4-H Weather and Climate Youth Learning Lab

Leader's Guide

NATIONAL PEER REVIEWED

5351 • April 2019

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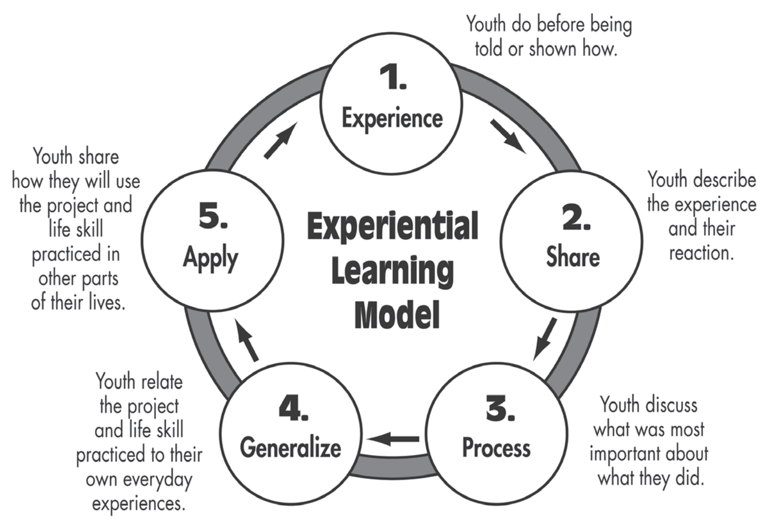
The 4-H Experiential Learning Model provides the framework for this curriculum.



Pfeiffer, J.W., & Jones, J.E., "Reference Guide to Handbooks and Annuals"
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Photos on the cover, clock-wise from top left: 1) Art Albin. 2) National Interagency Fire Center, Bugwood.org. 3) National Oceanic and Atmospheric Administration/Department of Commerce, Ethan Schisler, NOAA Weather in Focus Photo Contest 2015. 4) National Oceanic and Atmospheric Administration/Department of Commerce, Bob Larson, NOAA Weather in Focus Photo Contest 2015. 5) National Oceanic and Atmospheric Administration/Department of Commerce, Mr. Shane Lear, Orange Australia. 6) Kenneth M. Gale, Bugwood.org. 7) Billy Humphries, Forest Resource Consultants, Inc., Bugwood.org. 8) National Oceanic and Atmospheric Administration/Department of Commerce, Yaakov Wilson, NOAA Weather in Focus Photo Contest 2015. 9) Paul Bolstad, University of Minnesota, Bugwood.org.

Learning Lab Overview

Age Group The weather and climate activities are written for elementary school students (approximately grades 3-5).

What You Need There is a list of recommended supplies detailed in each activity; refer to these sections for required materials.

Note to Leaders Leader is the term we use throughout this document to refer to the leader of the activity. Leaders can help youth with ideas that are hard to understand, suggest ways to research specific topics and help participants set up and carry out the learning labs. Some of the activities require the use of supplies in the learning laboratory kit—please see each activity for a list of the materials that are necessary. Many of these materials can also be accessed via the internet at www.msucommunitydevelopment.org/4Hweatherandclimate.html.

Project Requirements This project can be completed in approximately twelve hours; each activity is meant to take approximately one hour to complete with several that are longer depending on the number of activities and time spent to complete them.

Fair Entry Suggestions Submit educational posters or displays from conducting the activities, videos related to the activities, and any other exhibits that share what was learned through this project. Be creative!

Activities Each activity shows a content skill, the life skills that you are working on, and the Next Generation Science Standards (NGSS) and the Climate Literacy Framework associated with the topic. 4-H leaders can choose to use any of these standards designed for science teachers. All activities must be completed for the project to be finished. Some activities should be completed in a special order.

Life Skills The 4-H life skills this curriculum addresses are: Managing and Thinking.

Next Generation Science Standards The Next Generation Science Standards (NGSS) is a multi-state effort in the United States to create new education standards that are "rich in content and practice, arranged in a coherent manner across disciplines and grades to provide all students an internationally-benchmarked science education" (see www.nextgenscience.org). The standards were developed by a consortium of 26 states and by the National Science Teachers Association, the American Association for the Advancement of Science, the National Research Council, and Achieve, a nonprofit organization that was also involved in developing math and English standards.

The following NGSS were used in this publication, and students who demonstrate understanding can:

- 3-ESS2-1 Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.
- 3-ESS2-2 Obtain and combine information to describe climates in different regions of the world.
- 3-ESS3-1 Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
- 4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
- 5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
- 5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Photo: Howard F. Schwartz, Colorado State University, Bugwood.org

3-LS3-2 Use evidence to support the explanation that traits can be influenced by the environment.

3-LS4-3 Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

3-LS4-4 Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

4-LS1-1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

5-LS1-1 Support an argument that plants get the materials they need for growth chiefly from air and water.

Climate Literacy Framework According to the Climate Literacy Framework from the U.S. Global Change Research Council, Climate Science Literacy is an understanding of your influence on climate and climate's influence on you and society. The U.S. Global Change Research Program works to promote greater climate science literacy by providing this educational framework of principles and concepts. Their work, titled *Climate Literacy: The Essential Principles of Climate Science,* can serve educators who teach climate science as a way to meet content standards in their science curricula. More information about the Framework is at: www.climate.gov/teaching/essential-principles-climate-literacy/teaching-essentialprinciple-2-climate-regulated, https://www.globalchange.gov/browse/educators and https://cleanet.org/clean/literacy/climate/index.html.

The following sections of the Climate Literacy Framework are applied in this Learning Lab:

1. The Sun is the primary source of energy for Earth's climate system.
   a. Sunlight reaching Earth can heat the land, ocean, and atmosphere.

2. Climate is regulated by complex interactions among components of the Earth system.
   a. Earth's climate is influenced by interactions involving the sun, ocean, atmosphere, clouds, ice, land, and life.
   b. Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles.
   c. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition.
   d. The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs.
   f. The interconnectedness of Earth's systems means that a significant change in any one component of the climate system can influence the equilibrium of the entire Earth system.

3. Life on Earth depends on, is shaped by, and affects climate.
   a. Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight.
   c. Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species.
   e. Life—including microbes, plants, animals and humans—is a major driver of the global carbon cycle and can influence global climate by modifying the chemical makeup of the atmosphere.

4. Climate varies over space and time through both natural and man-made processes.
    a. Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location.
    b. Climate is not the same thing as weather.
    c. Climate change is a significant and persistent change in an area's average climate conditions or their extremes.
    e. Based on evidence from tree rings, other natural records, and scientific observations made around the world, Earth's average temperature is now warmer than it has been for at least the past 1,300 years.
    g. Natural processes that remove carbon dioxide from the atmosphere operate slowly when compared to the processes that are now adding it to the atmosphere.

5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
    a. The components and processes of Earth's climate system are subject to the same physical laws as the rest of the universe.
    b. Environmental observations are the foundation for understanding the climate system.
    c. Observations, experiments, and theory are used to construct and refine computer models that represent the climate system and make predictions about its future behavior.
    d. Our understanding of climate differs in important ways from our understanding of weather.

6. Human activities are impacting the climate system.
    b. Emissions from the widespread burning of fossil fuels since the start of the Industrial Revolution have increased the concentration of greenhouse gases in the atmosphere.
    c. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns.

7. Climate change has consequences for the Earth system and human lives.
    c. Incidents of extreme weather are projected to increase as a result of climate change.
    d. The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere.

Guiding Principles (GP). Humans can take actions to reduce climate change and its impacts.

- a. Climate information can be used to reduce vulnerabilities or enhance the resilience of communities and ecosystems affected by climate change.
- b. Reducing human vulnerability to the impacts of climate change depends not only upon our ability to understand climate science, but also upon our ability to integrate that knowledge into human society.
- d. Humans may be able to mitigate climate change or lessen its severity by reducing greenhouse gas concentrations through processes that move carbon out of the atmosphere or reduce greenhouse gas emissions.
- e. A combination of strategies is needed to reduce greenhouse gas emissions.
- g. Actions taken by individuals, communities, states, and countries all influence climate. Practices and policies followed in homes, schools, businesses, and governments can affect climate.

Introduction to Activities

Multiple lines of evidence, careful analyses, and hundreds of articles and official reports indicate that human use of fossil fuels causes atmospheric CO_2 concentrations and global average air temperatures to rise. We assign features of our higher-CO_2 world as "weather," if they happen today or this week, or as "climate" when those changes occur over seasons to years. Increasingly, however, lines between short-term weather and longer-term climate become blurry. A tornado or hail storm still represents a short, fierce weather event but, due to changing climate, the location, frequency, duration, or intensity of those destructive, expensive events may change.

Weather and climate influence every aspect of life. The goal of this project is to study the world of weather and climate, and specifically how they are influenced by natural processes and human activities. While this Leader's Guide is written for the four states of Colorado, Montana, South Dakota and Wyoming, it can be applied in any state or region. When you finish teaching these activities, participants will have a better understanding of natural forces and human impacts through using the learning labs and conducting hands-on experiments and activities.

In this Learning Lab we guide participants as they explore data, patterns, extremes, and forecasts or predictions to better understand weather and climate connections. Based on our four-state region of focus, and its role in supplying water for agriculture, energy, industry and human consumption, we give particular attention to precipitation. Because of high social, economic, and environmental importance of precipitation patterns across these regions, present and future residents will need—and need to understand—climate and weather observations and projections.

We draw on and draw attention to recent weather and climate reports from each of our four states:

- *2017 Montana Climate Assessment:* www.montanaclimate.org/
- *2014 Climate Change in Colorado Report:* https://wwa.colorado.edu/climate/co2014report/
- *2006 Water, Drought and Wyoming's Climate Report* https: //www.uwyo.edu/haub/_files/_docs/ruckelshaus/pubs/2006-water-drought-wyoming-climate-final.pdf
- *2014 Climate Change across the Dakotas:* www.card.iastate.edu/land-use/climate-change-throughout-the-dakotas.pdf

Along with the 2018 USA National Climate Assessment (which includes regional and state-by-state projections: https://nca2018.globalchange.gov/), the National Oceanic and Atmospheric Administration's (NOAA) Western Water Assessment (https://wwa.colorado.edu/) and the NOAA U.S. Drought Monitor (https://droughtmonitor.unl.edu/), all of these reports and sources emphasize the importance of precipitation and water. In several activities we call attention to our region's high potential for wind and solar energy. We also note the presence within our region of prominent national parks and forest and grassland reserves.

For convenience and clarity, we specify and follow these definitions of time periods:

- Long ago: geological time spans involving different configurations of oceans and continents, up to and beyond 100 million years ago;
- Past: since about 2-3 million years ago, characterized by ice ages, recorded by ice cores, before development of agriculture;
- Recent: the period of direct temperature, precipitation and CO_2 measurements, 50 to 150 years in most cases, supplemented by 2000- or 3000-year climate reconstructions based on tree rings, speleothems (stalactites and stalagmites), etc., with land use reconstructions back to 12,000 years;
- Current: today, this year;
- Future: unless specified, from the present forward.

Consistent with 4-H goals, we present these activities as one helpful method to stimulate interest

Photo: Terry Spivey, USDA Forest Service, Bugwood.org

Activity One

Weather Data

Participants use scientific tools to observe and collect weather data close to home to begin to build a foundational knowledge about the difference between weather and climate.

Learning Outcomes

Participants will:

- Observe weather where they live.
- Learn about tools used to collect data about weather conditions.
- Identify daily and longer patterns in weather where they live
- Explore SNOTEL precipitation reports (More Challenges).

Content Skill: Observing, measuring and reporting weather data.

Life Skill: Managing, Thinking

Educational Standards: 3-ESS2-1

Success Indicator: Accurate weather report.

Background

Weather Data

Weather can be defined as the atmospheric conditions that exist at a certain place and time. Weather can be reported qualitatively (it's sunny and warm) or quantitatively (it's 70 degrees with a UV index of 6 and high pressure). The most useful weather reports usually involve both (it's sunny and 70 degrees). To get quantitative data, we use different tools or instruments including thermometers for temperature, anemometers for wind speed, wind vanes for wind direction, rain gauges for precipitation, and barometers to measure atmospheric pressure. When these tools are combined it is called a weather station. Weather stations exist in varying degrees of sophistication—from the basic weather station included in this kit, to backyard digital weather stations, and up to expensive, high-tech weather stations used by government agencies such as the National Oceanic and Atmospheric Administration (NOAA).

Time Needed: 1 hour (Walk-up Event option provided)

Materials

- Basic weather station
- Laminated weather report examples (4 per state)
- Laminated weather data collection sheets (10)
- Wet erase markers (10)
- Screen Interface Handout (participant copy page, one copy per participant)
- Markers
- Paper towels and water to clean data sheets (not included)
- Optional: device (phone, tablet, computer) with weather apps installed or websites loaded (for example, www.weather.gov, www.weather.com, Accuweather app).

Getting Ready

On a phone or tablet, download a weather app and find a weather report for another location.

Photo: National Oceanic and Atmospheric Administration/ Department of Commerce

What To Do

Walk-Up Event

Prior to the event:

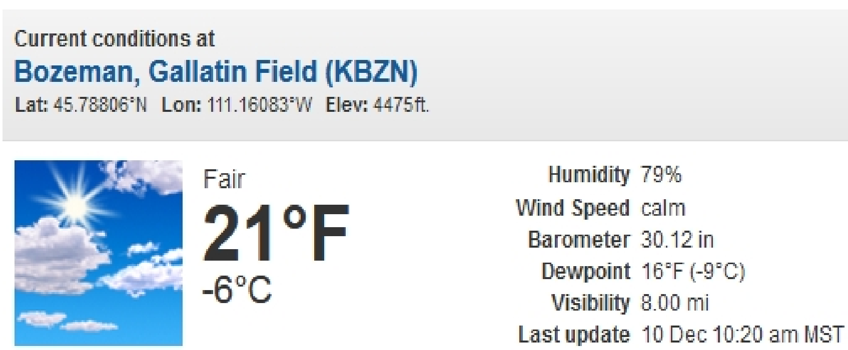
- On a phone or tablet, download a weather app and find a weather report for another location.
- Set up basic weather station (if outside).
- Set out weather report examples.
- Set out laminated weather data collection sheets and wet erase markers.

During the event:

- Provide participants with the Screen Interface Handout and markers.
- Show participants basic weather station (if possible)—challenge them to collect data using the data collection sheet and create a report on the Screen Interface Handout, including temperature, wind speed, wind direction, and other conditions.

Experience

Participants have likely looked at a weather report before. To make sure all participants have similar understanding, show them a current weather report for a location other than your own using those provided or the weather app on a phone, tablet, or computer screen (or print one out ahead of time). The report will look something like this example from www.weather.gov.



Source: www.weather.gov. Other example weather reports can be found using apps such as AccuWeather or websites such as www.weather.com.

Ask Participants

- What kind of information do we get when we look at the weather report? (Current temperature, whether it is currently clear, cloudy, raining, etc., graph of change in temperature over time (a day or several hours), humidity, UV (ultraviolet rays) index, wind speed, etc.)
- Where does the information come from that tells what the weather is right now? (Data collected using weather stations.)

Ask participants how they would describe the current weather in your location. They will likely use words like sunny, cloudy, rainy, windy, hot, cold, or wet. Ask participants what data they think might need to be collected to accurately describe the weather. Important variables include temperature, precipitation, wind speed, and wind direction. Ask participants if they can use the basic weather station to collect data to create a report with similar types of information as in the app or online weather report. They can design a "screen" interface that shares the following current information:

- temperature
- wind speed
- wind direction
- precipitation (Is it raining or snowing? How much precipitation has collected in the precipitation gauge?)
- conditions (sunny, cloudy, rainy, etc.)

