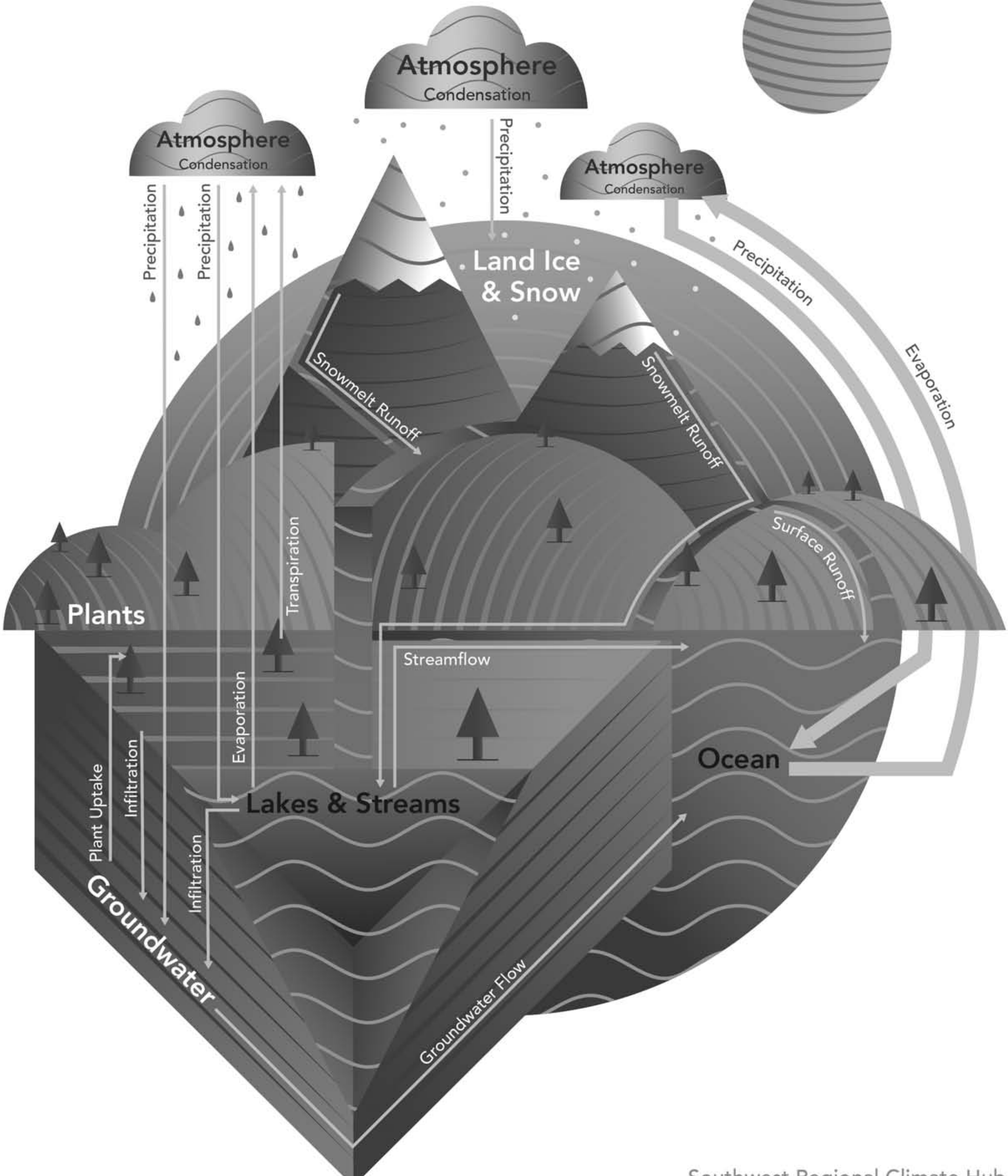

Southwest Regional Climate Hub

Name ____ Date __________________

THERE'S A BIG LEAK IN AMERICA'S WATER TOWER

by **CHRISTOPHER JOYCE**, NPR, All Things Considered

Source: www.npr.org/2014/08/27/341372550/theres-a-big-leak-in-americas-water-tower

An earlier spring in Montana's Glacier National Park means full waterfalls at first — but much drier summers. *Robert Glusic/Corbis*

The northern arm of the Rocky Mountains is sometimes called "the crown of the continent," and its jewels are glaciers and snowfields that irrigate large parts of North America during spring thaw.

But the region is getting warmer, even faster than the rest of the world. Scientists now say warming is scrambling the complex relationship between water and nature and could threaten some species with extinction as well as bring hardship to ranchers and farmers already suffering from prolonged drought.

To see how this vast natural irrigation system works, it's best to fly over it. Seated next to Richard Hauer in a Cessna he calls "Montana Rose," I can see snowcapped mountains and wide valleys spread out below. Hauer, an ecologist at the University of Montana, calls this place a giant sponge.

Moist air from the Pacific hits the mountains and falls as snow and ice. The mountains hold that water until spring. Then it melts and runs through the gravel valleys and across big parts of North America.

It's worked that way for millennia. But lately, Hauer says, Montana is warmer, and spring's melt starts earlier. "When that happens, all that storage of snow and water in the high country will go through the system [the mountains and valleys] much faster," he explains. "It's a change that's taking place because the snowmelt is occurring earlier. … Basically, if you turn the spigot on earlier, it runs out of water sooner."

Running out of water sooner means drier summers — just when plants, animals and people need it most.

Ecologists like Hauer say there are other changes happening as well — retreating glaciers, and more flash floods. "One of the expectations with climate change is that we're going to see a decrease in the permanent streams, particularly in the high alpine, and an increase in the temporary, ephemeral streams," Hauer says.

Already, scientists have noted the shrinking of the more than two dozen glaciers in Glacier National Park, as well as the disappearance of some snowfields that once lasted through summer.

Now they're trying to find out how this affects wildlife — wildlife that's important for holding together the complex food web here.

I join three scientists from the U.S. Geological Survey on a mountainside a couple of thousand feet below Hauer's flight path. We're hiking up into a snowfield in the park, toward a stream flowing down from the snow. "It's a great place to be if you are an obscure, high-alpine-stream insect," says aquatic entomologist Joe Giersch. Obscure insects are Giersch's life. Several species of very rare but important insects live here, in 40-degree meltwater.

Joe Giersch, an ecologist with the U.S. Geological Survey, studies stoneflies that live only in the melt from glaciers and snowpack in the northern Rockies. *Clint Muhlfeld/USGS*

Giersch bends over the stream — it's only a few inches deep — and turns over a few rocks. In 10 minutes, he finds what he wants: a tiny, brown, wet smudge of a fly. "All right! This is *Lednia tumana*." It's smaller than the head of a match and, to my eye, is just a brown blob. Giersch assures me that's what it is. "I've looked at a lot of these," he says. He calls the fly "charismatic microfauna."

Charismatic may be a stretch, but micro for sure. *Lednia tumana* is a stonefly. It spends part of its life in streams, but only icy streams in these mountains. It eats algae and other tiny organisms in the streams, and other insects and fish eat it. Stoneflies are part of a larger food web. Pull out one string, says our hiking companion, Daniel Fagre, and the web starts to come apart.

Lednia tumana is fish food that's long thrived in the glacier-fed streams of Montana's Glacier National Park. But as the glaciers are disappearing, so is the fly. *Joe Giersch/USGS*

"In only a few decades, we're going to lose all the glaciers here," says Fagre, a research ecologist with the USGS at the West Glacier Field Station. "And they've been persistent on the landscape here for 7,000 years — so suddenly you are having a profound change in just a few decades, and that's very difficult for many organisms to adapt to."

What's happening is that as the average temperature increases here, the snow and ice, in effect, retreat up the mountain to colder air. Ecologist Clint Muhlfeld, who also studies this fly, says eventually the ice and the insects will run out of mountain. "You know, there's nowhere to go," he says. "They're at the top of the continent — the water tower of the continent — and it's a squeeze play." Muhlfeld notes that the federal government is considering listing *Lednia* as an endangered species because of the effects of climate change.

Moving farther down the mountain, you can see more signs of this disruption in the way water works here — in places like Montana's Flathead Lake, for example, one of the biggest lakes in the country.

Jack Stanford, who runs the Flathead Lake Biological Station, has spent decades studying the complex interactions of plants, animals and water. "The way in which water is deposited first and then transported by the rivers is fundamental to the distribution and abundance of organisms," he says.

SAVING ONE SPECIES AT THE EXPENSE OF ANOTHER

Some of those organisms — for instance, salmon — are important, not only to nature but to people too.
If you get a warmer spring, you get flash floods, because the rain comes in before the snow has melted. It's called a "rain on snow event," and it can be trouble for salmon, which lay eggs in the gravel of stream beds. Rain on snow is like rain falling on pavement — it creates floods that wash the young salmon away, decimating the population.

"The way it plays out is that the food web gets a shakeup," Stanford says. "And ... the bottom line is, some players in that complex food web will be winners, and some will be losers."

Stanford says humans have already changed the natural world in ways we couldn't predict. Climate change is like putting another pair of dice in play.

QUESTIONS

1. Explain in your own words what ecologist Richard Hauer means when he says, "if you turn the spigot on earlier, it runs out of water sooner."

2. What is happening to stoneflies in the northern Rockies? Why?

3. How will changes to stonefly populations affect insects and fish that eat stoneflies?

4. Explain how the loss of 7,000-year-old glaciers over the course of a few decades may cause difficulties for organisms in the northern Rockies.

5. How are flash floods detrimental to salmon populations?

ANSWER KEY

THERE'S A BIG LEAK IN AMERICA'S WATER TOWER

by **CHRISTOPHER JOYCE**, NPR, All Things Considered

Source: www.npr.org/2014/08/27/341372550/theres-a-big-leak-in-americas-water-tower

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QUESTIONS

1. Explain in your own words what ecologist Richard Hauer means when he says, "if you turn the spigot on earlier, it runs out of water sooner."

   Snowmelt is happening earlier because of warmer temperatures. Because streams are flowing sooner, there is no longer water available throughout the season. Summers are drier, and that is when humans, plants, and animals need water the most.

2. What is happening to stoneflies in the northern Rockies? Why?

   Their populations are declining, and they may be listed as an endangered species. Their habitat is disappearing with the melting snow and ice because of warmer temperatures.

3. How will changes to stonefly populations affect insects and fish that eat stoneflies?

   As populations of stoneflies decrease, populations of their predators may also decrease unless there are other prey items available.

4. Explain how the loss of 7,000-year-old glaciers over the course of a few decades may cause difficulties for organisms in the northern Rockies.

   Because local organisms are adapted to live in glacier ecosystems, they will have difficulties as the climate changes relatively quickly. Organisms that are able may attempt to move up mountains to higher elevations and cooler temperatures, but they will run out of space if warming continues. Some species are unable to move, and they could face decreasing population sizes and possible extinction.

5. How are flash floods detrimental to salmon populations?

   Flash floods carry away young salmon, which results in a lack of juveniles to grow into adults.

How Does Climate Change Affect Primary Producers?

DESCRIPTION

Students play the roles of water-intensive and drought-tolerant plants to understand the impacts of climate change on water, primary producers, and the food web.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:

- Model the uptake of resources by plant structures
- Analyze the effects of limited resources on plant populations
- Synthesize understanding of resource availability, survival, and energy transfer to determine the effects on a food web

TIME
40 MINUTES – 1 HOUR

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7. 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).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

Grade 7 » Statistics & Probability
CCSS.MATH.CONTENT.7.SP.B.3. Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability.

NEXT GENERATION SCIENCE STANDARDS

Middle School
MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

High School
HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. [Extension Activity]

HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Extension Activity]

BACKGROUND

Plants are an important component of the water cycle and affect the movement of water through Earth's systems. Plants release water to the atmosphere through the process of transpiration. **Transpiration** occurs when water is absorbed by the roots and carried up through the stem to the leaves. Some of this water is used in photosynthesis and some is released as water vapor through the stomata, which are pores on plant surfaces that regulate gas exchange.