Share

Gather the group so participants can share "weather reports." Would this report be useful for participants? Parents? Others? How?

Process

Discuss the data collection process. How was temperature data collected? How was wind speed data collected? How was wind direction data collected? How was data about current conditions collected?

Generalize

Have participants collect weather data again. Has it changed from their first collection? How?

Apply

Have participants collect weather data regularly over several hours (if time allows). This data can be used to identify patterns and create graphs (such as those in Activity Two).

1. Create and print a customized daily calendar like the one found here. (www.timeanddate.com/calendar/create.html?typ=5&cst=1)
2. Provide participants with a copy of the daily calendar.
3. Ask them to observe and record weather data each hour for one day.

More Challenges

Participants are likely familiar with weather stations and reports, which they have explored in this activity, but may not know that special data collection stations called SNOTEL (Snow Telemetry: www.wcc.nrcs.usda.gov/webmap/) sites exist to measure and record more in-depth precipitation data, too. The majority of these sites are located in the Western United States where much of the nation's water supply originates as precipitation in the form of mountain snow. By looking at publicly-available SNOTEL reports online, it is possible to see how much precipitation an area has received and make predictions about how much water will be available. Follow the instructions below to find SNOTEL reports for your area.

1. Using a computer, visit https://wcc.sc.egov.usda.gov/reports/SelectUpdateReport.html
2. From the drop-down menus select your state, or a region, today's date, SNOTEL Snow/Precipitation Update Report and HTML. Click "Create Report."
3. When the report loads, scroll through to find the river basin where you are located. The number in the bottom right corner of the table for the basin indicates the percentage "Water Year-to-Date Precipitation," or how much precipitation has been received so far in the current year compared to what is average or normal. Other information is defined at the bottom of the page.

In this example SNOTEL report, dated 12/11/18, you can see that the Gallatin River has received more than average precipitation compared to an average year. What might this mean for plants, animals and humans in that basin?

Basin Site Name	Elev. (ft)	Snow Water Equivalent			Water Year-to-Date Precipitation		
		Current (in)	Median (in)	Pct. of Median	Current (in)	Average (in)	Pct. of Average
GALLATIN RIVER BASIN							
Beaver Creek	7850	4.8	5.4	89	7.6	7.1	107
Brackett Creek	7320	7.9	5.0C	158	12.5	9.4C	133
Carrot Basin	9000	7.0	8.8	80	8.2	9.2	89
Lick Creek	6860	3.3	3.2	103	6.8	5.2	131
Lone Mountain	8880	5.7	5.4C	106	8.3	6.6C	126
Sacajawea	6550	5.7	3.5C	163	12.9	8.7C	148
Shower Falls	8100	9.3	6.9	135	11.6	8.5	136
Basin Index (%)				**114**			**124**

Source: SNOTEL: https://wcc.sc.egov.usda.gov/reports/SelectUpdateReport.html

In this example SNOTEL report, dated 12/11/18, you can see that another basin has received less than average precipitation compared to an average year. What might this mean for plants, animals and humans in that basin?

Basin Site Name	Elev. (ft)	Snow Water Equivalent			Water Year-to-Date Precipitation		
		Current (in)	Median (in)	Pct. of Median	Current (in)	Average (in)	Pct. of Average
MADISON RIVER BASIN							
Albro Lake	8300	6.3	5.7C	111	8.1	7.4C	109
Beaver Creek	7850	4.8	5.4	89	7.6	7.1	107
Black Bear	8170	7.8	12.1	64	10.5	13.1	80
Carrot Basin	9000	7.0	8.8	80	8.2	9.2	89
Clover Meadow	8600	5.4	6.1	89	8.0	6.5	123
Lone Mountain	8880	5.7	5.4C	106	8.3	6.6C	126
Lower Twin	7900	6.3	6.1	103	7.1	7.7	92
Madison Plateau	7750	4.2	7.0	60	6.3	9.0	70
Tepee Creek	8000	2.9	4.4	66	3.2	5.6	57
West Yellowstone	6700	2.3	2.7	85	3.9	5.0C	78
Whiskey Creek	6800	2.2	4.2	52	3.2	7.3	44
Basin Index (%)				**81**			**88**

Source: SNOTEL: https://wcc.sc.egov.usda.gov/reports/SelectUpdateReport.html

Activity Resources

NOAA, National Weather Service: www.weather.gov

SNOTEL: www.wcc.nrcs.usda.gov/webmap; https://wcc.sc.egov.usda.gov/reports/SelectUpdateReport.html

TimeandDate.com: www.timeanddate.com/calendar/create.html?typ=5&cst=1

Screen Interface Handout

Name ______________________

Activity Two

Weather and Climate Patterns

Using real data and by looking for patterns, participants explore how weather and climate are related across a span of time, as well as how climate is defined in time and space. They also explore and compare climate types in different places.

Learning Outcomes

Participants will:

PART I

- Identify daily and seasonal patterns in weather where they live.
- Analyze and interpret weather data using bar graphs.

PART II

- Reflect on weather patterns and their impacts over a season where they live.
- Recognize that the definitions of weather and climate are related to time.
- Realize that weather and climate are complex and interconnected.

PART III

- Recognize that there is climate variability even within a relatively small area.
- Begin to recognize factors that influence climate.
- Compare different climate types from locations they are familiar with.
- Recognize that climates can be large or very small.

Content Skill: Graphing and interpreting historical weather data over different time periods.

Life Skill: Managing, Thinking

Educational Standards: 3-ESS2-1, 3-ESS2-2, 5-ESS2-1; 4a, 4b, 5a, 5b, 5d

Success Indicator: Successful graphing and identification of patterns.

Background

As this activity progresses, participants use historical weather data specific to their location and look for patterns over the course of a day. They then think about seasonal conditions, both quantitatively and qualitatively, to build toward an understanding of weather and climate as a factor of time, culminating in the creation of climographs for their location. They then study factors that influence climates of the west and compare various regional climate types. Finally, they explore microclimates in their own backyards.

Weather Patterns in the West

States in the Western U.S. are large and include varied terrain—mountains, plains, high desert, etc. Because of this, weather patterns vary across each state and across state borders (which weather does not recognize). There are many weather dynamics at play; for example, weather patterns tend to move west to east; moisture comes from both Pacific and Atlantic (Gulf of Mexico) oceans; there are many topographic influences in the region, particularly upslope airflows that tend to lead to the largest precipitation accumulations. Some general patterns in daily and seasonal weather for the West can be identified. For example, temperatures are typically warmer during the day and colder at night. Seasonally, the West typically experiences cold, snowy winters and hot, dry summers. Fall weather

Photo: Kenneth M. Gale, Bugwood.org

is generally sunny and cooler. During spring, snow shifts to rain and increasingly warmer temperatures. Local terrain and other factors influence what the weather does at any given time in each individual location across the western states.

Are Weather and Climate the Same?

According to the 2017 Montana Climate Assessment:

> The terms "weather" and "climate" are often used interchangeably. However, they are not the same, and understanding the difference helps us when we talk about Montana's [and other nearby state's] climate. The main difference between the two has to do with time. "Weather" occurs over a short period and is the day-to-day condition of the atmosphere ("it's a hot day" or "a storm is forecast this weekend"). "Climate" pertains to what happens over decades to centuries.

In other words, weather refers to the conditions outside right now, or over the next few days. Climate is the average weather in a place over many years. Climate is what you expect the weather to be like next month, this fall or next winter. Another way to think about it is weather will dictate what you wear today, but climate dictates what clothes are in your closet.

Weather can be predicted with some accuracy for a day or even up to a week based on data collected and our knowledge of weather patterns. When weather is observed, and data is recorded over weeks, months and years, long-term weather patterns can provide information about an area's climate. To find the climate of a certain place, you have to observe how often it is sunny, rainy, windy, cold, and hot.

The climate of an area influences what types of plants and animals live there, when and what types of crops can be grown, how much water is available, what industries and types of jobs exist for people, and much more.

Climate Patterns

To find the climate of a certain place, look at how often it is sunny, rainy, windy, cold, and hot. Yet, it is much more difficult to figure out why a place has that climate. Some of the factors that can impact the climate of a place are how far north or south it is, distance to water, whether it is flat or mountainous, and how high the elevation is. Even ocean temperatures and currents in faraway places can have an impact on climate because they have a strong influence on weather patterns.

Factors That Affect the Climate of a Location

Factor	What it Means
Latitude	How far north or south is it?
Proximity to water	Is it near an ocean, lake, or river?
Topography	Is it flat or mountainous?
Elevation	How high above sea level is it?
Distant ocean currents and temperatures	What types of currents are happening in the ocean this year? • El Niño (specific climatic conditions that influence ocean currents in specific ways) is characterized by unusually warm temperatures. El Niño can bring the U.S. Northwest warmer and drier winters. • La Niña (specific climatic conditions that influence ocean currents in specific ways) is characterized by unusually cool temperatures in the equatorial Pacific. La Niña can bring the U.S. Northwest colder and more wet winters.

Activity Two: Weather and Climate Patterns

Climate can change over a large or very small distance. Areas very close to each other can have different climates. For example, a town at the base of a mountain may have a very different climate than a ski resort close by, but further up the mountain. There are even microclimates. A microclimate is a small area that is different from the area around it. It may be warmer or colder, or more wet or dry. An example may be the area under the shade of a large tree. Less light, cooler temperatures, and wetter soil may cause different plants to grow and different insects and microbes to thrive.

A good indicator of a change in climate is difference in plants and animals. For example, near Bozeman, Montana, one end of the Gallatin Valley is full of large trees and green vegetation. The other end of the valley is much drier with sagebrush, fewer trees, and rattlesnakes.

Time Needed:

PART I: 1 hour
PART II: 1 hour
PART III: 1 hour
(Walk-up Event option combining Parts I, II and III provided)

Materials

PART I

- Access to Wunderground website (www.wunderground.com); prior to or during activity
- Access to a printer
- Example weather data (data for each state included)
- Reusable graph boards (10)
- Dry erase markers (10)
- Erasers (10)

PART II

- Season charts (participant copy page, one copy per participant)
- Pencils (12)
- Laminated climate data for different cities in MT, CO, WY and SD (or print climate data for your location at www.usclimatedata.com; feel free to add to kit)

PART III

- *Factors That Can Influence Climate* presentation
- Laminated climographs for different cities in MT, CO, WY, and SD (or print climographs for your own location at www.usclimatedata.com; feel free to add to kit)
- Köppen-Geiger Climate Classification maps for MT, CO, WY, and SD (included in the kit)
- Wet erase markers (10, included in Activity One)
- Infrared thermometers (3, battery included but may not be connected; see battery replacement instructions in the Part III, Getting Ready section)
- Pencils (12)
- Paper (not included)

What To Do

Walk-Up Event

Prior to the event:

PART I

- Access the internet and print (and laminate, if possible) daily, weekly and/or monthly datasets from the event's location (see Getting Ready, below) or use the laminated weather data provided for the location closest to yours.

PART III

- Find the climate map for your state. Use a wet erase marker to pinpoint the location of your event and determine what climate it is in.
- Find the climograph for your location (you may have to find it online) and nearby locations.
- Set out the infrared thermometers (if outside).

During the event:

PART I

- Provide participants with weather datasets, dry erase graph boards, markers and erasers.
- Ask participants to graph information from one of the data sets and look for patterns (work with them to identify patterns).

PART II

- Provide copies of the Season Chart and pencils for participants (one or more season per participant). Have them fill it in, while noting patterns.

PART III

- Let participants peruse the map and climographs. What climate are they in? Are there different climates nearby? Compare the climographs for nearby locations. How are they different? Why?
- Allow participants to use infrared thermometers to explore microclimates near your table if you are outside.

PART I

Getting Ready

If you will not have computer or internet access during the activity, prior to the activity visit www.wunderground.com and print weather data using the steps below.

- Search for your location (top right corner).
- Select the "History" tab.
- Choose daily, weekly, or monthly, depending upon which data you choose to graph during the activity.
- Click on the "Time" heading to sort data by time of day.
- Print the weather data at the bottom of the page (using the landscape paper/page setting on the printer).

Daily Observations

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Precip Accum	Condition
12:56 AM	33 ° F	31 ° F	92 %	NW	5 mph	0 mph	25.5 in	0.0 in	0.0 in	Fair
1:56 AM	35 ° F	32 ° F	89 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
2:00 AM	35 ° F	33 ° F	92 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
2:42 AM	29 ° F	28 ° F	96 %	ESE	6 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
2:52 AM	30 ° F	28 ° F	93 %	SE	7 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
2:54 AM	30 ° F	28 ° F	93 %	SE	7 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
2:56 AM	30 ° F	29 ° F	96 %	SE	7 mph	0 mph	25.5 in	0.0 in	0.0 in	Partly Cloudy
3:56 AM	31 ° F	30 ° F	96 %	SSW	6 mph	0 mph	25.5 in	0.0 in	0.0 in	Fair
4:56 AM	31 ° F	29 ° F	92 %	NE	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Cloudy
5:56 AM	30 ° F	29 ° F	96 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Mostly Cloudy
6:05 AM	30 ° F	29 ° F	96 %	N	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
6:13 AM	32 ° F	30 ° F	92 %	N	5 mph	0 mph	25.5 in	0.0 in	0.0 in	Cloudy
6:54 AM	32 ° F	30 ° F	93 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
6:56 AM	32 ° F	31 ° F	96 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
6:59 AM	32 ° F	31 ° F	96 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
7:32 AM	33 ° F	32 ° F	96 %	S	5 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
7:37 AM	33 ° F	32 ° F	96 %	S	6 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
7:41 AM	34 ° F	33 ° F	96 %	SSW	5 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
7:52 AM	34 ° F	34 ° F	100 %	SSW	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
7:56 AM	34 ° F	33 ° F	96 %	W	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Fog
8:56 AM	35 ° F	34 ° F	96 %	WSW	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Cloudy
9:03 AM	35 ° F	34 ° F	96 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Partly Cloudy
9:30 AM	36 ° F	34 ° F	93 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Mostly Cloudy
9:56 AM	36 ° F	34 ° F	93 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Cloudy
10:07 AM	36 ° F	34 ° F	93 %	VAR	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Cloudy
10:56 AM	40 ° F	35 ° F	83 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Cloudy
11:56 AM	43 ° F	35 ° F	74 %	VAR	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Cloudy
12:10 PM	45 ° F	36 ° F	71 %	SW	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Mostly Cloudy
12:25 PM	46 ° F	36 ° F	68 %	SE	5 mph	0 mph	25.5 in	0.0 in	0.0 in	Mostly Cloudy
12:56 PM	47 ° F	34 ° F	61 %	SSE	3 mph	0 mph	25.5 in	0.0 in	0.0 in	Mostly Cloudy
1:56 PM	48 ° F	34 ° F	58 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Partly Cloudy
2:56 PM	51 ° F	33 ° F	50 %	CALM	0 mph	0 mph	25.5 in	0.0 in	0.0 in	Partly Cloudy
3:56 PM	52 ° F	32 ° F	47 %	CALM	0 mph	0 mph	25.4 in	0.0 in	0.0 in	Fair
4:56 PM	53 ° F	31 ° F	43 %	NE	7 mph	0 mph	25.4 in	0.0 in	0.0 in	Mostly Cloudy
5:56 PM	49 ° F	33 ° F	54 %	ESE	10 mph	0 mph	25.4 in	0.0 in	0.0 in	Cloudy
6:56 PM	46 ° F	31 ° F	56 %	ESE	3 mph	0 mph	25.4 in	0.0 in	0.0 in	Mostly Cloudy
7:56 PM	45 ° F	30 ° F	56 %	ENE	3 mph	0 mph	25.4 in	0.0 in	0.0 in	Cloudy
8:56 PM	41 ° F	30 ° F	65 %	SE	3 mph	0 mph	25.4 in	0.0 in	0.0 in	Partly Cloudy
9:56 PM	40 ° F	30 ° F	68 %	CALM	0 mph	0 mph	25.4 in	0.0 in	0.0 in	Partly Cloudy
10:56 PM	41 ° F	29 ° F	62 %	VAR	3 mph	0 mph	25.4 in	0.0 in	0.0 in	Partly Cloudy
11:56 PM	41 ° F	31 ° F	67 %	CALM	0 mph	0 mph	25.4 in	0.0 in	0.0 in	Cloudy

Example daily weather data for Bozeman, MT on 10/15/77, retrieved 10/8/18 from www.wunderground.com. © Copyright TWC Product and Technology LLC 2014, 2018.

Experience

Weather data (temperature, wind speed and direction, precipitation, etc.) is collected continually and saved all over the world every day. People have been collecting and keeping records of weather data for a long time. With today's technology, anyone can look up weather data for their location for the last week, year, or many years.

For this activity, use weather data from your location that can be found on www.wunderground.com. Instructions to access historical weather data for your site are found above in the Getting Ready section. Or, you can use the historical weather data provided.

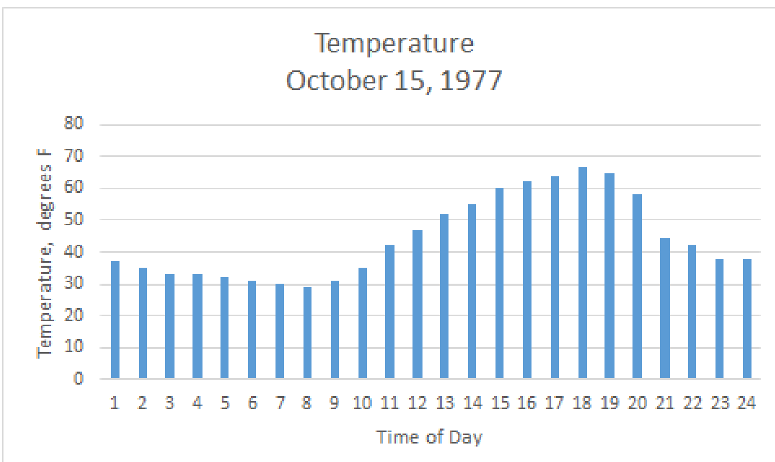
First, look for patterns in the temperature over the course of a day. Ideally, each participant will be able to look up the weather data for his/her birthdate, but any dates can be chosen. Provide data for at least four different days.

Weather Patterns Over the Course of a Day (24 hours)

What was the weather like in a certain place on a certain day (the day you were born in the city you were born in)? Use weather data from a specific date and location to create a graph of the day's weather and look for patterns.

- Go to www.wunderground.com.
- Search for your location.
- Select the "History" tab.
- Be sure the "Daily" tab is selected and then enter the date.
- Scroll to the bottom of the page to find "Daily Observations."
- Click on the "Time" heading to sort data by time of day.

Participants should use the time and temperature data to draw a bar graph (on the reusable graph boards with dry erase markers) that shows the temperature range on that day. Plot time of day from the x-axis and temperature from the y-axis of the graph. Ask participants, what temperature patterns do you see on the bar graph for that day? Participants should also look at the other data provided to learn more about the weather on the date of their birth (or other date). Was it raining? Snowing? Windy? This data could also be graphed.



Example graph created by the lead editor for her birth date in her hometown, retrieved 10/8/18 from www.wunderground.com. © Copyright TWC Product and Technology LLC 2014, 2018.

Share

Have participants share graphs with each other. Have them compare graphs from different days in the same location. What patterns did they find? (It is typically cooler in the morning, warms during the day, and cools off again at night.) Why do they think these patterns might occur? (Day and night.) Does the temperature go up and down every day? The Experience and Share steps can be repeated for different short time periods—a week, or a month (using daily minimum and maximum temperatures, or other variables including precipitation). Participants can experiment with graphing other variables besides temperature (for example, precipitation) and looking for patterns.

Process

Participants now have experience graphing and analyzing weather temperature data for short time periods (days, weeks, months). Discuss the patterns they saw at each time frame. What patterns happen daily? What patterns happen over a week? If they compared variables other than temperature, did patterns related to different variables correspond? How do these patterns impact their lives?

Generalize and Apply

As a group, work together to verbally summarize the patterns identified through the data. For example, daily temperatures generally rise throughout most of the day, and fall again in the evening. Or, it is generally coldest in the early morning hours and warmest during the afternoon each day. Or, temperatures rise during the day and fall at night over a week.

PART II

Getting Ready

If you will not have computer or internet access during the activity, prior to the activity visit www.usclimatedata.com and print climate data using the steps below.

- Search for your location.
- Print the monthly climate data presented in the top left corner of the page for your location.

Experience

Now participants will expand thoughts about weather patterns to a larger time frame—a season. If participants have lived in the same place for a year or more, they probably have a sense of what weather patterns to expect each season. Assign participants to create a narrative for each section of one of the season charts (divide the group relatively equally so that some participants are working on each season). As participants work through their chart, they should think about what the weather might bring where they live during each month of that season. Circulate through the group, as participants may need a little guidance in remembering the different months. It may help to point out holidays or things like summer break as a reminder.

Example Season Chart

Summer in Bozeman, MT				
	From June 21	**Through July**	**And August**	**Until September 20**
Temperatures	Starting to get hot: 70s and 80s, maybe 90s. Days are long, stays light and hot late	HOT: 80s-90s	Very hot: 80s, 90s, and hotter. Days getting shorter, dark earlier.	Some days still very hot, some cooler.
Precipitation	Some rain and occasional snow. Rains more in late afternoon than any other time.	Mostly dry but still some late afternoon thunderstorms.	Getting very dry. Sometimes still get late afternoon thunderstorms.	Mostly dry but some rain. Snow in mountains.
Extreme Weather	Thunderstorms, hail, flooding	Thunderstorms, hail, some forest fires start	Occasional thunderstorms, forest fires	
Impacts	Creeks too high to get in, evening soccer games cancelled regularly, cars get dented	Too hot to play in the sun, hail dents cars, garden is growing, lightning starts forest fires	Smoke from fires, can't go to some forest areas due to fire closure, garden drying out.	Nice weather to do things outside.

Share

After participants have each completed one season chart, they should share with the group. What are some of the conditions reported during Summer? Fall? Winter? Spring? Did some participants have the same things on their season charts? Were there any within a given season that were very different from each other? Together, using the season charts for reference, discuss how the conditions change over the course of a year where you live.

Process

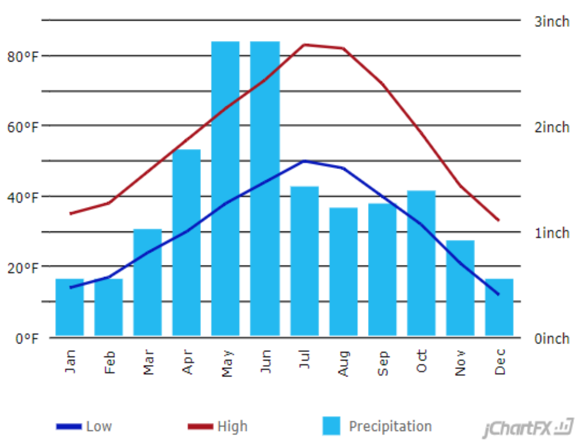
Now that participants have thought about seasonal conditions qualitatively, they will have a chance to do the same quantitatively and compare. Using the climate data provided in the kit, or accessed for your location through www.usclimatedata.com, participants should create a new graph using the graph board from Part I. This graph will show average temperature and precipitation for their locations, which are measured in different units. First, participants should graph average high and low temperatures by labeling the x-axis with the months of the year and the y-axis temperature (F°). These will be line graphs. They can plot a dot for the low temperatures first and connect them with a line, then do the same for the high temperatures (participants may need some help creating a line graph depending on grade level). Next, participants should use the average monthly precipitation data to create a bar graph on the same graph—label precipitation in inches along the y-axis on the other side of the graph. (An option may be to have each season group work together to create a graph for the months in their season. Put these graphs together to create a climograph for the year.)

An example of a data set and completed graph can be seen below.

Climate Bozeman - Montana °C | °F

	Jan	Feb	Mar	Apr	May	Jun
Average high in °F:	35	38	47	56	65	73
Average low in °F:	14	17	24	30	38	44
Av. precipitation in inch:	0.55	0.55	1.02	1.77	2.8	2.8
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-
Average snowfall in inch:	9	6	8	4	1	0

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F:	83	82	72	58	43	33
Average low in °F:	50	48	40	32	21	12
Av. precipitation in inch:	1.42	1.22	1.26	1.38	0.91	0.55
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-
Average snowfall in inch:	0	0	0	3	8	11



Source: U.S. Climate Data: www.usclimatedata.com

Generalize

When participants have completed their graphs, explain that participants have completed a climograph for their location. A climograph provides a visual model of what average temperature and precipitation data looks like over the course of a year. Ask participants what they notice about their climograph. They may say things like:

- The most precipitation occurs in May and June in Bozeman, MT.
- The warmest temperatures are in July and August in Bozeman MT.
- It's cold in the winter and hot in the summer in Bozeman, MT.

Discuss the climographs participants made in relation to their season charts. Do they match up? Are participants able to make predictions about what conditions will be like at a certain time next year based on the patterns they have identified related to seasons and climate?

Apply

Ask participants, do you think climographs for different locations look the same or different? Why? Show participants examples of climographs from other locations (you can find them using www.usclimatedata.com or use the other state examples included in the kit). Discuss why climographs might vary.

PART III

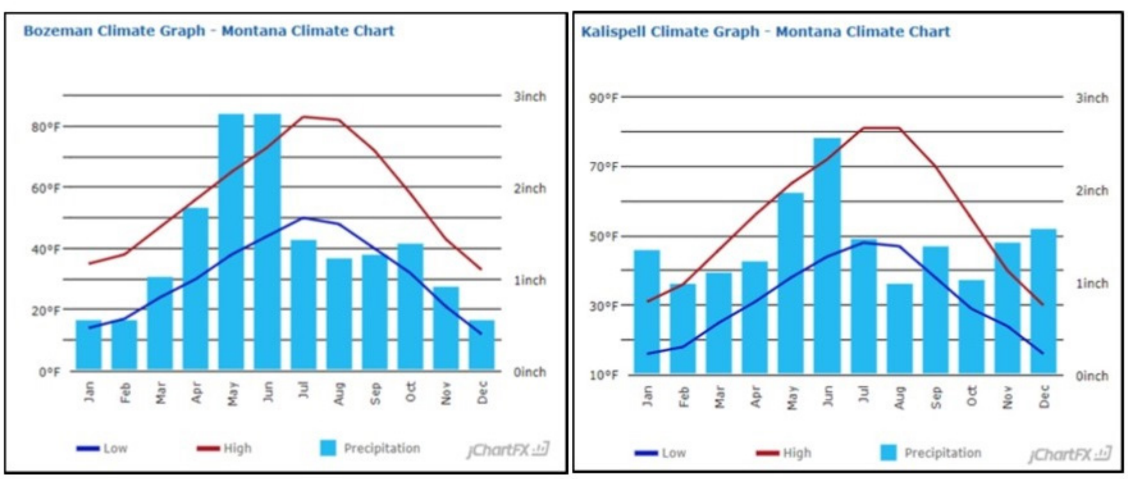
Getting Ready

If the temperature gun(s) needs new batteries, please watch the video at www.youtube.com/watch?v=C_tXx8kmzZY. The battery compartment is difficult to open.

Use the Köppen-Geiger Climate Classification map for your state to determine the climate type for your location. Then identify a location in another climate type and find the climograph for that location (you may have to print climographs at www.usclimatedata.com).

Experience

Ask participants to name two of the most important things that determine a place's climate. (Temperature and precipitation—make sure they know precipitation can be rainfall, snowfall, hail, etc.). Ask the participants if they think most of the places near their town have the same type of climate. Have them try to think of places close by with similar or different climates. Provide participants with a climograph from your location (or use the one they made in Part II) and a climograph from another location in a different climate in your state (you may need to find and print this ahead of time at www.usclimatedata.com). Participants should look at that city's climograph and compare it to the climograph where they live. What are the similarities? What are the differences? Is the climate the same or different in these two locations?



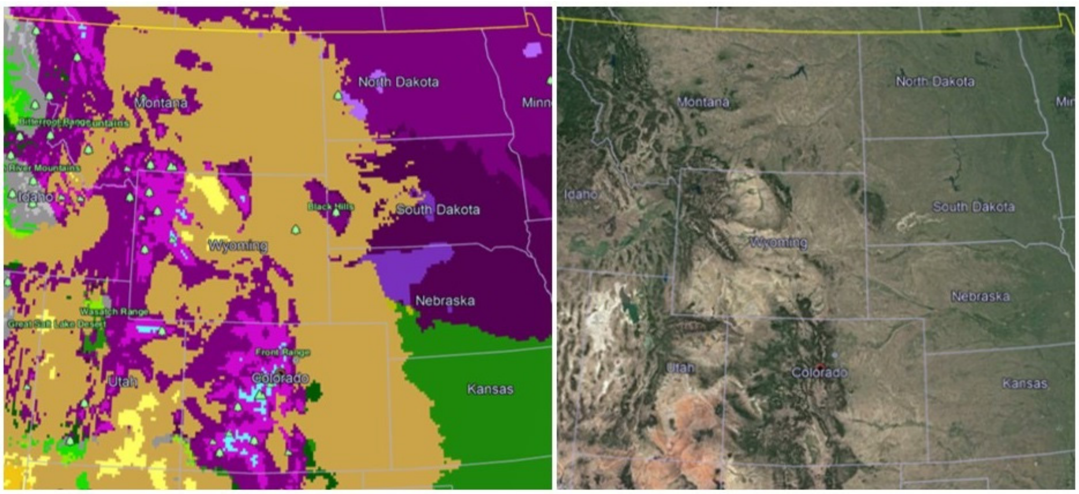
Comparing two example climographs from www.usclimatedata.com.

Share

As a group, discuss participant observations and conclusions. Point out factors to take into account, such as differences in temperature or precipitation scales between climographs. Can different climate types exist across your state? What factors that influence climate might lead to the differences in climate type for these two locations? For the example above, Kalispell is located near a large lake and Bozeman is not. Show participants the *Factors That Can Influence Climate* presentation (online or printed in the kit).

Process

Show participants the Köppen-Geiger Climate Classification map for your state and locate your town. There are many different (not necessarily better) climate classifications that exist, including those based on soil properties, watersheds, precipitation, land vegetation, and ecozones. We are using this map as it is one of the most widely-used climate classification systems. (Leaders can learn more at https://en.wikipedia.org/wiki/Climate_classification.) What climate is your town in? Read the description for your town's climate. Does it sound accurate? Use the wet erase marker to label your location's climograph with its climate type. Now locate the other town. What climate is that town in? Read the description and label. Reconsider the data on the charts in light of the information provided by the maps. Compare climographs for locations found in other climate types based on the climate map.



Left, Köppen-Geiger Climate Classification map for MT, WY, CO, and SD (http://koeppen-geiger.vu-wien.ac.at/present.htm). Right, topography map (map data ©2019 Google).

Generalize

This portion of the activity adapted with permission from: http://www.montana.edu/eu/climb/lessons/tempguns/CLIMB-MicroClimate-TempGuns.pdf

Why are there so many different types of climate so close to each other in your state? Participants will now work to determine how different landscape features influence the climate of an area.

Ask participants some of the reasons their surrounding area has the climate it does. Answers could include annual rainfall, nearness to mountains, elevation, proximity to a lake or an ocean, or being landlocked. Remind them that sometimes conditions far away can impact climates, such as ocean currents and the El Niño or La Niña effects.