Because transpiration rates vary with climatic conditions, plant response to climate change can have a large impact on plant populations and soil moisture. Transpiration rates increase as temperature increases, and transpiration rates increase as humidity decreases. As temperatures increase and water availability declines under climate change conditions in the US Southwest, plant transpiration rates will likely increase. Some plant species are drought tolerant and are adapted to warm, dry conditions. Under climate change conditions in the US Southwest, drought-tolerant plants may be more likely to survive than plants that do not have the same adaptations. Drought-tolerant plants include cacti and creosotebush throughout the continental desert Southwest and ifit trees, native on islands throughout the Indian and South Pacific Oceans.

How plants react to climate change may affect the entire ecosystem. If plant populations decline, there will be less food available to primary consumers, and their populations may also decline. These effects may be felt throughout the food web and could be especially detrimental in species with limited ability for resource switching.

MATERIALS

- *Ready, Set, Grow* handout [1 per student]
- Drought-Tolerant plant nametags, copied onto cardstock, cut and strung with a piece of ribbon or string long enough to be worn as a necklace [1 per every 1-2 students] (Figure 1)
- Water-Intensive Plant nametags, copied onto cardstock, cut and strung with a piece of ribbon or string long enough to be worn as a necklace [1 per every 1-2 students] (Figure 1)
- Carbon dioxide resource cards, copied onto colored cardstock and cut (Figure 2)
- Water resource cards, copied onto colored cardstock (preferably a different color than the carbon dioxide resource cards) and cut (Figure 2)
- Game Graph, Excel file **OR** hand-drawn graph on board or large piece of paper
- *Ready, Set, Grow* instructional video, optional introduction to the game for the educator
- Computer and projector (if using Excel graph)
- Set of four different colored pencils [1 set per every 2-4 students]

Figure 1. Drought-Tolerant and Water-Intensive Plant nametags

Figure 2. Carbon Dioxide and Water resource cards

PREPARATION

1. If possible, watch the *Ready, Set, Grow* instructional video for an introduction to the game.
2. Locate a suitable space in a classroom or outside area and scatter resource cards throughout the area. The space can be a room with surfaces like benches or tables, where students can quickly move through the area without hazards, or a suitable outdoor spot. Refer to table 1 for the recommended starting resource card numbers for round 1 based on class size.
3. Place drought-tolerant and water-intensive nametags and water and carbon dioxide resource cards in an accessible location for the educator.
4. Draw the Game Graph from page 1 of the *Ready, Set, Grow* handout on the board/large piece of paper or prepare to show it with a document camera or computer and projector. In the legend on hand-drawn graphs, indicate four colors that you will use to display the number of drought-tolerant plants, water-intensive plants, carbon dioxide resource cards, and water resource cards.

Table 1. Recommended resource card numbers based on class size

	20 STUDENTS		25 STUDENTS		30 STUDENTS		35 STUDENTS		40 STUDENTS	
	Water	***CO_2***	***Water***	***CO_2***	***Water***	***CO_2***	***Water***	***CO_2***	***Water***	***CO_2***
ROUND 1	45	40	55	50	65	60	75	70	80	80
SUBSEQUENT ROUNDS	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5

PROCEDURES

1. Pass out a *Ready, Set, Grow* handout to each student.
2. Ask students what plants need to survive and have them list the answers under the Focus Question on page 1 of their handout [answer: nutrients, water, sun, suitable temperature range, space, CO_2].
3. Ask students to name the limiting resource(s) in the ecosystem as climate change intensifies and circle them on their handout. Explain that limiting resources limit a population's ability to increase and/or spread out in an ecosystem. Also, climate change refers to any significant change in the measures of climate lasting for an extended period of time (e.g., global warming, precipitation patterns, severe storms). These changes in our climate are the result of increased greenhouse gases, mostly CO_2, in the atmosphere.
    a. Water: today we will focus on water as one of the largest limiting resources for plants throughout much of the Southwest.
    b. Suitable temperature range: linked to water availability. Plants can cool themselves if they have enough water.
    c. **Not** sun: stays relatively constant.
    d. Maybe soil nutrients: climate change will likely disrupt nutrient ratios in the soil. Phosphorous may increase, and carbon and nitrogen will decrease as soils dry out. This may negatively impact plant growth.
    e. Maybe CO_2: not much of a limiting factor itself for plants, but increasing CO_2 in the atmosphere affects water availability, temperature, and soil nutrient availability, which may negatively impact some plants.
4. Explain the following. Plants are part of the water cycle. Plants absorb water from the soil and move it through their structures, which allows them to have water available for photosynthesis. When a plant takes in carbon dioxide, needed for photosynthesis, it loses water to the air through microscopic openings on its surfaces called stomata (singular = stoma). This is known as transpiration, and it is the process by which plants release water vapor into the atmosphere. In this way, plants affect the movement of water through Earth's systems. However, the availability of water has a large effect on plants as well; it is a very important factor for plant survival, distribution, and population growth.

    Today, we will explore the effects of reduced water availability on plant populations because climate scientists predict that many areas of the world, including the southwestern United States, will experience increased and prolonged periods of drought. As global temperatures increase because of climate change, more water evaporates from Earth's surface. Because of this, some areas, including Alaska and other high latitudes of the Northern Hemisphere, will receive more precipitation. Many other areas, such as the US Southwest, Mediterranean, and southern Africa, will receive less annual precipitation.

PLAYING THE GAME

1. Assign 1/3 of the class as plants to begin the game. The rest of the students will wait in line for the next round. Half of the beginning students will be assigned as drought tolerant plants, and half will be water-intensive plants.

2. Begin the game by explaining the baseline conditions for each round. Each round is like a growing season, with a certain amount of water and CO_2 available for plants. Students act as plants to quickly and carefully gather resource cards to ensure survival until the next round. In reality, of course, plants do not move around to uptake resources. However, in the game, students move around to act as stomata taking up carbon dioxide and roots absorbing water.
3. At the end of every round, students will have to transpire an increasing number of water points back to the environment (Table 2). The transpiration cost for round 1 is 1 water point, and it increases by 1 water point every round. It may be helpful to draw Table 2 on the board.

Table 2. Transpiration cost for each round

ROUND	TRANSPIRATION COST
1	1
2	2
Subsequent Rounds	Increase by 1

4. At the end of each round and after transpiration, **drought-tolerant plants** must have **2 water points and 2 CO_2 points** to survive to the next round. **Water-intensive plants** must have **4 water points and 2 CO_2 points** after transpiration. It may be helpful to write this on the board. Advise students to pick up as many resource cards as they can, even if they get more than they need.
5. After ensuring that students understand the transpiration cost for the round and how many water and CO_2 points are needed, say "Ready, Set, Grow" and release students to gather as many cards as possible.
6. There is no set time for each round. In a medium-sized class, a round takes 15-20 seconds. Watch students gathering cards, and when almost all the cards are gathered, begin a 5-second countdown. Call students back to a central location to end the round.
7. Instruct students to transpire the appropriate number of water points for the current round back to the environment (Table 2).
8. After transpiration, ask how many drought-tolerant plant students have **2 water points and 2 CO_2 points**, and instruct students to show you their cards. Then ask drought-tolerant plants to return all of their resource cards back to the environment, making sure they are scattered well enough for the next round of play. The ones who had enough cards are the surviving drought-tolerant plants. The drought-tolerant plant students who did not survive this round must move to the end of the line of students waiting to play.
9. Ask how many water-intensive plant students have **4 water points and 2 CO_2 points** after transpiration, and instruct students to show you their cards. Then ask water-intensive plants to return all of their resource cards back to the environment, making sure they are scattered well enough for the next round of play. The ones who had enough cards are the surviving water-intensive plants. The water-intensive plant students who did not survive this round must move to the end of the line of students waiting to play.
10. Give each of the surviving drought-tolerant and water-intensive plant students a nametag that matches their own. Instruct these students to give the nametag to the next student in line to create a new "sprout."
11. Recap the events of round 1 as you graph the number of plants from the start of rounds 1 and 2 on the Game Graph.
    a. Graph the number of drought-tolerant and water-intensive plants at the beginning of round 1.
    b. Discuss the number of plants that survived and reproduced as you graph the number of drought-tolerant and water-intensive plants that will begin round 2.
12. Graph the number of carbon dioxide and water cards available at the beginning of round 1.
13. Tell students that climate change conditions are in effect. Ask students to predict what will happen to the amount of carbon dioxide in the environment [answer: it will increase].
    a. Explain that the number of **carbon dioxide resource cards will increase by 5** in round 2, and graph the carbon dioxide cards available for round 2 (Table 1).
14. Ask students to predict what will happen to the amount of water in the environment throughout most of the US Southwest [answer: it will decrease].
    a. Explain that the number of **water resource cards will decrease by 5** in round 2, and graph the water cards available for round 2 (Table 1).
15. Before beginning the second round, add 5 carbon dioxide resource cards to the environment, and remove 5 water cards from the environment.
16. Explain that, as conditions become drier and warmer, plants lose more water during transpiration, and the transpiration cost has gone up by 1 point. Plants will have to transpire 2 water points at the end of round 2.
17. Repeat procedures 3 – 10.
18. To begin subsequent rounds,

graph the number of drought-tolerant plants, water-intensive plants, carbon dioxide resource cards, and water resource cards at the beginning of each round.

19. Add 5 carbon dioxide resource cards to the environment, and remove 5 water cards from the environment.
20. Continue to repeat procedures 3 – 10.

ENDING THE GAME

1. Depending on the time available, end the game after any round or wait until one or both of the plant populations dies out.
2. If one or both of the plant populations dies out and there is time to conduct more rounds, restart the game.
3. At the conclusion of the game, finish the graph. Draw lines to connect the points for each of the graphed items. Discuss the trend(s) of each of the plant populations and how they relate to the amount of carbon dioxide and water available.
4. At some point during or at the conclusion of the game, instruct students to complete the Game Graph on their handout with colored pencils.

RESULTS AND CONCLUSIONS

1. Instruct students to answer the results questions on page 2 of their handout. Use the questions to elicit a discussion about the population trends over the course of the game.
2. Ask students to answer the first conclusion question on page 2 of their handout. Discuss whether plants are more or less likely to survive with limited water resources. Extend the discussion by asking students to infer from their game data which plants are better adapted to survive in drought conditions.
3. Instruct students to look over the food web and answer the associated questions. Explain that the arrows in a food web point in the direction that the energy is moving (e.g., energy moves from grasshoppers to coyotes when coyotes prey on grasshoppers).
   a. Discuss how impacts on primary producer populations affect primary, secondary, and tertiary consumers.
   b. Extend the discussion to include other species that may be affected and impacts of declining perennial grass populations (such as habitat loss and changes in biodiversity).

GAME VARIATIONS

1. In a large class, students may be left standing in the "sprout" line for too long. Here are some options to reduce the line size and/or give students tasks to complete while waiting.
   a. Reduce the line size by giving some students roles as game helpers. Ask students whether they would rather have a job as a helper or play the game. Here are possible game helper roles:
      i. A student could graph the numbers from each round on the Game Graph.
      ii. A student could add and remove carbon dioxide and water resource cards between each round.
      iii. A student could hand out plant nametags to surviving plants each round.
   b. Students waiting in line could keep the handout with them and add to the Game Graph after every round.
   c. If two educators are available, "seeds" from surviving plant students could spread to a second area to colonize it. This will require two sets of materials.
      i. In the first round, surviving plant students could be given two plant nametags that match their own. They could then give them to the next two students in the "sprout" line. The first new "sprout" student would join the current game, and the second new "sprout" student would act as a seed and move over to another area with the second educator to establish a new population and game.
      ii. Surviving plant students from each of the two games would pull students from the one "sprout" line, and the two games would continue simultaneously.
      iii. As an option, set up the second area with different resource availability (different numbers of starting water and carbon dioxide resource cards), and at the conclusion of the game, the trends in the populations from both areas could be compared.
2. If one of the populations looks like it will crash and you would like to keep playing the game without starting over, institute a wet season. A **wet season** is an adjustment round and a method for returning plant population numbers to higher levels.
   a. At the beginning of a round, increase the number of water resource cards available (instead of decreasing them).
   b. Try increasing the available water by 2 – 7 cards. Be cautious. Changing the water by a few points can dramatically change the outcome and the length of play. It may take awhile to get the feel for what works best for your group of students.
   c. If there is time, increase water conservatively and conduct more than one wet season if needed.
   d. Go on to play the round as usual after adding more water cards.