Ask participants if they have ever heard of microclimates and what they think a microclimate is. A microclimate is a small area that is different from the area around it. It may be warmer or colder, or more wet or dry. Their own backyard or schoolyard may have microclimates. For example, is there a part of the yard that is always shady (and therefore cooler) that holds snowpack and moisture for longer periods of time? Can they think of other examples of microclimates? How about the soil under a rock versus soil that is exposed to the sun all the time? Ever notice how if you flip a rock over, you are more likely to find worms and bugs? Hand out paper and pencils to each participant. Set the boundaries for an outdoor study area prior to going outside. Have participants sketch major features of their study area on their paper to create a map.

Divide the participants into small groups of two to five. Ideally, each group should have an infrared thermometer. Show participants how to use the infrared thermometer prior to going outside. Take the participants outside to look for and describe microclimates within the defined study area. Have participants use the infrared thermometer to find temperature transitions and add their measurements to their sketch. Have participants sketch any plants or insects they find and their observations about how wet or dry the area is.

Apply

Have participants share their maps. Ask participants to explain why the identified microclimates exist. As with larger climate regions, temperature and moisture will be two key variables. Are there other variables besides temperature and moisture that change (sunlight/shade, ground cover, elevation, etc.)?

More Challenges

Shift participant focus to the entire West by showing them the other Köppen-Geiger Climate Classification maps included in the kit. Have they visited other locations with climates similar to their location?

Activity Resources

IR Thermometer: https://www.youtube.com/watch?v=C_tXx8kmzZY and
http://www.montana.edu/eu/climb/lessons/tempguns/CLIMB-MicroClimate-TempGuns.pdf

U.S. Climate Data: www.usclimatedata.com

Weather and Climate Youth Learning Lab Online Resources:
www.msucommunitydevelopment.org/4Hweatherandclimate.html

Weather Underground: www.wunderground.com

World Map of the Köppen-Geiger Climate Classification: http://koeppen-geiger.vu-wien.ac.at/present.htm

Additional Resources

2017 Montana Climate Assessment:
www.montanaioe.org/sites/default/files/resources/climate_2_pager_final_1.pdf

MesoWest from University of Utah: https://mesowest.utah.edu/

Colorado Climate Office: http://ccc.atmos.colostate.edu/

Colorado Mesonet: https://coagmet.colostate.edu/

Montana Climate Office: https://climate.umt.edu/

Montana Mesonet: https://climate.umt.edu/mesonet/default.php

National Mesonet Program: https://nationalmesonet.us/

South Dakota Mesonet: https://climate.sdstate.edu/

South Dakota Climate Office: https://www.sdstate.edu/state-climatologist

Wyoming Climate Office: http://www.wrds.uwyo.edu/sco/climate_office.html

Winter Season Chart

Winter in:				
	From December 21	Through January	And February	Until March 20
Temperatures				
Precipitation				
Extreme Weather				
Impacts				

Spring Season Chart

Spring in:				
	From March 21	Through April	And May	Until June 20
Temperatures				
Precipitation				
Extreme Weather				
Impacts				

Summer Season Chart

Summer in:				
	From June 21	Through July	And August	Until September 20
Temperatures				
Precipitation				
Extreme Weather				
Impacts				

Fall Season Chart

Fall in:				
	From September 21	Through October	And November	Until December 20
Temperatures				
Precipitation				
Extreme Weather				
Impacts				

Activity Three

Weather and Climate Extremes

Participants explore extreme events and their impacts. They determine which types of extreme events occur where they live, which don't, and explore connections between weather and climate.

Learning Outcomes

Participants will:

- Explore different types of extreme weather and climate events.
- Determine what types of extreme events occur where they live.
- Think critically about how weather and climate events are related and influence each other.
- Explore impacts related to extreme events and solutions to lessen impacts.

Content Skill: Identify extreme weather and climate hazards and potential solutions in certain locations.

Life Skill: Thinking

Educational Standards: 3-ESS3-1, 4-ESS3-2, 5-ESS2-1; 7c

Success Indicator: Successfully identify local extreme weather and climate hazards and solutions to lessen impacts.

Background

Participants spent some time thinking about weather conditions in Activity One and then weather patterns over relatively short time frames in Part I of Activity Two. Then, in Parts II and III of Activity Two, participants thought about how weather and climate are related by looking at how patterns of weather over time define the climate of a region.

Recall in Activity Two, the definitions of weather and climate were introduced. To add to this understanding, here is another definition from the Montana Climate Office (https://climate.umt.edu/):

> The difference between weather and climate is a measure of time. To understand climate at a given place requires synthesizing the variation in weather over relatively long periods of time. Weather is the day-to-day interaction of factors like temperature, humidity, precipitation, cloudiness, visibility, and wind. Scientists pursue an understanding of climate trends or cycles of variability and place those phenomena into the bigger picture of possible longer-term changes in our climate.

Weather and climate are clearly related, but their relationship can be complex and difficult for participants to understand. In this activity, the focus is on extreme events and the frequency and intensity of these extreme events. Extreme events are evaluated by how often they occur (frequency) and how strong these events may be (intensity).

We can think of weather extremes as events including out-of-the-ordinary daily maximum or minimum temperatures, hail storms, wind storms, blizzards, or even tornadoes. Individually, these events depend on the local weather. Climate extremes can include events like prolonged drought, heat waves (depending on the characteristics and duration of the event), and wildfire seasons. Note that climate extremes almost never occur in isolation; for example, drought almost always also involves heat and will generally have combined weather, climate, and human causes (for example, water

Photo:
Kenneth M. Gale,
Bugwood.org

use). Likewise, a severe wildfire season often involves drought, wind, temperature, lightning, and human factors. Larger-scale patterns, such as the surface melting of the Greenland Ice Sheet, seem related to climate but also involve a series of warm, clear days (weather) that can greatly accelerate surface meltwater run-off from the ice. Other large-scale patterns that cross the line between weather and climate can include the loss of northern hemisphere snow cover, especially in late spring (more area of snow cover has disappeared than area of sea ice), and the loss of sea ice.

The take-home message is that, although we all experience extreme weather and extreme climate conditions where we live, scientists' understanding of what we call weather and what we call climate is becoming increasingly blurred, as one influences the other. In this activity, focus on which types of these events occur in your area and to help participants think critically about the complex relationship between weather and climate.

Time Needed: 1 hour (Walk-up Event option provided)

Materials

- *Wild Weather* books (hailstorms, hurricanes, snowstorms, thunderstorms, dust storms, tornadoes)
- *Extreme Weather* book
- Extreme Event cards
- Extreme Event mats

Getting Ready

Find all the materials in the kit.

What To Do

Walk-Up Event

Prior to the event:

- Set out Extreme Event cards, mats, and books.

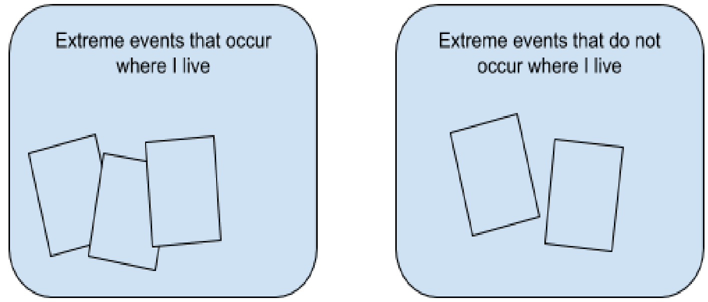
During the event:

- Set up the Experience section of the activity (below) at the booth. Participants can sort the Extreme Event cards onto the mats and determine what types of extreme events occur where they live. They can learn more about the different types of extreme events using the books. Engage participants in discussion about weather influencing climate and the blurred definition between weather and climate.

Experience

What types of extreme weather and climate events do you experience where you live? What types of extreme events do you not experience where you live? Ask participants to focus on events that are most relevant to their local area or region (for example drought, wildfire, smoke forecasts, etc.). Show participants the extreme event cards. Allow them to work together to categorize the cards as something that occurs where they live or as something that does not.

Share and Process



Do participants agree with how the group has categorized the cards? Have they heard about or observed other types of extreme weather or climate events where they live? Why do some of these events occur in some places and not others? What influences the location of extreme weather and climate events? For older participants, discuss each extreme event in terms of interactions between Earth's atmosphere (air), geosphere (rock and soil), hydrosphere (water), and biosphere (living things).

Which cards show discrete events, and which are the result of these events (for example, wildfires are the result of hot, dry conditions)? Think about the difference between extreme events and things that may happen due to extreme events.

Generalize

Ask participants, is it possible to categorize these events as weather events and climate events? Discuss a few events. As a group discuss how each can be categorized as both weather and climate events as a changing climate is leading to new weather situations. Examples include:

- Drought in the Northern Plains states (those represented in this kit, and other events in other states such as California.)
- Wildfires in Western states and widespread smoke across the region which participants likely experienced.
- Wildfires followed by flood-induced landslides.
- Future probability of wildfire near where participants live.

Apply

Each participant should choose a type of extreme event that occurs where they live. They can conduct further research about this type of extreme event, its impacts, how to describe it in terms of weather and climate, and possibly design solutions for impacts the event causes to humans using the books provided, along with other resources.

More Challenges

- Find and observe a local example of a way to stay safe in an extreme event (for example, levee for flooding, tornado shelter, etc.).
- Volunteer for the National Weather Service SKYWARN Storm Spotter Program: www.weather.gov/skywarn

Activity Resources

Montana State University Science Zone: Tornado: http://eu.montana.edu/pdf/outreach/msuscizone21.pdf

National Climate Assessment 2014, Extreme Weather:
https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather#intro-section-2

National Geographic, Weather Gone Wild:
www.nationalgeographic.com/magazine/2012/09/extreme-weather-global-climate-change-effects/

National Weather Service SKYWARN Storm Spotter Program: www.weather.gov/skywarn

NOAA tornado detection: www.nssl.noaa.gov/education/svrwx101/tornadoes/detection

Additional Resources

Active Fire Mapping Program: https://fsapps.nwcg.gov/

Flooding in Boulder CO: www.scied.ucar.edu/boulder-floods

Montana Climate Office: http://climate.umt.edu/

U.S. Drought Monitor: https://droughtmonitor.unl.edu/

U.S. Geological Survey: https://www.usgs.gov/products/data-and-tools/real-time-data/wildfire

NOAA Air Quality Forecasts: https://airquality.weather.gov/

Photo: National Oceanic and Atmospheric Administration/ Department of Commerce, Commander John Bortniak, NOAA Corps

Activity Four

Weather Forecasts

How do we know what we know about the weather tomorrow or next week?

Learning Outcomes

Participants will:

- Explore ways that data is collected and used to inform weather forecasts.
- Recognize that math, computer modeling, and technology are responsible for increasingly accurate weather forecasts.
- Emulate meteorologists by working in groups and determining which data is pertinent to forecast.
- Use real, local weather data from computer models to create a forecast.

Content Skill: Create a weather forecast from real data.

Life Skill: Thinking

Educational Standards: 3-ESS2-1, 3-ESS3-1, 4-ESS3-2, 5-ESS2-1

Success Indicator: Successfully interpret weather data maps to create an accurate forecast.

Background

In Activity One, participants learned how to measure and report weather conditions. Then, they looked at weather patterns in Activity Two and, in Activity Three, what kinds of conditions might lead to extreme events. In Activity Four, they will think about how to combine understanding about previous weather patterns with current observations to make informed predictions about what will happen into the future.

Meteorologists, scientists who study and predict the weather, gather information from a variety of sources to help them make informed forecasts. To learn more about their sources of weather data and the tools they use, please see the *How Weather Forecasting Works* presentation in the toolkit.

Because weather forecasts are very specific to an area, weather forecasters need to be able to analyze all the data they get and make decisions about what will influence the future weather and how. They use both incoming observations (up-to-date weather data) and their understanding from previous data and forecasts to help them. Weather forecasters gather information from many sources and use their expertise to synthesize data and create forecasts.

As part of the weather forecast provided by the National Weather Service, anyone can access the Area Forecast Discussion, which provides a narrative from a local meteorologist related to how they interpret weather data to come up with a forecast. In this activity, participants explore resources to learn which data is most important to a forecast on any given day (the data which is most important to forecasters changes depending upon conditions).

Because atmospheric conditions are constantly changing, weather forecasts can only be made accurately for a few days into the future. Uncertainties in weather forecast models grow to unreliable levels after five, seven or, occasionally, 10 days. Because of this, meteorologists look at the data and make new forecasts frequently. This helps people plan. For example, the weather forecast might be given during the morning news, and a new, updated forecast given during the evening news. Online forecasts are also updated multiple times a day. In some situations, even more up-to-date forecasts are critical. For example, airports have their own weather stations where observations are taken and forecasts are made very often since the weather has a large impact on airplane safety. It is important to note that the forecasting system has very necessary repeatability and reliability. Global forecasts are produced every 12 hours based on the processing of global observational data. Regional updates in areas where observational data is available may be produced every 6 hours if data allow and if weather conditions require. For aviation, updates are required at least every 3 hours. Private weather providers, for television or aviation, might provide more frequent updates during interesting weather situations (for example, using radar data during hours when tornadoes are most likely). Those local immediate warnings are part of a larger, regular global forecast cycle.

Time Needed: 1 hour (Walk-up Event option provided)

Materials

- *How Weather Forecasting Works* presentation
- Laminated state weather map sets
- Wet erase markers (10, included in Activity One)
- Cloud chart poster
- Access to a device or computer to find (and print, if desired) current Area Forecast Discussion (see instructions below).

Getting Ready

From the kit, find the weather map sets and sort by state and dates. Make sure any existing wet erase marker marks are wiped clean. Post cloud chart poster.

If you will not have access to a device or computer during the activity/event, find and print your Area Forecast Discussion for the current date following these instructions:

- Visit www.weather.gov.
- Scroll over the “Forecast” tab and from the drop down menu select “local.”
- In the “Enter location” box at the top left, enter your city and state or zip code and click “go.”
- When your local forecast page loads, scroll down to the “Additional Forecasts and Information” section. Here, click on the “Forecast Discussion” link.
- Keep this link open, or print the first page or two of the discussion.

What To Do

Walk-Up Event

Prior to the event:

- Using a device or computer, find (and print the most current portion of, if necessary) the Area Forecast Discussion for your location following the directions in the Getting Ready section above.
- Display *How Weather Forecasting Works* presentation (printed or on a device).
- Find and sort the weather maps for the state in which the event takes place and indicate the location of the event on each map using a wet erase marker. Put them out on display. Display the cloud chart poster.

During the event:

- Ask participants how they think a forecast is created. Discuss and allow them to peruse *How Weather Forecasting Works* slides.
- Show participants current Area Forecast Discussion information.
- Let participants peruse the maps. Ask them if they see any trends in how temperatures change over the course of a week. Can they make a forecast for the week based on this data?

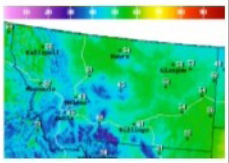
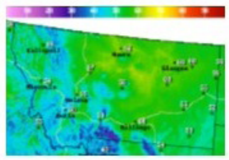
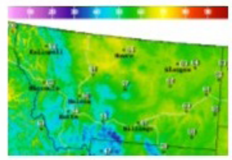
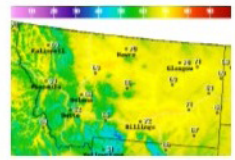
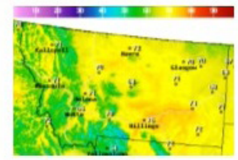
Experience

Show participants the *How Weather Forecasting Works* presentation and discuss the different ways weather data is observed and collected. Next, show participants the Area Forecast Discussion for their location. Read through some of the discussion with participants. Explain that this discussion is one way that weather forecasters work together to identify important weather data and create forecasts for an area.

Explain to participants that they will be using some of the products of the Advanced Weather Interactive Processing System (AWIPS), forecast maps generated by supercomputers through modeling, to create a forecast for their location. They will be working in groups and discussing weather data, just like meteorologists do (in the Area Forecast Discussion).

The maps provided in the kit are real data collected by the National Oceanic and Atmospheric Administration's National Weather Service. Use the maps provided in the kit, or to create maps specific to a certain time of year or area:

- Visit https://graphical.weather.gov/sectors/conus.php?element=T
- Choose your region (Go to Region above map)
- Once the chosen region loads, select the loops tab
- You can create maps for consecutive days by choosing each day from the Element Period drop-down menu (left of map).
- You can also select a Forecast Element other than Maximum Temperature from the drop-down menu above that.
- Within a region you can select a specific state by clicking on it in the image.
- You can print each map by selecting the print icon to the upper right of the map.

Montana High Temps (April 30-May 4, 2018)				
Monday	Tuesday	Wednesday	Thursday	Friday
				

Source: NOAA/National Weather Service: https://graphical.weather.gov/sectors/conus.php?element=T

Divide participants into small groups. Provide each group with a set of maps from your state (or, if you chose, sets from different western states with assigned locations). Ask participants to find the location of their town on each of the laminated maps and mark it using a wet erase marker. Now ask participants to carefully examine the weather maps at that location on each consecutive day. Can they use this information to create a weather forecast about how the temperature will change over the next few days? (The printed map data above comes from previous dates. Participants will be creating an example forecast using past weather data. By accessing more current maps, participants could create a forecast for upcoming dates.

Share

Write or give a weather forecast as if you are a meteorologist on television. Use the maps to show how temperatures will change over the week.

Process

As a group, discuss the experience of reading weather maps and creating forecasts. Where did the data for the weather map come from? Would these look the same for another week during the year? Discuss what the maps might look like during different seasons.

Now ask participants what information they got from the map that helped them create their forecast. Did everyone base their forecasts on the same thing? Would additional data have helped participants to create more accurate forecasts? Would working together provide more accurate forecasts? Explain to participants that the Area Forecast Discussion is a place where local meteorologists work together to interpret weather data and produce accurate forecasts.

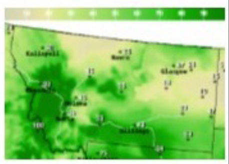
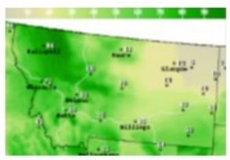
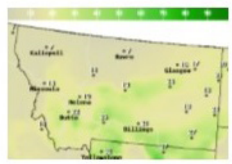
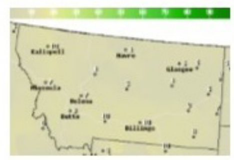
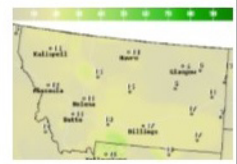
Other questions to think about:

- Do participants see any patterns between landforms and temperatures?
- Is there a possibility of any extreme events in this forecast?
- How far into the future is it possible to create an accurate forecast? Why?
- What might happen if we didn't have forecasts?
- Can you think of a time where the forecast allowed you to prepare for an extreme event?

Arrange the weather maps for all the states (MT, WY, CO and SD) so that participants can see the progression of the weather map for the entire region across the week (arrange all the Monday maps together, then all the Tuesday maps together, etc.). Can participants see any trends or patterns in how weather moves across the West? Do they see any trends or patterns related to landforms? Is it generally warmer or colder in one area or another? Why?

Apply

Now provide participants with another set of maps (perhaps probability of precipitation—you will need to find and print additional maps online at https://graphical.weather.gov/sectors/conus.php?element=T). Do they see evidence of any relationships between the two variables (for example, higher chance of precipitation where temperature is lower)?

Montana Probability of Precipitation (April 30-May 4, 2018)				
Monday	Tuesday	Wednesday	Thursday	Friday
				

Source: NOAA/National Weather Service: https://graphical.weather.gov/sectors/conus.php?element=T

More Challenges

- Continue to compare additional data for your state and look for relationships between variables.
- Use the current week's forecast data for your area for the above activity. Then check the accuracy of participant's predictions day-by-day through observing weather and/or compare to professional forecasts.
- Observe clouds in your area and connect cloud activity with forecasting.
- Ask participants to address the following questions:
  - Why do local forecasts only go out 10 days, or perhaps even seven days at certain times?
  - Why are aviation forecasts updated at a three-hour frequency but local weather forecasts are updated every six to 12 hours?
  - Why does a forecast update every 12 hours?
- Share with participants the list of information sources (see below) that inform participants about forecasting and introduce them to habits of looking at multiple sources.

Activity Resources

NOAA, National Weather Service: www.weather.gov

NOAA, National Weather Service: www.noaa.gov/stories/6-tools-our-meteorologists-use-to-forecast-weather

NOAA, National Weather Service: www.noaa.gov/stories/weather-prediction-its-math

NOAA, National Weather Service: https://graphical.weather.gov/sectors/conus.php?element=T

Weather and Climate Youth Learning Lab Online Resources:
www.msucommunitydevelopment.org/4Hweatherandclimate.html

Additional Resources

Doppler Radar: https://radar.weather.gov/index.htm
Find the Doppler Radar site nearest to where you live and see current Doppler Radar precipitation maps.

Geostationary Satellites: https://www.star.nesdis.noaa.gov/goes/
See current geostationary weather satellite data for the U.S. Western Region.

Geostationary Satellites: https://www.star.nesdis.noaa.gov/goes/
Find current geostationary weather satellite data for your state.

Geostationary Satellites: www.nesdis.noaa.gov/GOES-R-Spacecraft
Information about the GOES satellite.

Geostationary Satellites: www.goes-r.gov/
Information about the GOES satellite.

Deep Space Satellites: www.nesdis.noaa.gov/content/imagery-and-data
Interactive, real-time satellite images.

Preparing and Launching a Weather Balloon video, shows a weather balloon launch.
www.youtube.com/watch?time_continue=17&v=dLpyTodmfg8

Radiosondes/Weather Balloons: www.weather.gov/upperair/factsheet
Detailed information about radiosondes attached to weather balloons.

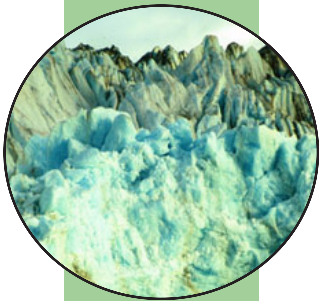
Create a Snowstorm: www.scied.ucar.edu/create-snowstorm
Snowstorm simulator—create weather conditions leading to a snowstorm (requires Flash).

Virtual Ballooning to Explore the Atmosphere: www.scied.ucar.edu/virtual-ballooning
Send a virtual weather balloon up through the atmosphere and collect data.

The Cloud Lab: www.pbs.org/wgbh/nova/labs/lab/cloud/
Learn to classify cloud types and look for different types of storms from satellite images.

Storm Evader: https://itunes.apple.com/us/app/storm-evader/id778806405?mt=8
A simulator app to re-route aircraft around real storm systems (IOS only).

Interpreting Satellite Imagery: http://cimss.ssec.wisc.edu/wxfest/SatImagery/index.html
Learn how to better understand satellite images.



Activity Five

CO_2, Greenhouse Impacts and Climate

As carbon dioxide (CO_2) increases in our atmosphere, how will temperatures respond? What do current CO_2 trends tell us about future climates?

Learning Outcomes

Participants will:

- Discover evidence for increasing CO_2 concentrations.
- Relate global atmospheric CO_2 data to local temperature records.
- Understand how the greenhouse effect works.

Content Skill: Model the greenhouse effect and CO_2 exchange.

Life Skill: Thinking

Educational Standards: 5-ESS2-1, 4-PS3-2; 1a, 2c, 2f, 4e, 5b

Success Indicator: Part I—ability to provide a basic explanation of the greenhouse effect; Part II—ability to provide basic explanation about what CO_2 is, where it comes from (natural and man-made sources), and role of plants in CO_2/Oxygen exchange.

Background

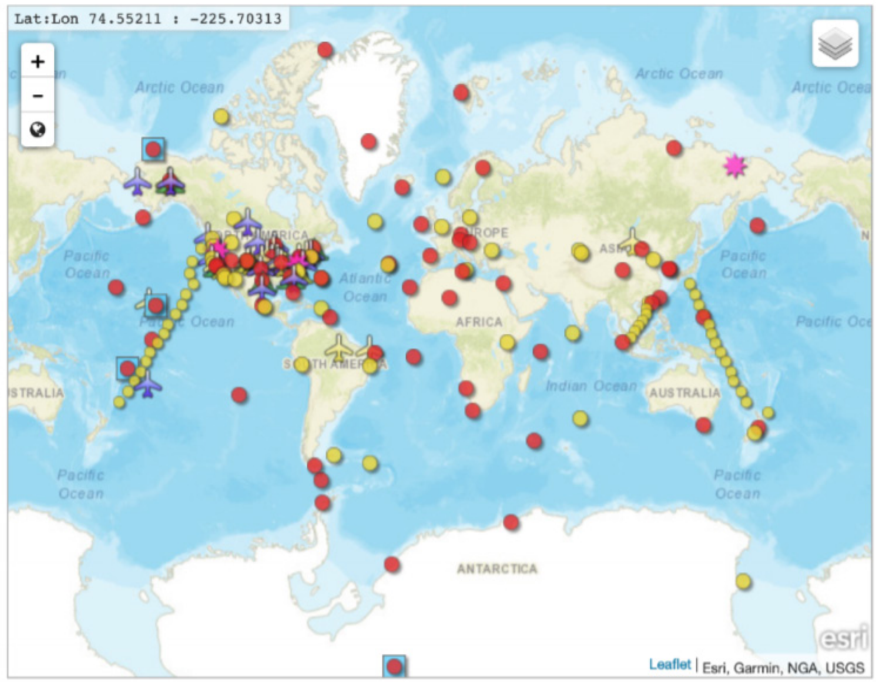
Participants should already have learned about weather data (Activity One) and about weather and climate patterns (Activity Two). Here, they will explore accurate, much-used sources of daily and yearly atmospheric CO_2 data from the past 50 years. In Part I, they will learn to find and access long-term local temperature records using web-based information including Google Earth and records which they can then use for comparison with CO_2 trends. With that background, in Part II, they will learn to conduct small, short-term CO_2-in-a-bottle experiments to confirm what they have observed about CO_2 and temperature in the real world. Experience gained in this activity will feed directly into Activity Six (Understanding Recent Climates Through Tree Rings), Activity Eight (Where Does the Carbon Go?) and Activity Nine (Weather and Climate Together: Now and in the Future).

CO_2 Data

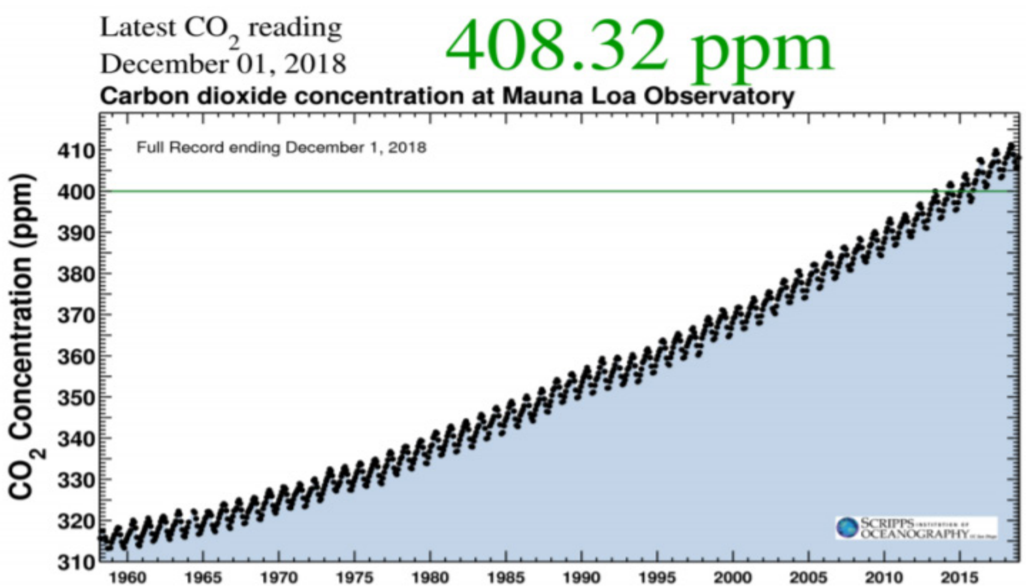
Researchers started systematic measurements of atmospheric CO_2 in 1958, more than 60 years ago. The first measurements came from Hawaii, at the Mauna Loa Observatory. Very soon, other countries added other CO_2 measurement sites at many locations; these measurements now extend around the world at reference sites, on measurement towers, and from ships and aircraft. The map image from the NOAA Earth System Research Laboratory shows locations of CO_2 collection sites around the world. Many of these local measurement sites also collect air samples in glass flasks to send to central laboratories such as at U.S. NOAA facilities in Boulder, Colorado, for careful analysis.

Photo:
Paul Bolstad,
University
of Minnesota,
Bugwood.org

Because the longest records of CO_2 come from the original measurement site on Mauna Loa, and because researchers world-wide now agree that Mauna Loa data represent a nearly-perfect one-site summary of global atmospheric CO_2 concentrations at any instant, the record of CO_2 concentrations measured at Mauna Loa now serve as one of the most important and much-used climate records on our planet. Participants can find hourly, daily, weekly, monthly, yearly, and 60-year records of atmospheric CO_2 at the website Daily CO_2 (www.co2.earth/daily-co2).



Source: NOAA Earth System Research Laboratory: www.esrl.noaa.gov/gmd/ccgg/ggrn.php

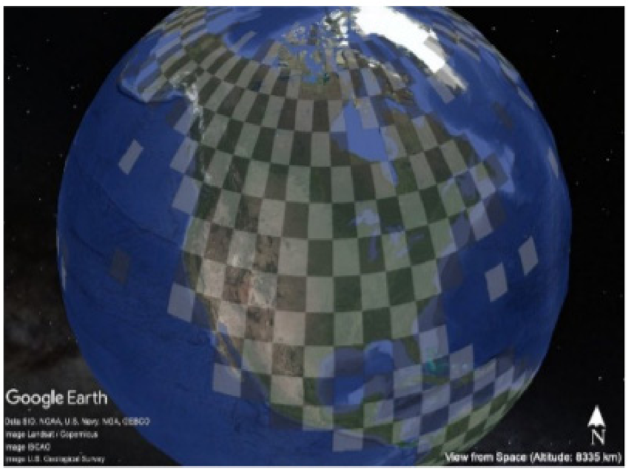


This image shows the entire history of recorded CO2 data from Mauna Loa, updated to early December 2018. Leaders can find the same record at Daily CO2, updated to the most recent day or two. Source: Daily CO2: https://www.co2.earth/daily-co2, used by permission from Scripps Institution of Oceanography at UC San Diego.

The image above demonstrates the steady rise of CO_2 concentrations in our global atmosphere. The overall trend of the graph shows that CO_2 concentrations have been increasing over the past 60 years. The smaller annual ups and downs are due to yearly growth of vegetation (which pulls some CO_2 from the atmosphere, called carbon uptake) and later decay of vegetation (which releases CO_2 into the atmosphere, called carbon release). Due to the predominance of land masses in the north and ocean in the south, this cyclical process occurs mostly in the northern hemisphere on a regular, annual basis. Underlying these small, seasonal patterns, the measurements clearly show the distinct uninterrupted increase of CO_2. From site comparisons, ocean-to-atmosphere and land-to-atmosphere comparisons, isotope measurements, comparisons to oxygen, and a variety of other chemical and modeling analyses, scientists know that the increase in atmospheric CO_2 comes from fossil fuels.