EXTENSIONS

1. Explore the concept of carrying capacity (K) by keeping resource availability constant instead of instituting climate change conditions.
   a. If students are not familiar with carrying capacity, introduce the topic. Carrying capacity is the number of individuals of a species that an area's resources can sustain. Populations that grow exponentially tend to start out slowly, grow rapidly, and then level off when the carrying capacity has been reached (Figure 3).

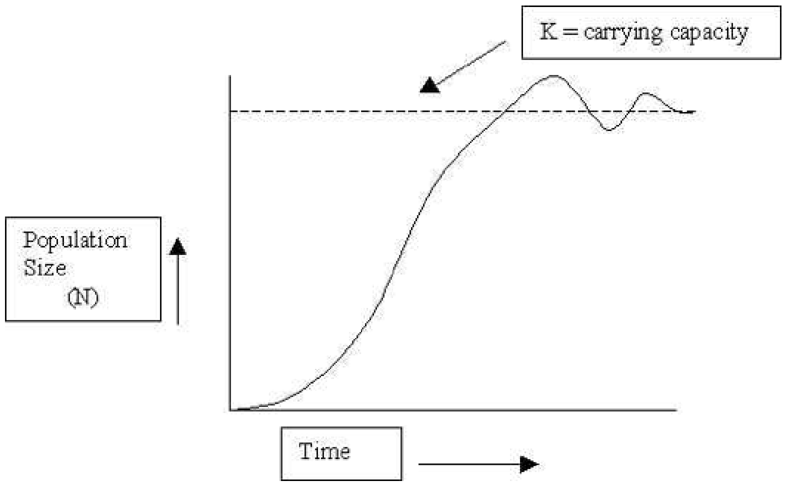


Figure 3. Graph of population size over time showing carrying capacity (K).
Source: faculty.plattsburgh.edu/thomas.wolosz/popbionote.htm

   b. Start with a fairly abundant amount of water and carbon dioxide, perhaps 5 or 10 more cards than suggested in Table 1 for your class size.
   c. Plan to play the game with only the drought-tolerant plant population, and then try it with both plant populations.
   d. Before playing, ask students to hypothesize about how the curves of population size over time will look for each version of the game (one plant population and two plant populations) when assuming a constant environment. Ask students whether they think drought-tolerant plants will have a larger or smaller carrying capacity once water-intensive plants are introduced, and ask them to draw their graphs to reflect their hypotheses.
   e. Try conducting the game with only one plant population (drought-tolerant plants); then play the game with both plant populations, and compare the graphs.
   f. Do not remove water resource cards or add carbon dioxide resource cards. Keep the environment constant.
   g. At the conclusion of both games, compare student hypotheses with the Game Graphs created while playing each version of the game (one plant population vs. two plant populations).
2. *Ready, Set, Grow* could work well in an evolution unit to demonstrate natural selection.
   a. Be creative with changing resource availability in relation to possible plant adaptations to investigate the effects on selection.
      i. For example, change the intensity of how drought tolerant or water intensive plants are in in the game by changing the amount of water they need after transpiration or how much they transpire. Survival can reflect selection for individuals of a species with favorable adaptations.

ADDITIONAL RESOURCES

1. Website with student-friendly information about transpiration:
   United States Geological Survey. Transpiration–The Water Cycle. Published 15 Apr. 2014. Web. Accessed 24 Mar. 2015. <http://water.usgs.gov/edu/watercycletranspiration.html>.
2. Website with helpful background information about population biology and carrying capacity for educators who are interested in conducting the carrying capacity extension activity:
   Wolosz, T., State University of New York, Center for Earth and Environmental Sciences. A Brief Look at Population Biology. Web. Accessed 9 Apr. 2015. <http://faculty.plattsburgh.edu/thomas.wolosz/popbionote.htm>.

Name ______________________________ Date ______________

How Does Climate Change 

Affect Primary Producers?

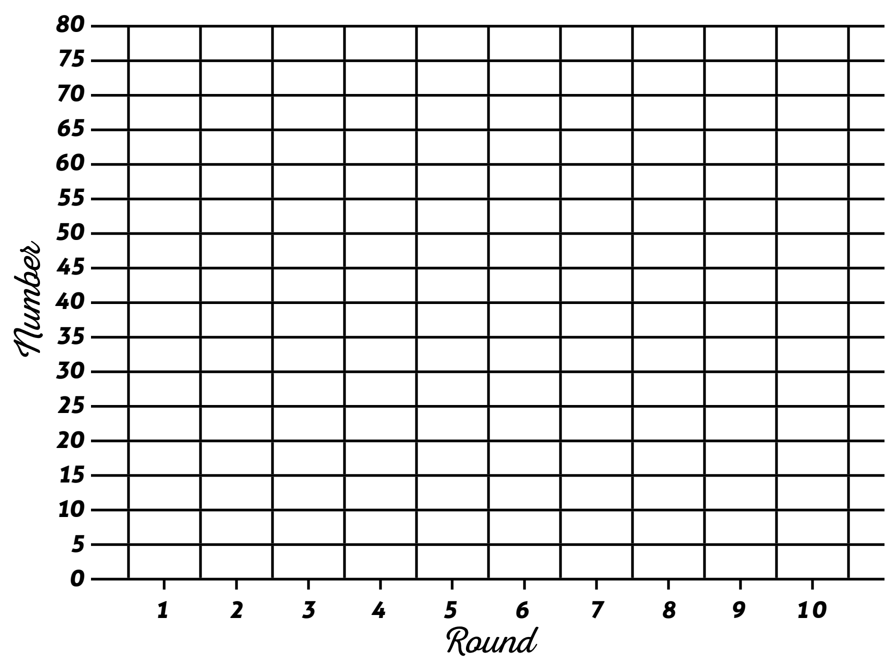
FOCUS QUESTION

1. What do plants need to live? Circle the limiting resource(s) in the ecosystem as climate change intensifies.

GAME GRAPH

In the legend, indicate four colors that you will use to display the number of each graphed item. Using the colors indicated in your legend, denote with a dot the number of water cards, carbon dioxide cards, water-intensive plants, and drought-tolerant plants at the beginning of each round. At the end of the game, connect the dots with a line of the corresponding color.

RESOURCES AND PLANT POPULATIONS OVER GAME ROUNDS



LEGEND

- ☐ Water
- ☐ Carbon Dioxide
- ☐ Water-intensive Plants
- ☐ Drought-tolerant Plants

RESULTS

1. Which plant population tended to have more individuals during most of the game rounds?

   a. Water-Intensive Plants   b. Drought-Tolerant Plants   c. Neither

2. At the conclusion of the game, which plant population had more individuals?

   a. Water-Intensive Plants   b. Drought-Tolerant Plants   c. Neither

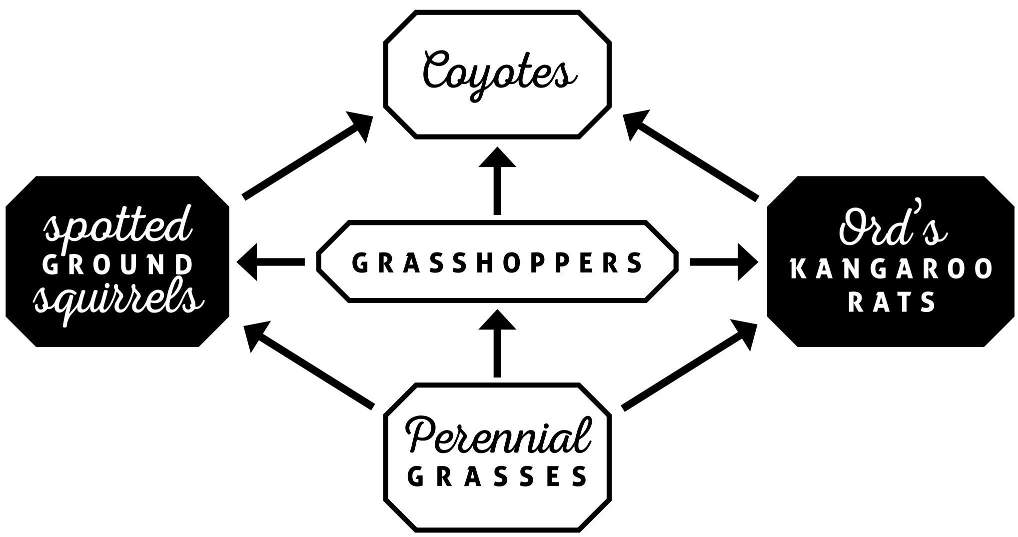
CONCLUSIONS

1. Based on the results of this game, are plant populations more likely or less likely to survive in areas with **limited water resources** due to intensifying climate change conditions?

   a. Plant populations are more likely to survive

   b. Plant populations are less likely to survive

2. Use the food web below to answer the following questions.



   a. What might happen to the grasshopper population if the perennial grass population declined sharply? Why?

   b. What might happen to the coyote population if the perennial grass population declined sharply? Why?

ANSWER KEY

How Does Climate Change

Affect Primary Producers?

FOCUS QUESTION

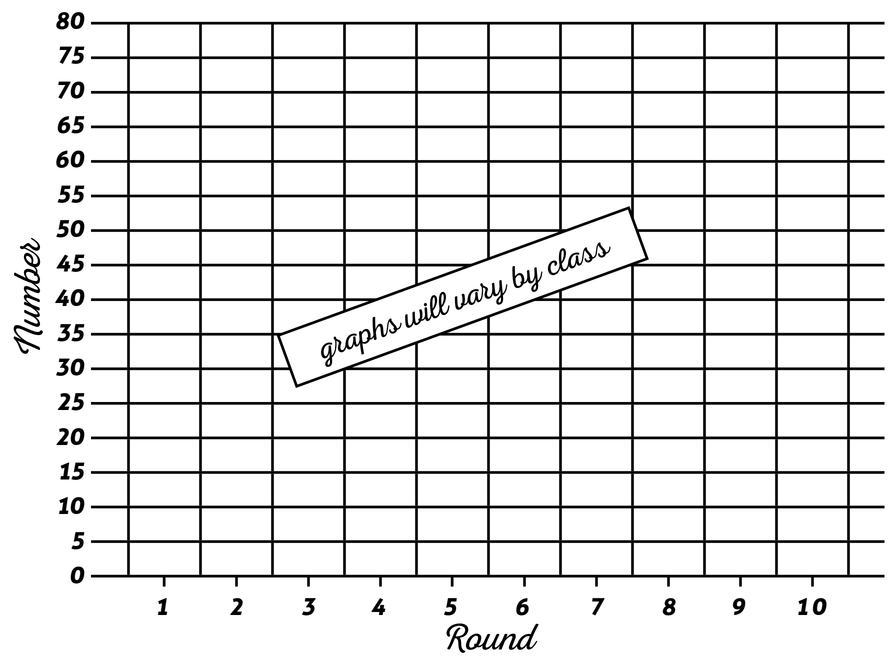
1. What do plants need to live? Circle the limiting resource(s) in the ecosystem as climate change intensifies.

maybe → Nutrients
Water
Sun
Suitable temperature range
Space
maybe → Carbon dioxide

GAME GRAPH

In the legend, indicate four colors that you will use to display the number of each graphed item. Using the colors indicated in your legend, denote with a dot the number of water cards, carbon dioxide cards, water-intensive plants, and drought-tolerant plants at the beginning of each round. At the end of the game, connect the dots with a line of the corresponding color.

RESOURCES AND PLANT POPULATIONS OVER GAME ROUNDS



LEGEND

- ☐ Water
- ☐ Carbon Dioxide
- ☐ Water-intensive Plants
- ☐ Drought-tolerant Plants

RESULTS

1. Which plant population tended to have more individuals during most of the game rounds?

student answers will vary

a. Water-Intensive Plants b. Drought-Tolerant Plants c. Neither

2. At the conclusion of the game, which plant population had more individuals?

student answers will vary

a. Water-Intensive Plants b. Drought-Tolerant Plants c. Neither

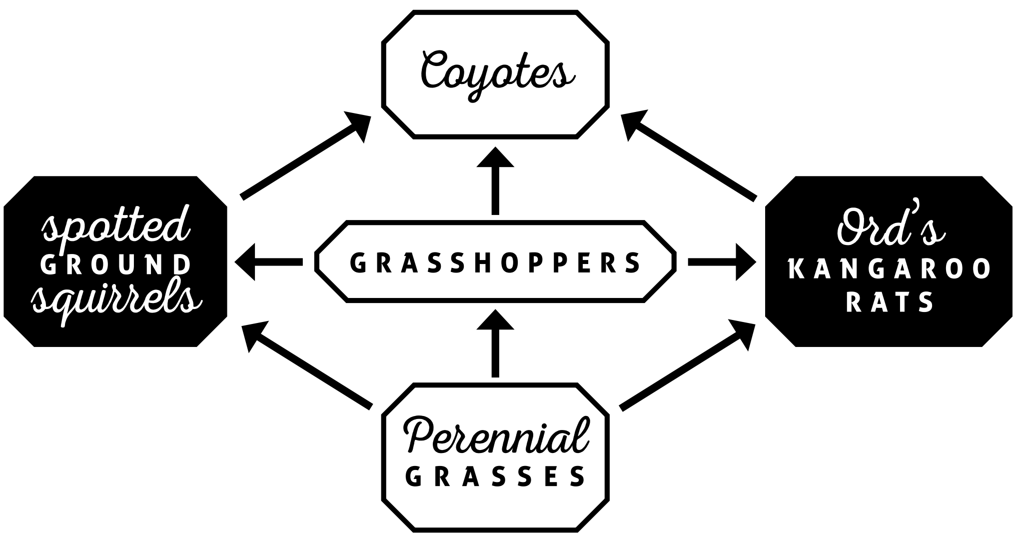
CONCLUSIONS

1. Based on the results of this game, are plant populations more likely or less likely to survive in areas with **limited water resources** due to intensifying climate change conditions?

a. Plant populations are more likely to survive

b. Plant populations are less likely to survive

2. Use the food web below to answer the following questions.



a. What might happen to the grasshopper population if the perennial grass population declined sharply? Why?

They would also likely decline sharply since there is no other food source for grasshoppers on this food web.

b. What might happen to the coyote population if the perennial grass population declined sharply? Why?

They would also likely decline because the primary and secondary consumers on this food web are the prey of coyotes, and they depend directly and/or indirectly on perennial grasses.

Drought-Tolerant Plant

Drought-Tolerant Plant

Drought-Tolerant Plant

Drought-Tolerant Plant

Water-Intensive Plant

Water-Intensive Plant

Water-Intensive Plant

Water-Intensive Plant

1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2
1 CO_2	1 CO_2	1 CO_2

1 water	1 water	1 water
1 water	1 water	1 water
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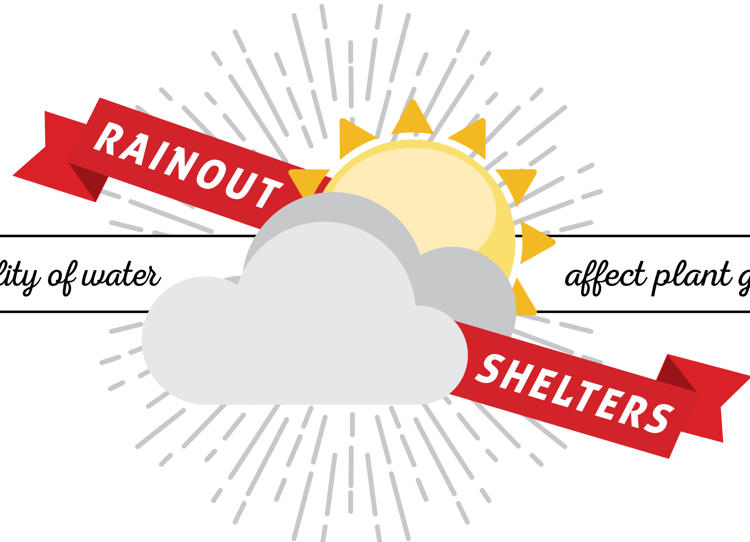


How does the availability of water affect plant growth in the desert?

DESCRIPTION

Students analyze data from a desert field experiment to examine the effect of water availability on plant growth.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Identify a research hypothesis
- Determine the independent and dependent variables in an experiment
- Interpret the results of an experiment and a graph
- Develop research questions and determine data needed to address them

TIME
1 HOUR

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8

CCSS.ELA-LITERACY.RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts.

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7. 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).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10

CCSS.ELA-LITERACY.RST.9-10.1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12

CCSS.ELA-LITERACY.RST.11-12.1. Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

CCSS.ELA-LITERACY.RST.11-12.8. Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Grade 6 » Statistics & Probability

CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: CCSS.MATH.CONTENT.6.SP.B.5.C. giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

High School: Statistics & Probability » Making Inferences & Justifying Conclusions

CCSS.MATH.CONTENT.HSS.IC.B.5. Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

NEXT GENERATION SCIENCE STANDARDS

Middle School

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

High School

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

BACKGROUND

As climate change intensifies, climate scientists predict that many areas of the world, including the southwestern United States, will experience increased and prolonged periods of drought. Reduced rainfall will decrease the availability of water for plants and other organisms in these areas.

Ecologists from Arizona State University hypothesized about the effects of reduced water availability on plant growth. They developed a field experiment to test their hypothesis that involved installing plots in the Chihuahuan Desert and manipulating the amount of water received on the plots. Some plots received less than ambient rainfall because rain was partially blocked by structures called **rainout shelters**. Some plots received more than ambient rainfall through irrigation.

The researchers found that reducing the amount of water decreased plant growth. Adding more water increased plant growth, although the relationship was not linear because other limiting resources, such as nitrogen, affect plant growth as well. These results suggest that reduced water availability may have a negative effect on plant populations. In turn, decreases in primary producers could have broader impacts throughout food webs and ecosystems.

MATERIALS

- *Rainout Shelters* handout [1 per student]
- Calculators [1 per student]
- Optional: *Asombro Institute* informational video, short introduction to the rainout shelter study
- Computer and projector (if showing video)

PREPARATION

1. Set up a computer and projector to show the video if using. Open a web browser and prepare to show the *Asombro Institute* informational video (link below). This video includes students collecting data and then discussing rainout shelters, the equipment used in the focus experiment of this activity. It is helpful for students to visualize how the experiment was conducted. Showing the entire video is not necessary. https://www.youtube.com/watch?v=PhFjgdvG0Iw

PROCEDURES

This activity can be completed with varying levels of educator guidance. Students can complete the activity on their own or with direction. Modify these procedures to best suit the needs of students.

1. Optional: show the *Asombro Institute* informational video featuring rainout shelters and plant growth data collection.
2. Pass out a *Rainout Shelters* handout to each student.
3. Instruct students to read the Research Background on page 1 of the handout.
4. Once it seems like most students have had enough time to read the research background, discuss the Automated Rainfall Manipulation System (ARMS) study design. If the video was shown, discuss the additional treatments that were used on ARMS. The video features rainout shelters that reduce rain by 50% on the plots.
   a. Explain that the ARMS experiment included five treatments: 80% rainout, 50% rainout, control (no treatment), 50% increase in irrigation, and 80% increase in irrigation.
5. Discuss the two graphs at the bottom of page 1 of the handout
   a. Figure 1 shows three options for linear (straight line) relationships between water and plant biomass. In other words, as water increases, plant biomass increases. If water is the only factor limiting plant growth, we expect that adding increasing amounts of water to plants would result in increasing plant biomass. The graph shows three possible scenarios for the rate of biomass increase in a linear relationship with increasing water.
   b. Figure 2 shows three options for a nonlinear relationship between water and plant biomass. As water increases, plant biomass increases up to a point, and then it levels off. If water is not the only factor limiting plant growth, we expect plant biomass to plateau at higher water availability. In this scenario, other resources, such as nitrogen, limit plant growth, and simply adding more water will not increase plant biomass further. The graph shows three possible scenarios for the rate of biomass increase in a non-linear relationship with increasing water.

6. Guide students to answer the questions beginning on page 2 of the handout. After allowing time for students to answer, lead a discussion of each question.
   a. **Prediction Question 1**: locate the prediction in the background information on page 1 of the handout and write it.
   b. **Data and Analysis Question 1**: calculate the mean biomass for each treatment and record the answer on the blanks to the right of the table.
   c. **Data and Analysis Question 2**: identify the independent and dependent variables from the experiment and write them in the blanks.
   d. **Data and Analysis Question 3**: have students make a bar graph of the mean biomass for each treatment in the graph on page 3 of the handout.
   e. **Results and Conclusions Question 1**: determine whether there appears to be a linear relationship between biomass and water, and circle A or B accordingly.
   f. **Results and Conclusions Question 2**: decide whether it appears that water is the only limiting factor in this ecosystem and explain.
   g. **Results and Conclusions Question 3**: develop further research questions related to this study and identify the data needed to address them.
7. Wrap up with a discussion of the effects of water availability on plants and how decreasing plant populations may affect the local food web and Chihuahuan Desert ecosystem. Ask students what other effects reduced water availability could have on ecosystems throughout the Southwest [possible answers: declining plant populations, and primary consumer populations may also decrease, which could cause declines to populations of organisms throughout the food web/drier soil that is more susceptible to erosion/less water directly available for wildlife/ more wildfires].

EXTENSIONS

1. Have students read a summary article (link below) about a long-term international study that investigated the ability of plants to tolerate drought conditions. Instruct students to write a paragraph that summarizes the findings and includes a prediction about how changes in water availability will affect plants and other organisms in your area.
   http://uanews.org/story/plants-adapt-drought-limits-are-looming-study-finds
   Original source:
   Ponce-Campos, GE, Moran, MS, Huete, A, Zhang, Y, Bresloff, C, Huxman, TE, Eamus, D, Bosch, DD, Buda, AR, Gunter, SA, Scalley, TH, Kitchen, SG, McClaran, MP, McNab, WH, Montoya, DS, Morgan, JA, Peters, DPC, Sadler, EJ, Seyfried, MS, Starks, PJ. 2013. Ecosystem resilience despite large-scale altered hydroclimatic conditions. Nature 494(7437): 349-352.

ADDITIONAL RESOURCES

Article with more information about the Automated Rainfall Manipulation System experiment:

Gherardi, L and Sala, OE. 2013. Automated rainfall manipulation system: A reliable and inexpensive tool for ecologists. Ecosphere 4(2): art 18, 1-10. Accessed online. 19 May 2015. <http://sala.lab.asu.edu/wordpress/wp-content/uploads/ARMS-reprint.pdf>.

Name ____ Date ________________

RAINOUT SHELTERS

How does the availability of water affect plant growth in the desert?

Plants are amazing organisms. Through a process called photosynthesis, they are able to "fix" carbon dioxide and turn it into sugars that allow them to grow and reproduce. The growth of a plant is often measured by calculating the increase in the plant's biomass, which can include stems, roots, flowers and fruits.