Recent Air Temperature Records at Land Sites

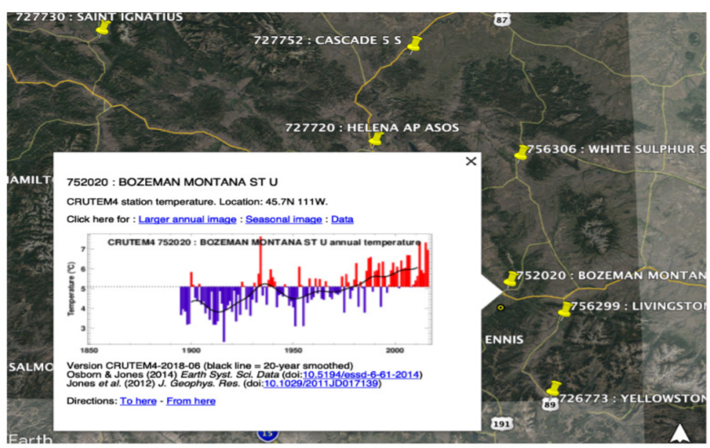
Researchers and private citizens, mostly in the service of national meteorological services, have measured air temperatures persistently and skillfully for, in many cases, more than 100 years. Once researchers correct these temperature records for instrument upgrades and site changes, the data can serve as a useful record of local climate. One of the best of these temperature data sets comes from the Climate Research Unit at the University of East Anglia in Norwich, England. That unit has made all their data, updated to the most recently available records every six months, publicly available through Google Earth.



Source: Map data ©2019 Google

The image on the above left shows the availability of these global temperature records on 5 degree by 5 degree (in latitude and longitude) boxes that cover all land masses on our planet. Each degree of latitude is approximately 69 miles (Leaders will find the most recent .kml file, updated every 6 months, at the link referenced in the materials list). By zooming in on any particular box, participants can find local stations included in the temperature record (as can be seen in the image on the above right) and, at any of those stations, the historical temperature data for that location. A click on the data "button" in any data window will allow the participant to view the actual data as displayed in easily-accessed and used formats.

This example, right, from Bozeman, Montana, which provides more than 100 years of annual data, clearly shows the recent temperature increase typical of the four-state region covered by these activities. Participants can and should explore other 5-by-5-degree boxes that include their homes, other nearby or distant stations, and—if they wish—similar and similarly-reliable data from other regions of the world.



Source: Map data ©2019 Google

With this information from the combination of open, free, and reliable public sources, participants can explore and confirm the persistent, widespread, upward rise of both atmospheric CO_2 concentrations and local air temperatures. Through exploration of these resources, participants gain the fundamental background knowledge necessary to learn about the greenhouse effect.

The Greenhouse Effect

In a glass greenhouse, the enclosure of air by transparent windows restricts exchange (mixing) with exterior, surrounding air while allowing visible sunlight to enter but preventing the heat energy from the sunlight from leaving. This restricted air exchange causes air in the interior of the greenhouse to warm. Exactly the same process can occur in a parked car exposed to sunlight. In the greenhouse example, the temperature rise may favor plant growth. In the parked car, the temperature often makes dark surfaces too hot for comfort. This is why people sometimes use folding windshield screens to shade car interiors.

Although not enclosed, CO_2 and other gases in our atmosphere produce a similar effect as glass in a greenhouse—they allow visible sunlight to pass through but capture returning heat from the earth, thereby warming the atmosphere. As occurs in greenhouses, natural atmospheric CO_2 provides a necessary and beneficial impact on planetary temperatures. Too much CO_2, however, introduced by human activities to levels above and—by now—beyond recent and even past concentration levels, causes global warming. Although this warming occurs more in some regions than others, more over land surfaces than over ocean surfaces, and often differentially between local nighttime and daytime, the fact that CO_2-induced planetary heating happens both quickly and globally causes great concern.

The most recent report of the UN Intergovernmental Panel on Climate Change (IPCC)—like all IPCC products initiated, reviewed and approved by national governments—issued in October 2018, confirmed that evidence for human impact on climate, through the greenhouse impact of CO_2, grew stronger than ever. The IPCC has reported this CO_2-based influence consistently and with high degree of certainty for nearly 20 years. The official *2018 National Climate Assessment* of the USA also confirms this human impact in no uncertain terms; "evidence consistently points to human activities, especially emissions of greenhouse or heat-trapping gases, as the dominant cause" of global temperature increases.

Time Needed: 1 hour (Walk-up Event option provided)

Materials

PART I

- Google Earth software or app (download at www.google.com/earth/versions/)
- Google Maps .kml file (CRUTEM4-2018-06_gridboxes.kml) from https://crudata.uea.ac.uk/cru/data/crutem/ge/. Use a more recent .kml file from the same website if available
- Laminated example CO_2 data
- Laminated example temperature data for MT, WY, CO and SD
- Wet erase markers (10, included in Activity One)

PART II

- Pencils (12, included in Activity Two)
- Effervescent tablets (3 tablets) or baking soda
- Clear 2-liter bottles (2)
- Bottle labels
- Stoppers with hole in the center (2)
- Digital probe thermometers (2)
- Heat lamp (1)
- Timer (1)
- Graphing boards (10, included in Activity Two)
- Dry erase markers (10, included in Activity Two)
- Notebooks (not included)
- Water

What To Do

Walk-Up Event

Prior to the event:

- Set up and label bottles with and without CO_2, place bottles the same distance from the light, record start time and initial temperatures, and turn on light so that it is shining on the bottles.

During the event:

- If a computer is available, explore and compare CO_2 data from the Daily CO_2 website with temperature records from Climate Research Unit on Google Earth, as described in Part I below.
- Have participants monitor and compare temperatures in each bottle.

PART I: Global CO_2 Data Compared to Local Temperature Data

Prior to the activity, view (and download if appropriate) the most recent image(s) for CO_2 data at the Daily CO_2 website, choosing "Record since 1958." Using the .kml file and Google Earth, view (and download if appropriate) the most recent image(s) or data for air temperature for a location nearest your present location. View or download data from neighboring or more distant locations for comparison. The CO_2 reading from December 2018 and temperature data from one site in each state has been provided in the kit, but you may access more current information if possible. Feel free to add local temperature data and more recent CO_2 data to the kit.

Experience

Divide the group in two. Explain to participants that each group is going to look at a graph of real data and then share what they notice. Explain that each graph has lots of information, and there will be a focus on specific parts.

Give one group the global CO2 data. Explain to this group that the air around the planet is a mixture of gases and that CO2 is one of the gases. Explain that this gas has been accurately measured since 1958 at this location in Hawaii. Ask participants to focus on the line. What do they notice?

Give the other group the temperature graph for their location (and if possible, show them how it was accessed on Google Earth). Explain that this graph shows annual average temperatures recorded each year for their location. Explain that this is the average temperature for the whole year, not the temperature on any given day as the participants measured in Activity One. Ask participants to focus on the line (a trend line). What do they notice? Give both groups some time to explore and discuss their graphs.

Share

Bring the groups back together. Start with the temperature group. Ask them to share with everyone:

- What does the graph show? (An average temperature for each year since whenever records began.)
- What did you notice about the trend line? (It goes up.)
- What does the trend line on this graph show? (Average annual temperature has increased over time in the location).

Next, ask participants from the CO_2 group:

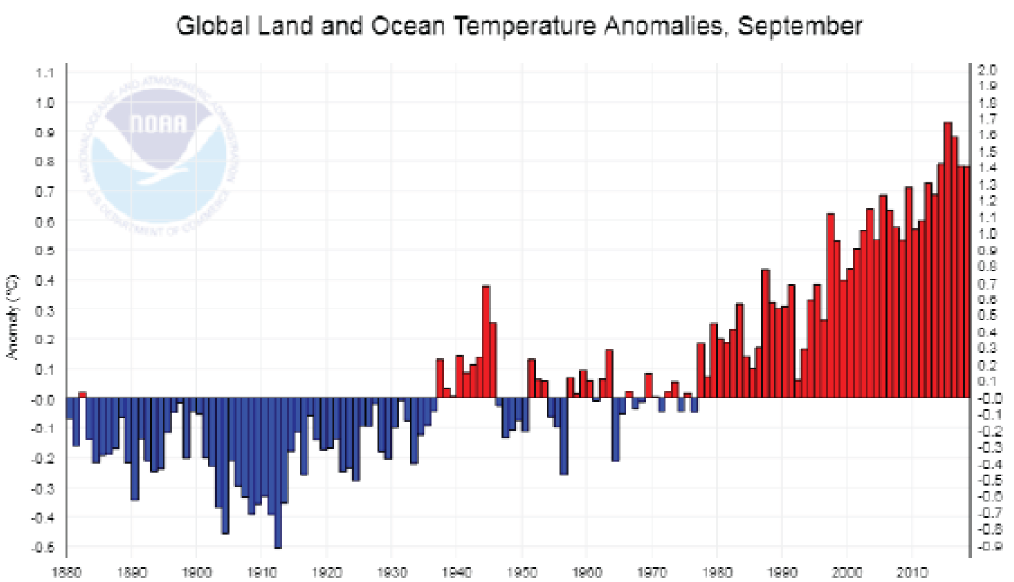
- What does the graph show? (How the amount of CO_2 in the atmosphere changes over the years.)
- What did you notice about the trend line? (It goes up and down a little each year but generally goes up.)
- What does the trend line on this graph show? (CO_2 has increased over time globally.)

Process

Facilitate a discussion with all participants comparing the data on the two graphs. What is the same? (Both temperature and CO_2 increase over time.) What is different? (The graphs may show two different time scales, but the time scales overlap.) What conclusions can participants draw from this comparison? (Temperature and CO_2 have both increased over time in their location.) Is this true in other locations, too?

Generalize

Show participants temperature graphs for other locations (use the graphs for the other states included in the kit or use Google Earth). Are the trends the same? Ask participants, what kind of generalizations can be made about temperature over time in your state or region? (In general,



Source: https://www.ncdc.noaa.gov/cag/global/time-series temperatures across these states and the region have increased over time.) Ask participants, does this trend extend beyond Montana, Colorado, Wyoming, and South Dakota? (Yes, global temperatures have increased over time and show a similar trend.)

Apply

Facilitate a discussion around the connection between rising CO_2 levels and increasing temperatures. Can they identify any relationships between CO_2 in the atmosphere and temperature? How might one affect the other? At this point, participants should discuss connections based on trends.

They will explore these connections further in Part II.

In transition to Part II of this activity, ask participants if they have heard of the phrase "the greenhouse effect"? Many participants will likely have heard of this but won't necessarily understand it. Ask participants if they have ever been inside a greenhouse. What is it like inside? (It is generally warmer than outside.) Explain to participants that Part II of this activity will focus on what is called "the greenhouse effect."

PART II: CO_2 and the Greenhouse Effect

Participants will now focus on how CO_2 in the atmosphere can act like a greenhouse to cause air temperatures to rise. In this part of the activity, participants will create a model to compare how air containing extra CO_2 and air that does not contain extra CO_2 change temperature when exposed to heat energy. For information on this CO_2 in a bottle demonstration, go to www.youtube.com/watch?v=kwtt51gvaJQ

To set up the experiment prior to the arrival of the participants:

- Place the two plastic bottles on a table or flat surface.
- Fill each bottle halfway with water. Add the provided "treatment (additional CO_2)" and "control (without additional CO_2)" labels next to the appropriate bottle.
- Prepare the stoppers and thermometers by inserting a thermometer through the center hole in each stopper such that the base of the thermometer will remain above the water. Turn the thermometers on.
- Set up the lamp about 2 feet away from the bottles and adjust it so that the light will shine directly and equally on both bottles.
- Set the timer for one hour, but do not start it yet.

Experience

Start Part II with a discussion of the greenhouse effect. Ask participants what they think it is. Explain that the greenhouse effect has to do with Earth's atmosphere. Explain that, as participants observed in Part I, CO_2 levels in the atmosphere are rising (show participants the CO_2 data again).

Explain to participants that they will be observing and comparing a model of Earth's atmosphere with increasing amounts of CO_2, to a control without additional CO_2 to see how the amount of CO_2 in the air affects temperature. Explain the set up to participants and that one bottle contains effervescent tablets that release CO_2 gas when they are added to water (in other words, one bottle will have additional CO_2 and the other will not).

Make sure participants have their science notebooks and pencils ready. Assign participants tasks to participate in starting the experiment.

- Place 3 effervescent tablets in the bottle labeled "additional CO_2." The other bottle has no additions, just water.
- Immediately place the stoppers with thermometers (make sure they are on) in the bottles. Turn on the light and start the timer.
- Participants should immediately record the initial temperatures inside each bottle.
- Participants can record the temperature of each bottle every 5 to 15 minutes.
- If possible, let the experiment run for an hour.

Share

After participants have taken several readings, have them analyze and discuss the data they have collected. As a group or independently (using graphing boards and dry erase markers) create a temperature vs. time graph for each bottle.

Process

Discuss the following questions using the data collected.

- What happened to the temperature in each bottle when the light was shining on them? (Both increased.)
- Was it the same for both bottles? (No, the one with CO_2 increased more.)
- How were they the same? (The heat from the lamp made the air in both bottles warmer.)
- How were they different? (The only difference between the two bottles was the mixture of gas inside.)

Generalize and Apply

Facilitate a discussion where participants think about what parts of the experiment represent what aspects of the real world. Ask participants, what does each piece of the model represent? (The gases inside each bottle represent gases in Earth's atmosphere. One bottle represents the atmosphere with additional CO_2. The light from the lamp represents the sun's energy.) How does this experiment model the greenhouse effect? Ask participants to explain how the activity models how the greenhouse effect is causing air temperatures to rise. (Each bottle represents what the Earth's atmosphere is like with different mixtures of gases, one with additional CO_2. The heat energy from the lamp enters the bottles and raises the temperature of the gases inside.)

What kind of conclusions can be drawn from this experiment? (Air with additional CO_2 gets warmer than air without additional CO_2.) How does increasing the amount of CO_2 in Earth's atmosphere act like a greenhouse? (CO_2 gases in the atmosphere trap heat just like the glass surrounding a greenhouse. The air inside this layer of gas heats up.) Does it make sense that we call this process "the greenhouse effect"?

For participants who have a good grasp of the activity, ask them to discuss strengths and weaknesses of this simple experiment. Possible strengths include that there is only one variable (CO_2) to measure; that it is relatively easy to measure temperature with a thermometer; and that it is a relatively fast response. Possible weaknesses include that we don't know the actual CO_2 concentration in the bottles; that one bottle might have heated more than the other; and that we couldn't measure other variables like the initial water temperatures or air humidity. What might we do to improve our results or outcomes? Other questions for participants to think about include: Do the temperatures in the experiment, initially or as they changed, seem realistic compared to outdoor temperatures in your location? What would have happened if we did this experiment in the dark?

Activity Resources

CO_2 in a bottle demonstration: www.youtube.com/watch?v=kwtt51gvaJQ

Daily CO2: www.co2.earth/daily-co2

Google Earth software or app: www.google.com/earth/versions/

University of East Anglia, Climatic Research Unit: https://crudata.uea.ac.uk/cru/data/crutem/ge/ and download most recent Google Maps .kml file, for example CRUTEM4-2018-06_gridboxes.kml

Additional Resources

U.S. National Oceanic and Atmospheric Administration: https://www.ncdc.noaa.gov/cag/global/time-series

2018 National Climate Assessment: https://nca2018.globalchange.gov/chapter/2/

U.S. National Oceanic and Atmospheric Administration Earth System Resource Laboratory: www.esrl.noaa.gov/gmd/ccgg/ggrn.php

Activity Six

Understanding Recent Climates Through Tree Rings

How can trees keep a record of changing climate?

Adapted with permission from *4-H Science Toolkit: Climate, Temperature Through Time Activity* from Cornell Cooperative Extension. Activities created by NYS 4-H and Cornell's Paleontological Research Institution (PRI).

Learning Outcomes

Participants will:

- Observe tree cookies from tree specimens.
- Analyze tree rings to interpret climate information.

Content Skill: Observe tree rings and interpret past climate history.

Life Skill: Thinking

Educational Standards: 3-LS3-2, 3-LS4-3, 3-LS4-4, 3-ESS2-2, 4-LS1-1, 5-LS1-1, 5-ESS2-1, 5-ESS3-1; 3a, 3c, 4c, 5b,

Success Indicator: Successful creation of a tree ring timeline with wet and dry years indicated.

Background

All over the planet, organisms react to changing temperature and precipitation. From an organism's habitat, one can infer what type of climate, what consistent temperatures, and how much or how little precipitation the organism can tolerate. With that knowledge, we can infer things about temperature and precipitation from long before there were accurate thermometers or precipitation measurement gauges. We can use the organisms themselves, to help figure out the temperature and precipitation patterns of regions all over the planet for hundreds of years.

The thickness of tree growth rings tells us about the environment that a tree was growing in. If another tree starts growing 50 years after the first tree, and the second tree continues to grow for 50 years after the first tree has died, the years that both trees were alive at the same time will have the same tree rings. This is because they lived under the same environmental conditions. By finding multiple trees of different ages, we can "paste" tree growth ring records together by matching up the parts of the tree rings that were alive at the same time. Each series of years has its own unique signature, and when trees are alive during the same time period, their signatures are the same. Some environmental conditions that can be inferred from tree rings include moisture, temperature, precipitation, and even gas composition of the atmosphere. Most researchers now accept that tree rings record some combination of temperature and precipitation and that sometimes trees are more influenced by temperature in one location and more influenced by precipitation in a different region. For the four-state region, tree rings record precipitation as well as temperature. There can be some uncertainty in the mixed recording of data.

Trees can live a long time. There are some redwood trees in the U.S. that are nearly 2000 years old. Preservation of a dead tree depends on lack of oxygen (for example, under water). Paleontologists or paleoclimatologists who look at tree rings often study living trees and the narrow horizontal cores that can be obtained without hurting the tree, and not the full cross sections like those shown in this activity. When you look at the rings of trees

Photo:
Deborah Albin

alive since 1850, the width of the ring can be calibrated to the accurately recorded temperature and precipitation conditions of the year. Then, the older rings of live trees and those of dead trees can be used as proxies of temperature and precipitation for those years before we had accurate temperature records. In the case of the redwoods, we could get a temperature/precipitation record of the narrow coastal strip of northern California for almost 2000 years! The limited area would also provide a good example of a microclimate.

Time Needed: 1 hour (Walk-up Event option included)

Materials

- Laminated tree cookie images (10)
- Pencils (12, included in Activity Two)
- Paper (not included)

Getting Ready

Gather all the materials for the activity.

Walk-Up Event

Prior to the event:

- Get out the laminated tree cookie images. A tree cookie is a cross section of a tree trunk, used to study the growth rings of a tree.

During the event:

- Let participants observe the tree cookies and attempt to analyze how climate changed based on observations.

What to Do

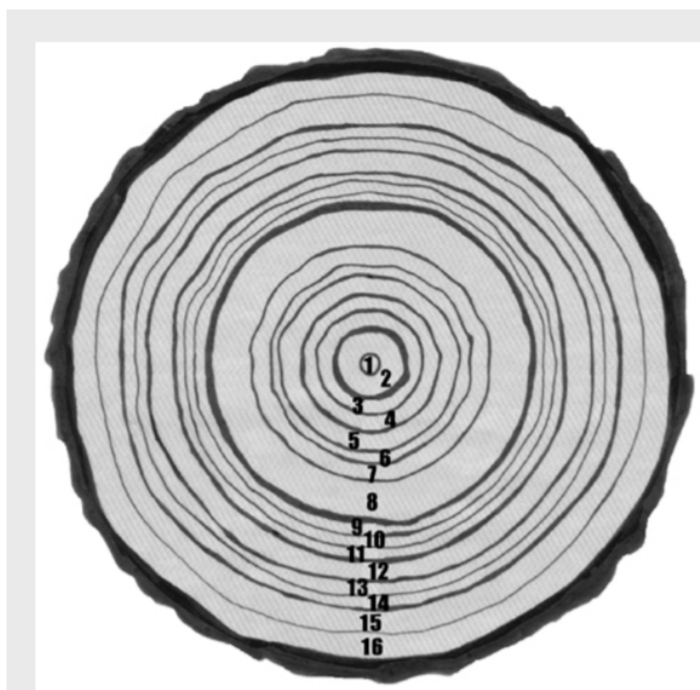
Experience

In this activity, participants will learn a little about how to read tree rings from a tree cookie like the one you see pictured. First, participants learn how to read the tree rings. As a group, observe the tree cookies. What do you notice? Do you see rings? How many are there? What does each ring represent? Are all the rings the same? How are they different?

Share and Process

As a group, discuss the following questions:

- What can tree rings tell us about the weather the tree lived through?
- What else can tree rings tell us other than information about weather and the age of the tree?
- What would wider rings signify?
- What would narrow rings signify?



Source: *4-H Science Toolkit: Climate, Temperature Through Time Activity*

Activity Six: Understanding Recent Climates Through Tree Rings

- In what year of growth was there the least rainfall?
- In what year of growth was there the most rainfall?
- Find the ring that grew the year you were born. Was it a wet or dry year? How do you know?

Generalize and Apply

Now participants will use the tree cookie to make a timeline that helps us understand how climate has changed over time. Take a sheet of paper and lay it carefully across half of the tree cookie so that the corner of the paper points into the center circle (see diagram). Then, with a pencil, start in the center and work to the right, placing a small tick mark along the edge of the paper where each tree ring stops. The first marks will indicate the year the tree started to grow (center ring). Each mark to the right indicates one year of growth. Which years were wet? Which years were dry? Do you see any indications of other events based on your tree cookie (for example, a burned area that indicates forest fire)?

Source:
4-H Science Toolkit: Climate, Temperature Through Time Activity

If you have additional time, find tree rings from two different trees growing in the same area. Do you see any patterns in the rings? Look at actual weather data for the area where trees grew and compare precipitation data for different years as they relate to the size of the rings.

Additional Resources

Anatomy of a Tree: www.arborday.org/trees/RingsTreeNatomy.cfm
Learn more about tree rings and how trees grow.

Tree Rings Simulation-Dendrochronology: www.scied.ucar.edu/tree-ring-interactive
Interactive tree ring game.

Activity Seven

Oceans, Ice and Modeling Climate

Understanding climate now and into the future requires understanding the roles of oceans and ice.

Learning Outcomes

Participants will:

- Discover how oceans "work."
- Explore differences between "bright" snow and ice and "dark" land.
- Understand basic processes of predicting future climate.

Content Skill: Understand how oceans and ice impact climate models.

Life Skill: Thinking

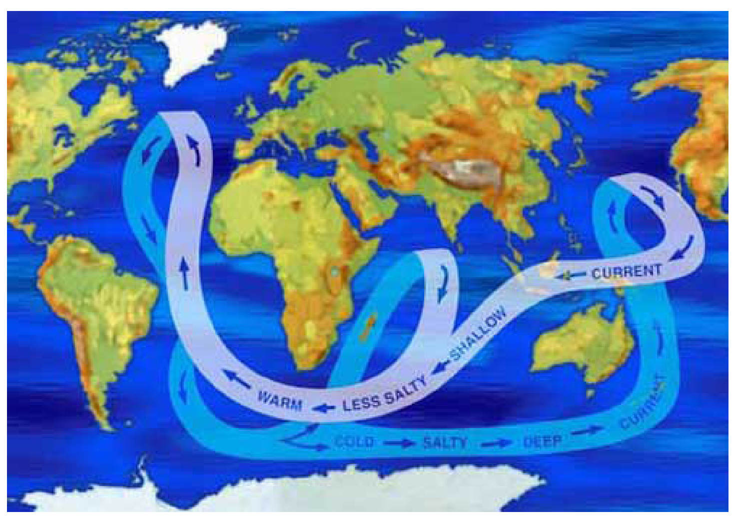
Educational Standards: 4-PS3-2, 4-ESS3-1, 5-PS1-2, 5-LS2-1, 5-ESS2-1; 1a, 2a, 2b, 2c, 2d, 2f, 5a, 5b, 5c, 6b, 6c

Success Indicator: Successful understanding and identification of patterns from experiments and models.

Background

Participants will have learned about weather forecasts in Activity Four. Those weather forecasts involve models of the atmosphere initiated with and guided by data including air temperature and wind as measured in Activity One. To predict climate, we need an atmospheric model coupled with similar models of ocean and ice. These coupled models become much more complicated (and expensive) but predicting future climate requires that we know how the ocean takes up and distributes heat and how snow and ice reflect sunlight back to space. Climate modeling also requires that we understand where carbon dioxide comes from and where it goes; participants will have learned why we focus on CO_2 and how to find recent CO_2 data in Activity Five. Experience gained in this activity will lead directly into Activity Eight (Where Does the Carbon Go?) and Activity Nine (Weather and Climate Together, Now and in the Future).

Oceans and Climate

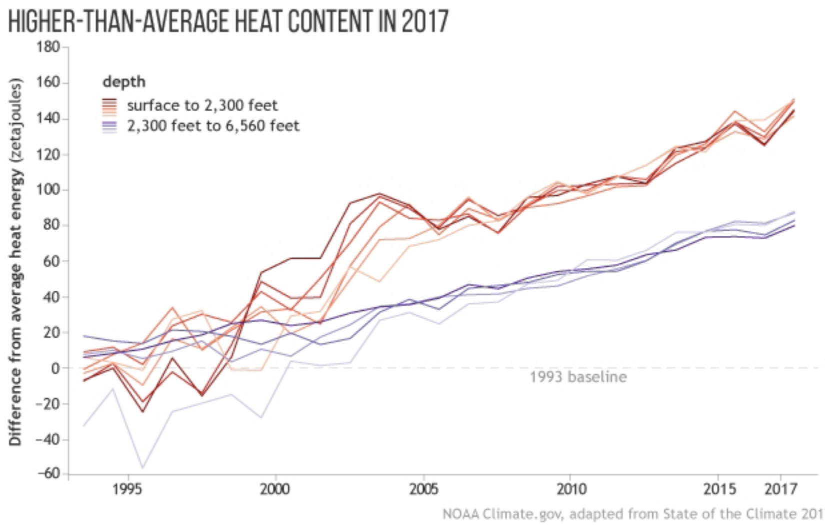


Source: NASA: htpps://climatekids.nasa.gov/ocean/

Compared to the atmosphere, the oceans represent a huge reservoir (storage) for heat, water and carbon. More than 90% of the excess heat so far produced by rising atmospheric CO_2 concentrations has gone into the oceans. The oceans not only store heat, they move it from warm regions to cold regions and vice versa by steady surface and deep currents. The surface currents are driven mostly by wind while deep currents are driven by density; denser water sinks. Very cold, very salty waters sink and flow below warmer and fresher (less salty) waters; this process is known as the Great Ocean Conveyor Belt (see NASA image, above).

Photo: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org

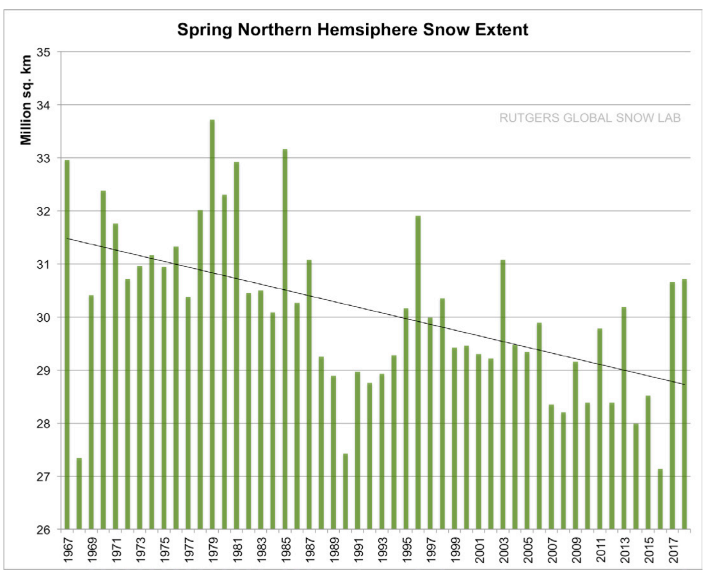
This oceanic transport of heat around the planet can take tens to hundreds of years but is responsible for distributing heat to keep our planet habitable. Changes to temperature or salinity of the oceans lead to substantial long-term consequences. Over the past few decades, the oceans have absorbed massive amounts of heat. The graph on the right shows the steady increases of ocean temperature at all depths compared to 1993.



Source: https://www.climate.gov/news-features/featured-images/2017-state-climate-ocean-heat-content

Ice and Climate

In the most basic terms, a warmer planet means less snow and ice. Because warmer air holds more moisture, the atmosphere of a warmer planet will have more overall moisture, leading to more precipitation. That precipitation will more often fall as rain and less often as snow (again, because the planet is warmer). Because many regions of our planet, including our own four states, rely on winter snow in nearby or distant mountains to meet a substantial part of yearly water needs, changes to snow pack or glaciers (snow compressed to ice that persists for multiple years) can have dramatic impacts on agriculture and industry.

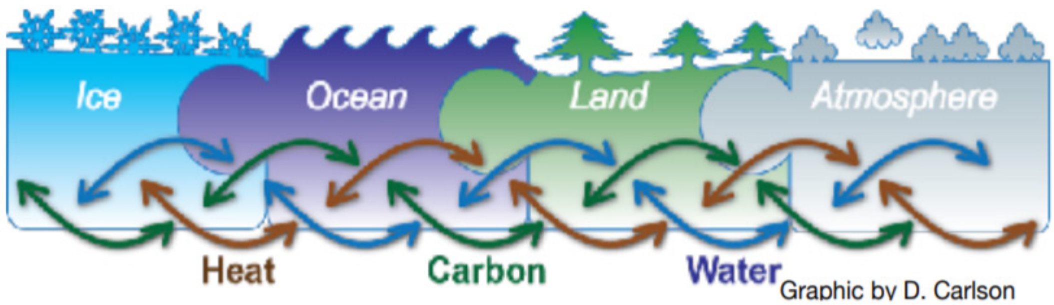


Source: https://climate.rutgers.edu/snowcover/chart_seasonal.php?ui_set=nhland&ui_season=2

Snow and ice have a second, equally-important climate impact. When present, snow and ice crystals form a very bright surface that reflects a large fraction of incoming sunlight back to space. Disappearance of snow and ice changes these reflection processes; loss of snow cover over land exposes the darker land and loss of sea ice exposes the darker ocean. Darker land and ocean surfaces absorb more sunlight energy, which causes more local heating, which in turn reduces snow and ice coverage even further. This creates what is called a "negative feedback loop"—the reduction of snow and ice causes changes that result in further snow and ice reductions. This is often referred to as an albedo feedback (albedo means reflectivity) and can have significant consequences in high latitude regions. Although the loss of Arctic sea ice often makes the news, the loss of snow cover area in the northern hemisphere, most often due to less mid-winter snow coverage and earlier melt-induced disappearance in the spring, in many years exceeds the area of sea ice disappearance (see image, above). For our region, loss of snow cover means substantial changes in both reflectivity and in water storage.