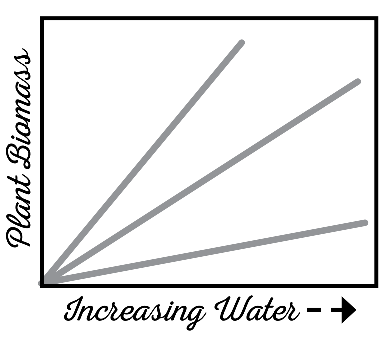
In order to grow, plants need light, nutrients, and water. Nitrogen is the nutrient most often limiting plant growth. In the Chihuahuan Desert, water also limits plant growth. The average annual rainfall at the research site in Las Cruces, New Mexico is 298 mm (11.7 inches). Many climate change models predict that the Chihuahuan Desert will receive less annual rainfall, with the largest decreases in the spring.

Rainout shelter and irrigated plots

How does the availability of water affect desert plant growth and how might this change as annual rainfall decreases? Scientists at the Jornada Basin Long Term Ecological Research Program (LTER) are conducting a large experiment that helps answer this question and many more. They installed an Automated Rainfall Manipulation System with five types of plots: (1) rainout shelters that reduce rain on the plot by 80%, (2) rainout shelters that reduce rain on the plot by 50%, (3) controls, (4) irrigated plots that receive 50% more than ambient rainfall, and (5) irrigated plots that receive 80% more than ambient rainfall. Scientists then estimate plant biomass on each plot using measurements of plant species cover and the volume of shrubs.

This experiment tests the effect of water availability on plant growth. If water is the **only** factor limiting plant growth, we expect plant biomass to increase linearly with increasing water (Figure 1). However, if nitrogen is also a limiting factor for plant growth, we expect plant biomass to level off at higher water availability, resulting in a plateau in the curve of the graph of biomass against water (Figure 2).

*Figure 1. Possible outcome #1 – three possible **linear** (straight line) relationships; as water increases, plant biomass increases.*



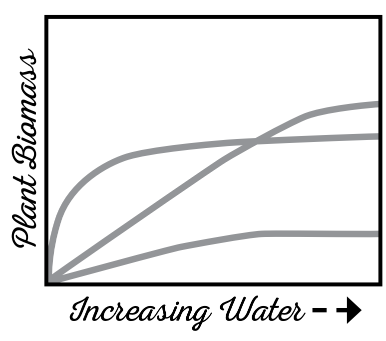


*Figure 2. Possible outcome #2 – three possible **nonlinear** relationships. At some water level, plant biomass levels off.*

PREDICTION

1. What do scientists predict they will see if both water and nitrogen are limiting? Find the prediction in the background information on page 1, and write it below.

DATA & ANALYSIS

1. Here are the data collected in the experiment. Calculate the mean biomass for each treatment and write it on the line to the right.

WATER MANIPULATION	AMOUNT OF WATER RECEIVED (MM)	BIOMASS (G/M^2 YR)
Rainout 80%	19	15.9
Rainout 80%	19	14.4
Rainout 80%	19	11.8
Rainout 80%	19	64.1
Rainout 80%	19	36.6
Rainout 50%	48	27.1
Rainout 50%	48	47.5
Rainout 50%	48	50.4
Rainout 50%	48	37.1
Rainout 50%	48	33.2
Control	95	61.1
Control	95	76.8
Control	95	57.8
Control	95	85.0
Control	95	49.1
Irrigation 50%	143	121.5
Irrigation 50%	143	74.6
Irrigation 50%	143	56.9
Irrigation 50%	143	99.7
Irrigation 50%	143	95.6
Irrigation 80%	171	60.8
Irrigation 80%	171	110.0
Irrigation 80%	171	94.3
Irrigation 80%	171	81.9
Irrigation 80%	171	84.2

Mean plant biomass on rainout 80% plots = ______________

Mean plant biomass on rainout 50% plots = ______________

Mean plant biomass on control plots = __________________

Mean plant biomass on irrigation 50% plots = ____________

Mean plant biomass on irrigation 80% plots = ____________

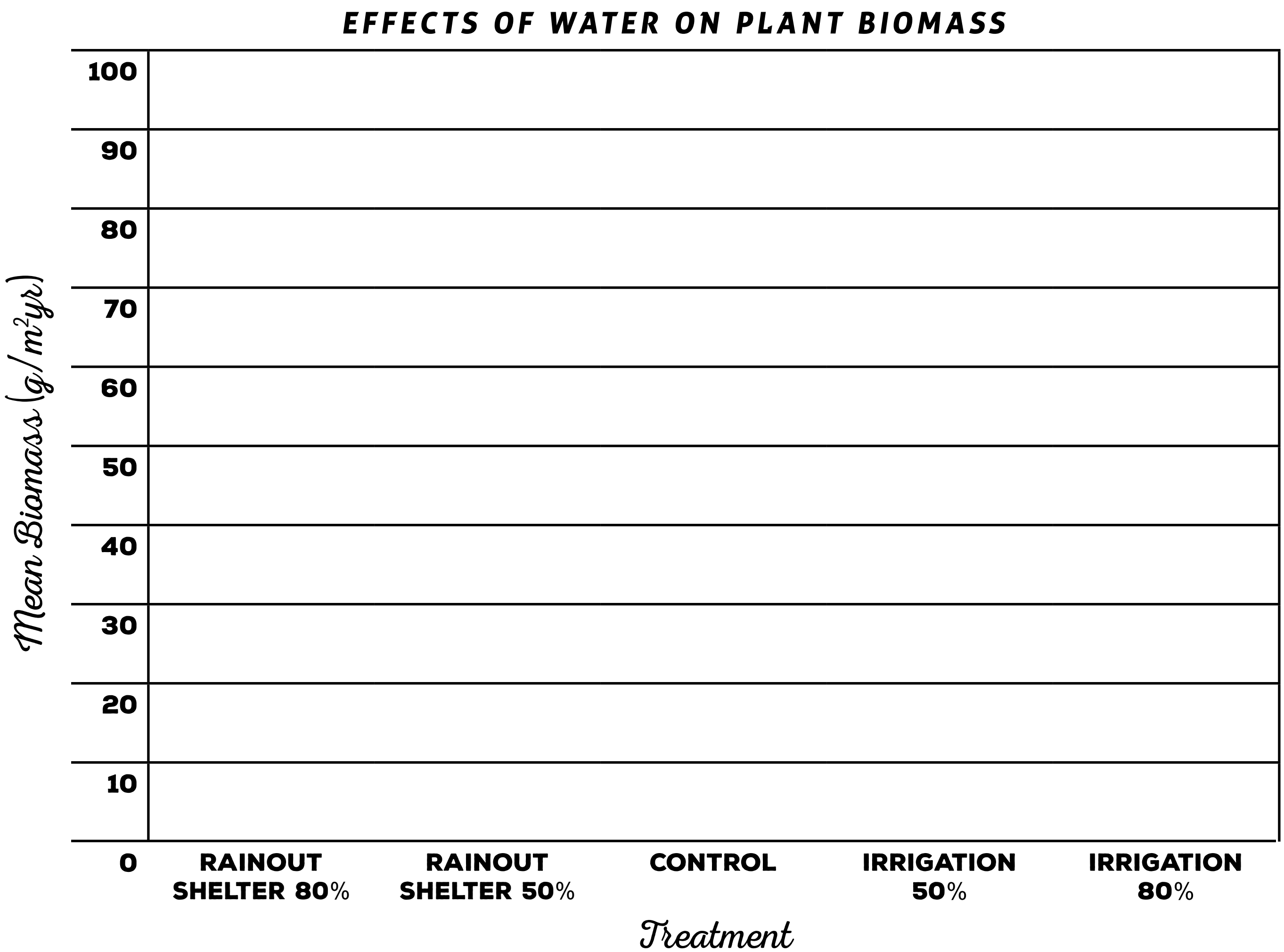
2. Which are the independent and dependent variables in this experiment?

Independent variable: ____
This is the variable that is not changed by the other variables measured in the experiment; independent variables are often manipulated by the researchers in an experiment.

Dependent variable: ____
This is the variable that may be changed by other variables; it is the response that is measured in the experiment.

3. Create a bar graph with the means from this experiment.

BAR GRAPH OF EXPERIMENTAL DATA MEANS



RESULTS & CONCLUSIONS

1. Circle the letter of the idea that is **most** supported by these data.

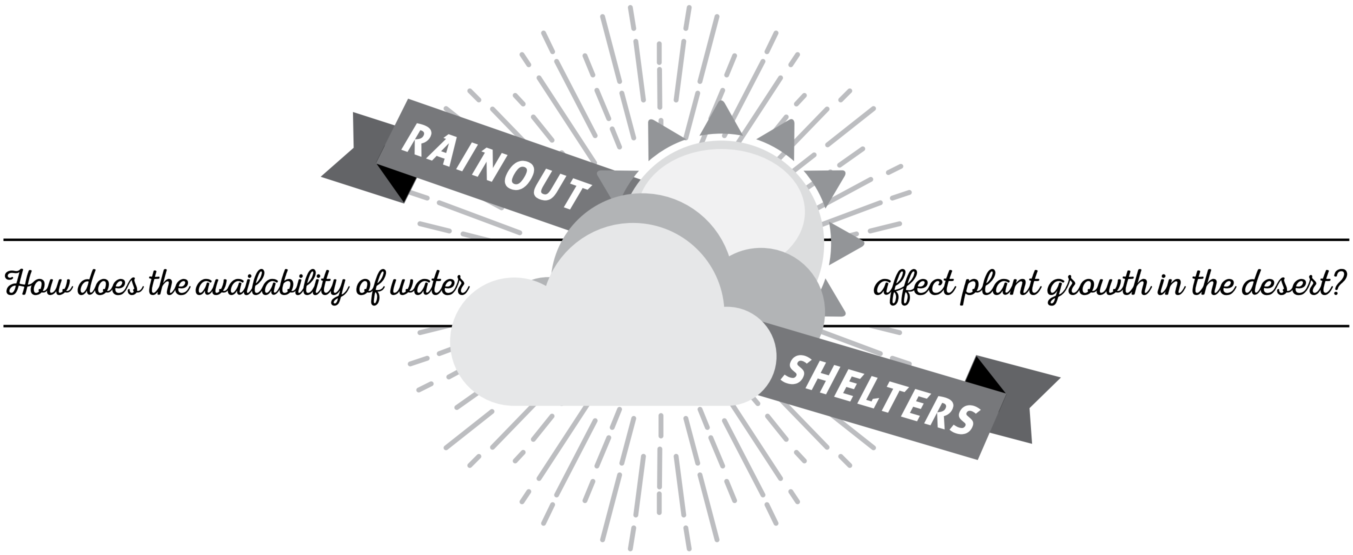
a. Based on the data, there appears to be a linear relationship between biomass and water (like in Figure 1 on page 1).

b. Based on the data, it appears that there is a nonlinear relationship between biomass and water; biomass levels off at higher water availability (like in Figure 2 on page 1).

2. Based on your answer to question #1, does is appear that water is the only limiting factor in this ecosystem across the range of different water treatments studied? Why or why not?

3. Science is an ongoing process. In the space below, write new questions you think should be investigated **related to this study**. What future data should be collected to answer your new questions?

ANSWER KEY



Plants are amazing organisms. Through a process called photosynthesis, they are able to “fix” carbon dioxide and turn it into sugars that allow them to grow and reproduce. The growth of a plant is often measured by calculating the increase in the plant’s biomass, which can include stems, roots, flowers and fruits.

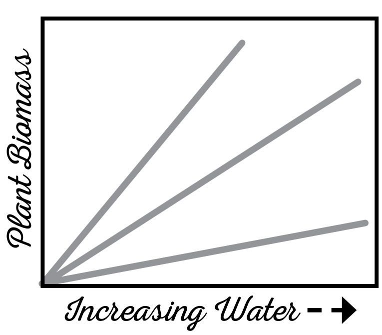
In order to grow, plants need light, nutrients, and water. Nitrogen is the nutrient most often limiting plant growth. In the Chihuahuan Desert, water also limits plant growth. The average annual rainfall at the research site in Las Cruces, New Mexico is 298 mm (11.7 inches). Many climate change models predict that the Chihuahuan Desert will receive less annual rainfall, with the largest decreases in the spring.

How does the availability of water affect desert plant growth and how might this change as annual rainfall decreases? Scientists at the Jornada Basin Long Term Ecological Research Program (LTER) are conducting a large experiment that helps answer this question and many more. They installed an Automated Rainfall Manipulation System with five types of plots: (1) rainout shelters that reduce rain on the plot by 80%, (2) rainout shelters that reduce rain on the plot by 50%, (3) controls, (4) irrigated plots that receive 50% more than ambient rainfall, and (5) irrigated plots that receive 80% more than ambient rainfall. Scientists then estimate plant biomass on each plot using measurements of plant species cover and the volume of shrubs.

Rainout shelter and irrigated plots

This experiment tests the effect of water availability on plant growth. If water is the **only** factor limiting plant growth, we expect plant biomass to increase linearly with increasing water (Figure 1). However, if nitrogen is also a limiting factor for plant growth, we expect plant biomass to level off at higher water availability, resulting in a plateau in the curve of the graph of biomass against water (Figure 2).

*Figure 1. Possible outcome #1 – three possible **linear** (straight line) relationships; as water increases, plant biomass increases.*



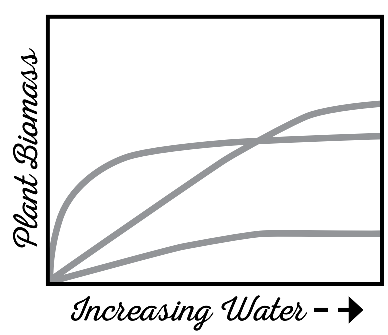


*Figure 2. Possible outcome #2 – three possible **nonlinear** relationships. At some water level, plant biomass levels off.*

PREDICTION

1. What do scientists predict they will see if both water and nitrogen are limiting? Find the prediction in the background information on page 1, and write it below.

If nitrogen is also a limiting factor for plant growth, we expect plant biomass to level off at higher water availability.

DATA & ANALYSIS

1. Here are the data collected in the experiment. Calculate the mean biomass for each treatment and write it on the line to the right.

WATER MANIPULATION	AMOUNT OF WATER RECEIVED (MM)	BIOMASS (G/M^2 YR)
Rainout 80%	19	15.9
Rainout 80%	19	14.4
Rainout 80%	19	11.8
Rainout 80%	19	64.1
Rainout 80%	19	36.6
Rainout 50%	48	27.1
Rainout 50%	48	47.5
Rainout 50%	48	50.4
Rainout 50%	48	37.1
Rainout 50%	48	33.2
Control	95	61.1
Control	95	76.8
Control	95	57.8
Control	95	85.0
Control	95	49.1
Irrigation 50%	143	121.5
Irrigation 50%	143	74.6
Irrigation 50%	143	56.9
Irrigation 50%	143	99.7
Irrigation 50%	143	95.6
Irrigation 80%	171	60.8
Irrigation 80%	171	110.0
Irrigation 80%	171	94.3
Irrigation 80%	171	81.9
Irrigation 80%	171	84.2

Mean plant biomass on rainout 80% plots = *28.56g/m²yr*

Mean plant biomass on rainout 50% plots = *39.06g/m²yr*

Mean plant biomass on control plots = *65.96g/m²yr*

Mean plant biomass on irrigation 50% plots = *89.66g/m²yr*

Mean plant biomass on irrigation 80% plots = *86.24g/m²yr*

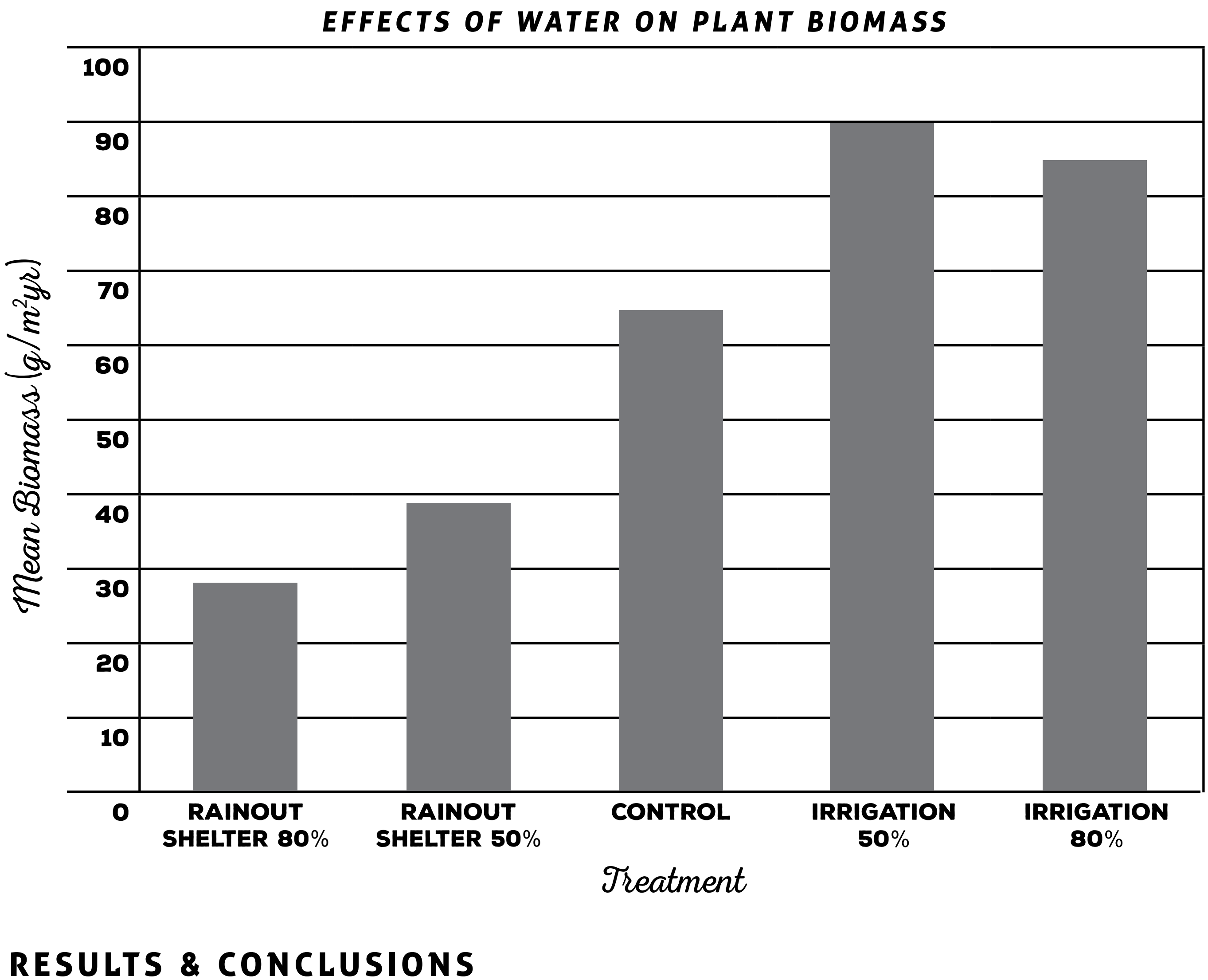
2. Which are the independent and dependent variables in this experiment?

Independent variable: Water Manipulation or Amount of Water
This is the variable that is not changed by the other variables measured in the experiment; independent variables are often manipulated by the researchers in an experiment.

Dependent variable: Biomass
This is the variable that may be changed by other variables; it is the response that is measured in the experiment.

3. Create a bar graph with the means from this experiment.

BAR GRAPH OF EXPERIMENTAL DATA MEANS



RESULTS & CONCLUSIONS

1. Circle the letter of the idea that is **most** supported by these data.

a. Based on the data, there appears to be a linear relationship between biomass and water (like in Figure 1 on page 1).

b. Based on the data, it appears that there is a nonlinear relationship between biomass and water; biomass levels off at higher water availability (like in Figure 2 on page 1).

2. Based on your answer to question #1, does is appear that water is the only limiting factor in this ecosystem across the range of different water treatments studied? Why or why not?

   No, it does not appear that water is the only limiting factor in this ecosystem. Plant growth did not continue to increase with increasing amounts of water. It is possible that nitrogen is also a limiting factor. Mean biomass leveled off on the 80% irrigation plot.

3. Science is an ongoing process. In the space below, write new questions you think should be investigated **related to this study**. What future data should be collected to answer your new questions?

   Student answers will vary.

Communicating Climate Data to Nonscientists

CLIMATE DATA JAM

DESCRIPTION

Students analyze and then showcase climate data by developing a creative project to communicate data trends to nonscientists.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:

- Analyze long-term, local precipitation and temperature data
- Evaluate local predicted precipitation and temperature conditions
- Identify and explain a data trend
- Develop a creative project to portray a data trend and communicate scientific data to nonscientist audiences

TIME
4 HOURS TOTAL OVER 4 DAYS

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7. 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).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

CCSS.ELA-LITERACY.RST.11-12.7. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

NEXT GENERATION SCIENCE STANDARDS

Middle School
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

High School
HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

BACKGROUND

As the climate changes, changes in temperature and precipitation will impact humans and ecosystems. Temperatures are predicted to increase throughout the United States. Some areas will receive less precipitation than historic levels, and some will receive more. However, *how* and *when* these changes in precipitation affect people and ecosystems may be complex. For example, in some counties, total annual precipitation is predicted to increase, but seasonal predictions show that much of the precipitation may occur at different times of the year than it historically fell. Seasonal changes in precipitation may have important effects on local ecosystems and human residential, commercial, and agricultural water supplies.

Most areas in the United States are predicted to experience warmer temperatures in the future. As temperatures continue to increase, more water from lakes, streams, oceans, soil, and plants will likely evaporate or transpire, especially in arid areas. Evaporation and transpiration are often combined and termed **evapotranspiration**, which is the total of evaporation and transpiration from Earth's surfaces, bodies of water, and plants. Heat causes water to evaporate more quickly because water molecules move faster when they are warm. Since the molecules are moving faster, more of them can leave the surface at one time. For evapotranspiration to occur, however, the humidity of the atmosphere must be less than the surface, and therefore evapotranspiration rate increases will be most pronounced in dry regions. In dry regions, evapotranspiration rates may offset any gains experienced through increased precipitation rates.

Interactions between precipitation and temperature in our global climate are complex. Predicting how climate change will affect water supplies for humans and ecosystems is an important first step to developing adaptation and mitigation strategies. The effects may vary greatly in localized areas because of seasonal variability in climatic conditions, especially precipitation and temperature.

MATERIALS

- *Climate Data Jam* handout [1 per student]
- *Climate Data Jam Scoring Rubric* handout [1 per student and enough for project scoring]
- Precipitation map
- Maximum Temperature map
- PowerPoint presentation
- Computer and projector for the educator
- Computers or tablets with web browser and internet connection for students [1 per every 1-3 students]
  - If not available, plan to access data in advance and provide for students
- A large assortment of craft and recycled household supplies to be used for projects such as:
  - Large-format paper, butcher paper, and/or poster boards
  - Markers and/or crayons
  - Glue
  - Pipe cleaners
  - Plastic/paper cups
  - Plastic/paper plates
  - Paper bags
  - Fabric
  - Pom poms
  - Googly eyes
  - Streamers
  - Beads
  - Stickers
  - Cardboard
  - Empty, clean egg cartons

PREPARATION

1. Prepare the craft and recycled household supplies for student use. If you have space, it is helpful to lay the supplies out on a surface so that students can more quickly assess available supplies and develop project ideas.
2. Set up a computer and projector and display the PowerPoint presentation.
3. Set up student computers or tablets. If you would like to save time, you can open the precipitation and maximum temperature maps for students on a web browser. Precipitation: http://spatial-web.nmsu.edu/flexviewers/PrecipitationByCounty/ Maximum Temperature: http://spatial-web.nmsu.edu/flexviewers/MaxTempByCounty/
   a. If student computers or tablets with internet access are not available, access the maps in advance and fill out tables 1 and 2 on page 3 of the handout. Show the tables using a document camera or draw them on the board.

PROCEDURES

DAY 1 – INTRODUCTION

1. Pass out a *Climate Data Jam* handout and a *Climate Data Jam Scoring Rubric* to each student.
2. Give an introduction to the Climate Data Jam using the PowerPoint presentation.
   a. **Slide 2**: scientists around the world are collecting vast amounts of data every day. However, the general public often learns very little, if anything, about the information that scientists have amassed. There is a gap in the communication of scientific information to nonscientists.
   b. **Slide 3**: students will be creating a Climate Data Jam project over the next few days. The goal is to design a creative project and presentation that explains local precipitation and temperature data to an audience not familiar with this information.
   c. **Slide 4**: here is an example of an effective way to communicate data. This infographic is interesting and easy to understand because it puts data into a context to which most people in the continental United States can relate. Simply stating that Major League Baseball players

ran a total of 1,245 miles in 2006 may be considered by some to be a dry statistic. However, scaling a baseball diamond to represent 1,245 miles and overlaying it on a map of the continental United States may help people understand how large the distance is and inspire them to take an interest in the statistic.

d. **Slide 5**: this is an example of using music to communicate data. A University of Minnesota student, Daniel Crawford, created a song to represent the increase in average global temperatures since 1880. He was looking for a method to communicate scientific data in a way that would be more appealing to nonscientists and "people who would get more out of [a song] than maps, graphs, and numbers." His video may inspire students to be creative with their projects: https://vimeo.com/69122809
e. **Slide 6**: here is an example of a student using painting to communicate data. The different colored paint splatters were scaled to reflect the amounts of solar radiation, soil temperature, air temperature, and precipitation over several 4-year periods in Las Cruces, New Mexico.
f. **Slide 7**: this is an example of a student using dance to communicate data. The height of the student's foot was scaled to represent the amount of precipitation received every two year in Las Cruces, New Mexico. The ribbon tied to her foot helps visualize the differences each year.
g. **Slide 8**: students may work individually or in teams of up to three students. Larger groups are not recommended for this project because of the difficulties of ensuring that all group members are equally involved. Students should develop a very creative project to represent the data and appeal to nonscientists. The project should not be a graph or table. Instruct students to use their imaginations to design a project that will be attention grabbing and appealing. Example products could include songs, demonstrations, poems, children's stories, newscasts, physical models, infographics, and skits. Representations of the data trend or trends must be scaled accurately.
    i. Emphasize that students should represent a trend or trends in the data in a creative way rather than using the data directly in their projects. For example, the amount of annual precipitation could be represented in a physical model with cardboard cutout raindrops that represent 100 mm of water instead of simply stating that the county received 278.8 mm.
    ii. Ensure that students understand the word **trend** by asking for a volunteer to define it [answer: the general direction in which something is changing. For example, in the future, our county is predicted to receive less annual total precipitation than we did historically.]

    Students may go beyond the data and begin to examine the implications; however, their projects must also include representations of the data trends. For example, a student could write a rap song that includes a hypothesis about how increased temperatures in their county may lead to increased evapotranspiration, but they must incorporate a clear, accurately scaled description of the trend in the data as well.
h. **Slide 9**: direct students to look at the top of page 1 of their handout. A good Data Jam project is clear in that it accurately represents the data in a way that is understandable to nonscientists. The data must be scaled correctly, and a legend explaining how the data are represented must be included. The project should also be creative. Think of an imaginative way to get the attention of nonscientists. Finally, the project should be concise. Focus on one or two important trends, and explain them well.
i. **Slide 10**: today, students will be introduced to the project and start examining local precipitation and temperature data. Over the next two days, students will create a project and develop a 5-minute (maximum) presentation to explain their project to the rest of the group. On day 4, students will present their projects to the group.
j. **Slide 11**: direct students to look at the project directions on page 1 of their handout.
    i. Students should decide if they would like to work alone or with one or two other students to complete their Climate Data Jam project.
    ii. Use the online USDA Southwest Regional Climate Hub Precipitation and Maximum Temperature maps to acquire the needed data from your county. Fill in the data tables on page 3 of the handout.
    iii. Examine the data and find one or two trends of interest.
    iv. Read the Scoring Rubric so you know how the presentation and project will be evaluated.
    v. Brainstorm and fill out the brainstorming notes section.
    vi. Create the Climate Data Jam project (infographic, skit, etc.).
    vii. Fill out the Climate Data Jam Summary.
    viii. Practice the presentation.
k. **Slide 12**: direct students to look at the *Climate Data Jam Scoring Rubric*.

   i. Students will use this rubric to score each other's projects.
   ii. Forty percent of students' total score will be based on their presentation.
      1. At the start of their presentation, students must state their names, the title of the project, and the data trends that they portrayed.
      2. Speak clearly.
      3. Hold the attention of the audience.
      4. Include an explanation of the factors leading to increased temperatures.
      5. Include a brief reflection of the presentation explaining what they liked best and what was most challenging about this project.
   iii. Sixty percent of students' total score will be based on creativity in communicating data trends.
      1. The project idea must be creative.
      2. The data presentation must be easily understandable and appealing to nonscientist audiences.
      3. Resources and/or materials must be used effectively in a creative way.
      4. The project must accurately portray the trend or trends of the data, and a legend must be included.

l. **Slide 13**: students will first acquire the precipitation data from their county by using the USDA Southwest Regional Climate Hub Precipitation map. Direct students to look at the data directions on page 2 of the handout and open the URL below. It may be helpful to display the map and provide a tutorial.
   http://spatial-web.nmsu.edu/flexviewers/PrecipitationByCounty/

m. **Slide 14**: direct students to locate and record precipitation data for their county in table 1 on page 3 of the handout.
   i. Use the zoom and pan buttons on the left to zoom in to your state.
   ii. Locate your county and click on it.
   iii. A data box with a scroll bar will appear. Verify that you have clicked on the correct county by reading the county name in the data box.
   iv. In table 1 on page 3 of the handout, record the following historic (1971-2000) mean precipitation data in mm: Annual Total, Winter Total, Spring Total, Summer Total, and Fall Total. These seasonal mean precipitation data were derived from PRISM data, up-scaled (or generalized) to the county level, and represent the average mean seasonal precipitation for the county.
   v. In addition to historic values, this map provides predicted average annual and seasonal precipitation amounts for the future, 2040-2069. These values were derived from the Multivariate Adaptive Constructed Analogs (MACA, http://maca.northwestknowledge.net/) statistically downscaled data. They are based upon the mean of the 20 Coupled Model Intercomparison Project (CMIP) 5 general circulation models. In addition to averaging over models, means were derived over seasons to obtain an estimated change in precipitation up-scaled to the county level for the 2040-2069 time frame. Data are intended to provide a general estimate of broad seasonal changes in average precipitation at the county scale.
   vi. Scroll down to the predicted data for your county. Also in table 1, record the following mean predicted future (2040-2069) precipitation data in mm: Annual Total, Winter Total, Spring Total, Summer Total, and Fall Total.
   vii. Students may notice that a delta value is also available in the data box. Delta (Δ) is a Greek letter used to denote a change in quantity in science and mathematics. In this case, the delta value is future precipitation minus historic precipitation, or the change in mean future precipitation and annual precipitation (mm).

n. **Slide 15**: students will then acquire the maximum temperature data from their county by using the USDA Southwest Regional Climate Hub Maximum Temperature map. Direct students to look at the data directions on page 2 of the handout and open the URL below. It may be helpful to display the map and provide a tutorial.
   http://spatial-web.nmsu.edu/flexviewers/MaxTempByCounty/

o. **Slide 16**: direct students to locate and record temperature data for their county in table 2 on page 3 of the handout.
   i. Use the zoom and pan buttons on the left to zoom in to your state.
   ii. Locate your county and click on it.
   iii. A data box with a scroll bar will appear. Verify that you have clicked on the correct county by reading the county name in the data box.
   iv. In table 2 on page 3 of the handout, record the following historic (1971-2000) mean maximum temperature data in °C: Annual Max, Winter Max, Spring Max, Summer Max, and Fall Max. These seasonal mean maximum temperature data were derived from PRISM data,

up-scaled (or generalized) to the county level, and represent the average mean seasonal maximum temperature for the county.

v. In addition to historic values, this map provides predicted average annual and seasonal temperatures for the future, 2040-2069. These values were derived from the Multivariate Adaptive Constructed Analogs (MACA, http://maca.northwestknowledge.net/) statistically downscaled data. They are based upon the mean of the 20 Coupled Model Intercomparison Project (CMIP) 5 general circulation models. In addition to averaging over models, means were derived over seasons to obtain an estimated change in temperature up-scaled to the county level for the 2040-2069 time frame. Data are intended to provide a general estimate of broad seasonal changes in average maximum temperature at the county scale.

vi. Scroll down to the predicted data for your county. Also in table 2, record the following mean predicted future (2040-2069) data in °C: Annual Max, Winter Max, Spring Max, Summer Max, and Fall Max.

vii. Because many students may be unaccustomed to thinking about temperature in Celsius, you may want to instruct students to convert temperatures to Fahrenheit for their own use. Students can convert temperatures manually or by using an online calculator such as: http://www.onlineconversion.com/temperature.htm

viii. Students may notice that a delta value is also available in the data box. Delta (Δ) is a Greek letter used to denote a change in quantity in science and mathematics. In this case, the delta value is future temperature minus historic temperature, or the change in mean future temperature and annual temperature (°C).

3. Direct students to divide into groups of 1 – 3 students.
4. Instruct students to examine the data to find one or two trends that interest them. You may want to provide an overview of the data, explaining trends and highlighting changes in the historic and predicted values. For example, in San Diego County, California, the historic mean annual precipitation total was 403.66 mm, and the predicted mean annual precipitation total is 400.11 mm. There is a predicted decrease in mean annual total precipitation of 3.55 mm, which is a relatively small amount. It is interesting to note the predicted seasonal changes, however. The historic mean spring precipitation total was 114.32 mm, and the predicted mean spring precipitation is 100.25 mm. There is a predicted decrease in mean spring precipitation of 14.07 mm. In this case, it would be useful to prompt students to think about the implications of a reduction in spring precipitation for humans and the ecosystem.
5. Tell students to complete the brainstorming notes section on page 2 of the handout. In this section, they will list the trend or trends that they might like to represent with their project and provide some possible ideas for a creative product.
   a. At this time, students may want to examine the available craft and recycled household supplies to help generate project ideas.
6. If you have the ability to purchase additional supplies for student projects, you may want to solicit the needs of students and create a list of supplies to obtain for them by tomorrow. You can also instruct students to bring in materials for their projects.

DAY 2 – PROJECT PREPARATION

1. Provide guidance while students are creating their projects. This may take several forms, and the level of support needed will vary by group. Students may need help with data interpretation, scaling data, project ideas, technical issues, and obtaining materials.
2. When approximately 30 minutes are remaining, ask students to fill out the Climate Data Jam Summary on page 4 of the handout. Explain that students will use this page to plan and prepare their presentation.

DAY 3 – PROJECT PREPARATION

1. Continue to provide guidance and support while students are creating their projects.
2. Remind students to review their Climate Data Jam Summary on page 4 of the handout and practice their presentations.

DAY 4 – PROJECT PRESENTATION

Additional preparation for today: make the necessary number of copies of the *Climate Data Jam Scoring Rubric*. For each group, you will need enough copies for each of the students who will not be presenting with that group. You may wish to make an additional copy for each group if you would like to participate in scoring.

1. Explain that students will be given five minutes to present their projects.
2. Tell students that they may use the Climate Data Jam Summary on page 4 of the handout to prompt them to include all of the necessary components.
3. Explain that students who are not presenting will be scoring the presentation.
4. Pass out the appropriate number of rubrics to each student. Review the rubric, explaining each section and how students can earn a high score.
5. Determine the order of group presentations by asking for

volunteers, drawing numbers from a hat, or assigning an order that is preferable to you.

6. Begin the first presentation. Set a timer or plan to watch the clock for five minutes.
7. Give the students who were scoring a moment to finish if needed.
8. Repeat with the remaining groups until all have presented.
9. Lead a discussion about the Climate Data Jam projects and what students learned. Solicit feedback for ideas about how this project could be extended further.

EXTENSIONS

1. Challenge students to showcase their Climate Data Jam project in a public setting.
2. Find additional climate data for your county, state, or region, and have students create another Data Jam project with the new data.

ADDITIONAL RESOURCES

1. Website that provides precipitation and temperature data over time by areas within states; could be useful for comparisons or extension activities:
   National Oceanic and Atmospheric Administration (NOAA), Climate at a Glance. Time Series. Accessed 16 Jul 2015. <http://www.ncdc.noaa.gov/cag/>.
2. Website with student-friendly information about evapotranspiration:
   North Carolina State University, Climate Education for K-12. Evapotranspiration. Modified 9 Aug 2013. Web. Accessed 11 Jun 2015. <https://www.nc-climate.ncsu.edu/edu/k12/.evapo>.
3. Report that summarizes research findings about evapotranspiration:
   Intergovernmental Panel on Climate Change (IPCC). 2013. Climate Change 2013: Physical Science Basics. Section 2.5 Changes in Hydrologic Cycle, Subsection 2.5.3 Evapotranspiration Including Pan Evaporation, p. 205. Accessed Online. 10 Jun 2015. <http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter02_FINAL.pdf>.

Name ____ Date ________________

CLIMATE DATA JAM

Communicating Climate Data to Nonscientists

GOAL - Examine climate data from your county, and then design a creative project that explains these data to a non-scientist audience. A good Data Jam project is:

> ***Clear:*** represent the data accurately and in a way that is understandable to non-scientists. **Make sure to include a legend explaining how you represent the data** (e.g., one water droplet graphic represents 10 mm of precipitation).
>
> ***Creative:*** use your imagination! This could be a song, demonstration, physical model, poem, skit, newscast, infographic, dance, rap, etc.
>
> ***Concise:*** keep it short and to the point. It is more effective to focus on one or two important trends in the data than to try to explain it all.

PROJECT DIRECTIONS

1. Decide if you would like to work alone or with one or two other students to complete your Climate Data Jam project.
2. Use the online USDA Southwest Regional Climate Hub Precipitation and Maximum Temperature maps to acquire the needed data from your county. Fill in the data tables on page 3 of this handout.
3. Examine the data and find one or two trends that interest you.
4. Read the Scoring Rubric so you know how your presentation and project will be evaluated.
5. Brainstorm and fill out the brainstorming notes section on page 2.
6. Create your Climate Data Jam project (infographic, skit, etc.).
7. Fill out the Climate Data Jam Summary.
8. Practice your presentation.

BRAINSTORMING NOTES

1. Look at the data carefully and list some trends you might like to explain to your audience.

2. List some possible ways to present the data (song, rap, interpretive dance, etc.). Think about the positive and negative aspects of each one.

CLIMATE DATA

BACKGROUND

As the climate changes, changes in temperature and precipitation will impact humans and ecosystems. Temperatures are predicted to increase throughout the United States. Some areas will receive less precipitation than historic levels, and some will receive more. However, how and when these changes in precipitation affect people and ecosystems may be complex. For example, seasonal changes in precipitation may have large effects on residential and agricultural water supplies if less precipitation falls in seasons that it is most needed by people. In addition, it is important to consider how temperature changes will affect water supplies. In warmer temperatures, more water is likely to evaporate or transpire from lakes, streams, oceans, soil, and plants (note: **evapotranspiration** is the total of evaporation and transpiration from the Earth's surfaces, bodies of water, and plants). Think about the effects of increased evapotranspiration on water for human use and plants and the food web. For your project, you will examine precipitation and temperature data from your county and identify a trend or trends in the data. Consider how climate change is affecting precipitation, temperature, and possibly the water supply and ecosystem in your county.

DATA DIRECTIONS

Use the online USDA Southwest Regional Climate Hub Precipitation and Maximum Temperature maps to acquire the needed data from your county. Write the name of your county in the blank at the top of page 3.

1. Follow the link for the Precipitation map: http://spatial-web.nmsu.edu/flexviewers/PrecipitationByCounty/
   a. Use the zoom and pan buttons on the left to zoom in to your state.
   b. Locate your county and click on it.
   c. A data box with a scroll bar will appear. Verify that you have clicked on the correct county by reading the county name in the data box.
   d. In table 1, record the following historic (1971-2000) mean precipitation data in mm: Annual Total, Winter Total, Spring Total, Summer Total, and Fall Total.
   e. Scroll down to the predicted data for your county. Also in table 1, record the following mean predicted future (2040-2069) precipitation data in mm: Annual Total, Winter Total, Spring Total, Summer Total, and Fall Total.
2. Follow the link for the Maximum Temperature map: http://spatial-web.nmsu.edu/flexviewers/MaxTempByCounty/
   a. Use the zoom and pan buttons on the left to zoom in to your state.
   b. Locate your county and click on it.
   c. A data box with a scroll bar will appear. Verify that you have clicked on the correct county by reading the county name in the data box.
   d. In table 2, record the following historic (1971-2000) mean maximum temperature data in °C: Annual Max, Winter Max, Spring Max, Summer Max, and Fall Max.
   e. Scroll down to the predicted data for your county. Also in table 2, record the following mean predicted future (2040-2069) data in °C: Annual Max, Winter Max, Spring Max, Summer Max, and Fall Max.

Your County Name: ____

TABLE 1: MEAN PRECIPITATION IN YOUR COUNTY

	HISTORIC (1971 – 2000) IN MM	PREDICTED FUTURE (2040-2069) IN MM
Annual Total		
Winter Total		
Spring Total		
Summer Total		
Fall Total		

TABLE 2: MEAN MAXIMUM TEMPERATURE IN YOUR COUNTY

	HISTORIC (1971 – 2000) IN °C	PREDICTED FUTURE (2040-2069) IN °C
Annual Total		
Winter Total		
Spring Total		
Summer Total		
Fall Total		

CLIMATE DATA JAM SUMMARY

Each group will have a maximum of 5 minutes to present their Data Jam project to the rest of the class. During these presentations, you will "show" your project. This will look different depending on your project. For example, you may act out your skit, show your video, read your poem, or show and discuss your physical project. While these presentations will vary depending on your project, the components listed below should be included in all presentations. **Use this page to write answers that will help as you plan and prepare your presentation**.

1. Introduce all of the **students** who worked on the project.

2. Give the **title** of your project. Make sure it is descriptive.

3. Explain the **data trend** you are trying to get across in your project.

4. **Showcase your project.** For example, read your poem, act out your play, or give a tour of your physical model. Make sure to explain your legend (how the data is represented). Work with your teammates to decide how to best show your project to the audience. Practice!!!

5. **Explain factors leading to increased temperatures.** In your own words, explain the factors that have resulted in the rise of local or global temperatures (even if your project focused on precipitation).

6. Give a **brief reflection** at the end of your presentation. Include the parts of this project that you enjoyed the most and the parts that were most challenging.

Climate Data Jam Scoring Rubric

Title:	
Students' Names:	

Directions: For each criterion, please circle the score that most accurately describes the students' performance.

Presentation — 40 points maximum

	Outstanding	Above Average	Average	Below Average	Poor	No Evidence
1. Students stated their names, the title of the project, and the data trends that they portrayed at the start of their presentation.	10	8	6	4	2	0
2. Students spoke clearly during their presentation.	10	8	6	4	2	0
3. The presentation held the attention of the audience.	10	8	6	4	2	0
4. Students included an explanation of the factors that have lead to increased temperatures locally or globally. Please give an "outstanding" rating if this section was included or a "no evidence" rating if it was not included.	5					0
5. Students included a brief reflection in their presentation explaining what they liked best and what was most challenging about this project. Please give an "outstanding" rating if this section was included or a "no evidence" rating if it was not included.	5					0

Creativity in Communicating Data Trends — 60 points maximum

	Outstanding	Above Average	Average	Below Average	Poor	No Evidence
1. Project idea (e.g., video, infographic, poem) is creative	15	12	9	6	3	0
2. Data presentation is easily understandable and appealing to nonscientist audiences.	15	12	9	6	3	0
3. Resources and/or materials were effectively used in a creative way	15	12	9	6	3	0
4. The project accurately portrays the trend(s) of the data, and a legend is included to explain the data (e.g. one water drop in a physical model represents 1 mm of precipitation).	15	12	9	6	3	0

Comments:

TOTAL SCORE:

CLIMATE CHANGE AND THE WATER CYCLE
COMMON CORE STATE STANDARDS ACTIVITY CHARTS

These charts identify the Climate Change and the Water Cycle activities that apply to each of the listed Common Core State Standards and are organized by Middle School and High School. Some standards are fully met by the activities, and some standards are addressed by the activities but require further teaching.

	Climate Data Jam	Evaporation Investigation	Insulating You, Insulating Earth	Rainout Shelters	Ready, Set, Grow!	Streams and Steam	Understanding the Difference	The Water Cycle Game	Weather or Climate? You Decide!
MIDDLE SCHOOL LITERACY									
CCSS.ELA-LITERACY.RST.6-8.1				●		●[EA]	●		
CCSS.ELA-LITERACY.RST.6-8.3		●	●					●	
CCSS.ELA-LITERACY.RST.6-8.4	●	●	●	●	●	●		●	●
CCSS.ELA-LITERACY.RST.6-8.7	●			●	●	●		●	●
CCSS.ELA-LITERACY.RST.6-8.8							●		
MIDDLE SCHOOL MATH									
CCSS.MATH.CONTENT.6.SP.B.5.C		●	●	●					
CCSS.MATH.CONTENT.7.SP.B.3.					●				
HIGH SCHOOL LITERACY									
CCSS.ELA-LITERACY.RST.9-10.1				●		●[EA]	●		
CCSS.ELA-LITERACY.RST.9-10.3		●	●					●	
CCSS.ELA-LITERACY.RST.9-10.4	●	●	●	●	●	●		●	●
CCSS.ELA-LITERACY.RST.9-10.7	●			●	●	●		●	●
CCSS.ELA-LITERACY.RST.11-12.1				●		●[EA]			
CCSS.ELA-LITERACY.RST.11-12.3		●	●					●	
CCSS.ELA-LITERACY.RST.11-12.4	●				●	●		●	●
CCSS.ELA-LITERACY.RST.11-12.6							●		
CCSS.ELA-LITERACY.RST.11-12.7	●								
CCSS.ELA-LITERACY.RST.11-12.8				●					
HIGH SCHOOL MATH									
CCSS.MATH.CONTENT.HSS.IC.B.5				●					

EA = Extension Activity

CLIMATE CHANGE AND THE WATER CYCLE
NEXT GENERATION SCIENCE STANDARDS ACTIVITY CHARTS

These charts identify the Climate Change and the Water Cycle activities that apply to each of the listed Next Generation Science Standards and are organized by Middle School and High School. Some standards are fully met by the activities, and some standards are addressed by the activities but require further teaching.

	Climate Data Jam	Evaporation Investigation	Insulating You, Insulating Earth	Rainout Shelters	Ready, Set, Grow!	Streams and Steam	Understanding the Difference	The Water Cycle Game	Weather or Climate? You Decide!
MIDDLE SCHOOL									
MS-PS1-4		●							
MS-PS3-3			●						
MS-LS2-1				●	●				
MS-LS2-3					●				
MS-LS2-4				●	●				
MS-ESS2-4								●	
MS-ESS3-1						●			
MS-ESS3-2						●			
MS-ESS3-5	●								
HIGH SCHOOL									
HS-PS1-5		●							
HS-LS2-1					●[EA]				
HS-LS2-2				●					
HS-LS2-4					●				
HS-LS4-4					●[EA]				
HS-ESS2-2			●			●			
HS-ESS2-4			●						
HS-ESS3-1						●			
HS-ESS3-5	●		●						

EA = Extension Activity