Building Climate Models

Climate prediction models and weather forecast models both involve complex equations and require massive super-computers. Even a short-term weather forecast relies on detailed computer models. Recall from Activity Four that weather forecast models typically start from yesterday's weather, add as many fresh observations as possible from today, and produce a forecast (most often at 12-hour intervals) relevant tomorrow and extending out for five to seven (occasionally 10) days into the future. Weather forecasters can validate yesterday's model output by observing today's weather. Climate prediction models face a different set of challenges. Models must reliably show the interactions of heat, carbon and water across ice, ocean, land and atmosphere (see image below). Once started, because they factor decades or centuries into the future, they gain no additional information; they cannot benefit from fresh observations incoming over the past 24 hours. They must accurately represent connections and exchanges.



To validate their predictions, climate modelers tend to use historical models to show how their models reproduce the recorded climate observations of the 20th century. Again, however, once started, climate models run without regular injections of fresh observations. If they start in 1950 for a 50-year run to year 2000, they must run uninterrupted without external data inputs from 1959, 1972, etc. For climate predictions, these models typically start with a pre-defined CO_2 increase pattern which they then follow throughout their runs; often this external carbon input represents the only mass or energy change imposed or allowed. A full, complex climate model with clouds, land vegetation, ocean mixing, and sea ice, running with global spatial resolution of perhaps 25 km (16 miles) at half-hourly time steps can require an hour or more of high-speed computing to output a year of climate predictions; to predict a full century ahead can require hours to days of computing time. In other words, these models involve an incredible number of factors and highly complex calculations.

Participants who grasp how these models work can perhaps appreciate the challenge in these terms: to calculate at nearly 2 million time steps (roughly the number of half-hours in a century), all physical, biological, and chemical parameters (more than 100 at a minimum) one needs to track carbon at every one of more than 200,000 grid points (approximate, for 25 km) at 15 or more levels in the atmosphere and 20 levels in the oceans, without errors in water or heat. These numbers represent an oversimplification of climate model operations, but they highlight for leaders and participants the fact that computing efficiency goes side-by-side with scientific accuracy in developing better climate models. Most global modeling centers save only daily or, more often, monthly averages to facilitate exchange, research, and inter-comparisons; full parameter, full resolution files with all time steps recorded become too large for most users to download, open or process. For exactly these reasons, this activity focuses on a "very, very simple" climate model.

Time Needed: 1 hour (Walk-Up Event option provided; Part III requires participants to use or view a computer screen and to use a keyboard.)

Materials

PART I

- 1 liter beakers (2)
- Food coloring
- Golf balls (2)
- Spoon (not included)
- Water
- 2/3 cup non-iodized salt (not included)

PART II

- Notebooks (not included)
- Light meter (1)
- Infrared thermometer (3, included in Activity Two)
- If conducting activity indoors: squares of white and black poster board (4)
- If conducting activity outdoors: snow-covered and adjacent cleared (soil or pavement) surfaces
- Optional: squares of reflective and non-reflective surfaces (for example, aluminum foil, dark cloth or carpet, etc.)

PART III

- Notebooks
- Online access to www.scied.ucar.edu/simple-climate-model. (The leader should test this link.)
- Laminated instructions for *Very, Very Simple Climate Model*
- Laminated example climate model graphs (3)

What To Do

Walk-Up Event

Prior to the event:

In three separate stations along a table, set up the following:

- The demonstration described in Part I so that one golf ball is suspended between two layers of different density in one beaker (see YouTube video link below).
- The black and white poster board, infrared thermometers, and light meter.
- Laminated copies of example graphs from the *Very, Very Simple Climate Model* included in Learning Lab (if possible, also include a device or laptop with the *Very, Very Simple Climate Model* loaded).

During the event:

- Show participants the density demonstration. Ask them why they think the golf ball floats where it does. Discuss density differences between salt and fresh water here and in the ocean.
- Encourage participants to predict and then explore the differences in reflectivity and temperature between the black and white poster board using the light meter and temperature guns, respectively. Ask participants if they see differences and discuss why those might occur. Discuss albedo, negative feedback loops and what impacts this might have in the real world.
- Show participants the graphs. Ask them if they can identify any differences (the gigatons of carbon, or GtC, levels). Discuss the implications of the changing GtC levels, as well as how these values reflect real world values. If possible, allow participants to explore the *Very, Very Simple Climate Model* online.

Part I: Ocean Currents

Participants explore how salinity affects the density of water. A golf ball sinks in fresh water but floats in very salty water.

Prior to the set-up, leaders may want to view a YouTube demo at www.youtube.com/watch?v=bp7-xYG1D6s&feature=youtu.be to see how the activity is set up. Before participants arrive, set up the following:

1. Add 700 ml of water into each beaker.
2. Dissolve the 2/3 cup of non-iodized salt (iodine makes the water cloudy) into one of the 1-liter beakers of water. Stir until completely dissolved.

Experience

Gather participants so that all can see both beakers of water. Do not tell participants that the water is different in each beaker. Challenge a participant to see if he/she can float a golf ball in the beaker containing fresh water. Tell participants it takes a soft touch and that few people "have what it takes." As the leader, you should then place the other golf ball in the salty water. It will float. Participants should deduce that something is different between the two beakers. Eventually they will ask to try the water that you used. Now that you've got their attention, explain the relationship between salinity and density. (Salt makes the water denser, therefore, things—including humans—float more easily. Participants may already know that they float more easily in the ocean than in a pond or pool filled with fresh water. For young participants, explain that salty water sinks and fresh water floats on top of salty water.)

Now remove both golf balls. Add several drops of food coloring to the beaker of fresh water. Using the spoon to cushion the stream, slowly pour some of the colored fresh water into the beaker containing salty water (see YouTube demo referenced above). Since it is less dense, the fresh water should float on the salty water.

Before adding the golf ball, ask participants to predict what they think will happen when it is placed in the beaker. Will it sink? Will it float? If it floats, where will it float? They can write their prediction and the reason for it in their science notebooks. Gently place a golf ball into the beaker near the boundary between the two layers. It should float near that boundary for several days if left undisturbed.

Share

Facilitate a discussion with the participants about the demo they just saw. Ask them:
Before the addition of food color, could you distinguish salty water from fresh water? If not visually, how could you have predicted in which beaker the ball would float? (Taste.) Was the prediction you made about where the ball would float correct? Why did the ball float where it did?

Process

Now ask participants to think about how this demo relates to the real world. Ask them, have you ever gone swimming in ocean? Have you ever gone swimming in a lake? Could you float more easily in one than in the other? Why?

Generalize

Now think about how this concept—salty water sinking and fresh water floating on top of it—applies in the ocean. We know ocean water is salty. In this experiment we increased density by adding salt. Are there ways that ocean water can become more salty? (By removing fresh water by evaporation or by ice formation; both leave salt behind.) If some ocean water becomes more salty, what will happen to it? (It will sink, just like we saw in the demo.)

Apply

If participants have grasped the concepts presented so far, add in the factor of temperature. In this experiment the water in both beakers was approximately the same temperature.

- What would happen if you cooled the salt water beaker? Water would become more dense as the water cooled (salt content remains basically constant so long as the water does not freeze or evaporate). If you cooled the water to the freezing point, freezing processes would preferentially incorporate fresh water into the ice, leaving salt behind in the liquid. In polar oceans, sea ice formation (freezing) leaves behind saltier seawater.
- What would happen if you warmed the fresh water beaker? Fresh water gets less dense as temperature rises (up to the boiling point).
- What would happen if you cooled the fresh water? Fresh water will get more dense as it cools, until it freezes (note that ice floats).
- What would happen if you warmed the salt water? Salt water will get less dense as it warms (salt content will not change unless one gets substantial evaporation).

Ask participants to think critically about the following questions:

- If ocean saltwater is cold enough to freeze, so that the ice is composed of relatively fresh water, will the remaining ocean water sink or rise? (Sink, because very cold, very salty, very dense water sinks. It forms "ocean bottom water.")
- Where on our planet would these processes of cooling and freezing occur? (Closer to the poles.)

PART II: Snow and Ice Reflectivity Compared to Darker Surfaces

Participants explore the brightness (reflectivity) of snow (light) and land (dark) surfaces.

Experience

Ask participants which they would prefer to wear on a hot sunny day—a black t-shirt or a white t-shirt? Why? Some participants may know that they will be hotter in a black t-shirt than a white t-shirt but may not know why. Explain to participants that this phenomenon has to do with how dark and light surfaces reflect sunlight or absorb heat. To learn more, participants will conduct an experiment. They will measure and compare how much light is reflected from dark and light surfaces, as well as how much heat each absorbs. Show participants the black and white squares of poster board. Ask them to make a prediction in their science notebooks about two things:

- Which square (black or white) will reflect more light?
- Which square (black or white) will absorb more heat (become warmer)?

Show participants the light meter and explain that it measures reflected light. Show them how to use it. Then show participants the infrared thermometer and how to use it. Participants can practice using both the light meter and infrared thermometer by pointing them at a light source (lamp, sky) and then at a dark area (deep shadow, bottom of a bin, etc.). Develop the idea that the light meter measures visible light while the infrared thermometer measures heat.

Set the black and white poster board squares in an area with comparable lighting conditions (or, ideally, use snow-covered and nearby bare ground outside). Explain that participants need to take their measurements for each at about the same distance away. Discuss the value of a controlled experiment. Depending on the sensor, they may wish to do multiple trials for each surface. Participants should record their measurements in their science notebooks.

If possible, let participants experiment with a variety of other materials and factors (for example, clear sky, cloudy sky, lights on, lights off, rough, or smooth surfaces). Discuss their findings.

Share and Process

Facilitate a discussion with participants. What did they observe? Was the prediction about which color would reflect more light correct? Was the prediction about which color would absorb more heat correct? Did you get the same measurement each time for each surface and each condition? Why or why not? Did measurements provide evidence for why a person might prefer to wear a white shirt instead of a black one on a hot, sunny day? Explain. In what other areas of life do you experience this issue? (For example, car exterior/interior colors.)

Generalize and Apply

Why does this matter? Ask participants to think about ways this idea—albedo—might affect the planet. Ask them to consider the transitions from bright to dark surfaces in the outside world, such as the melting of snow to expose bare ground or the melting of sea ice to expose open ocean; what do they predict for heating effects as a result? Facilitate a discussion about how snow and ice reflect sunlight, while darker surfaces, such as exposed ground and open ocean absorb more heat. What might be the consequences of melting snow or ice? (See Background for explanation.)

PART III: Climate Models

Participants interact with a simple climate model that allows them to predict future global air temperatures in response to various CO_2 emission scenarios.

Experience

Prior to participants arriving, access the online climate model at www.scied.ucar.edu/simple-climate-model. To set up the climate model for use in this activity start by clicking on and reading the "Instructions" tab (also included in Learning Lab).

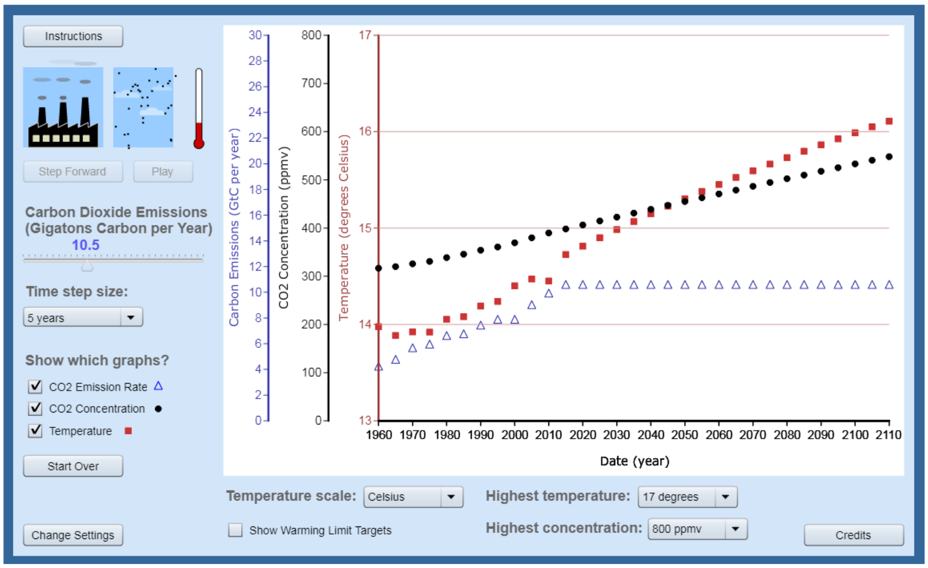
Remind participants what they learned about in Activity Five, Part II – that air containing increased CO_2 heats up more than air that does not contain extra CO_2. Explain that, in this activity, they will be looking at how computer models can be used to predict how the concentration of CO_2 in the atmosphere might change and how that might affect air temperatures.

When you are ready, show participants the model. Explain that the model on the graph will show three things: CO_2 emissions, CO_2 concentrations in the atmosphere, and temperature. Show participants how these are represented on the graph (triangles = CO_2 emissions, black circles= CO_2 concentration, and red circles = temperature). Discuss with participants how they think these things might be related.

Explain that the group will place varying CO_2 emission values into the model. Explain that the CO_2 emissions amount is the only number that the group will change. The model will then help them see how different CO_2 emissions amounts will change the CO_2 concentration of the air and temperature. Explain that for first time, you will use a CO_2 emissions value of 10.5 (the default). The graph they create using this value will be used for comparison with the other graphs they create.

Control Graph

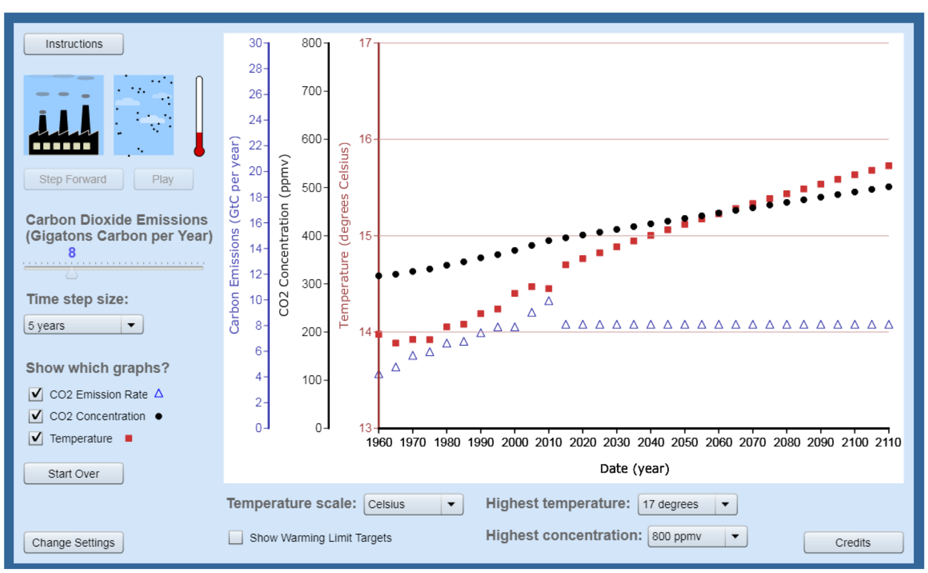
1. Be sure that the "CO_2 Emissions", "CO_2 Concentration" and "Temperature" boxes are all checked.
2. Be sure that the emission slider value is set at 10.5 (the default). Run the model by clicking the "Step Forward" button multiple times. You will produce a graph like the one below.
3. Create a screenshot or printout of this graph (or use the copy in the kit).



Graph produced with default emission value (10.5). Source: University Corporation for Atmospheric Research Center for Science Education (UCAR SciEd): www.scied.ucar.edu/simple-climate-model

Lower CO_2 Emission Graph

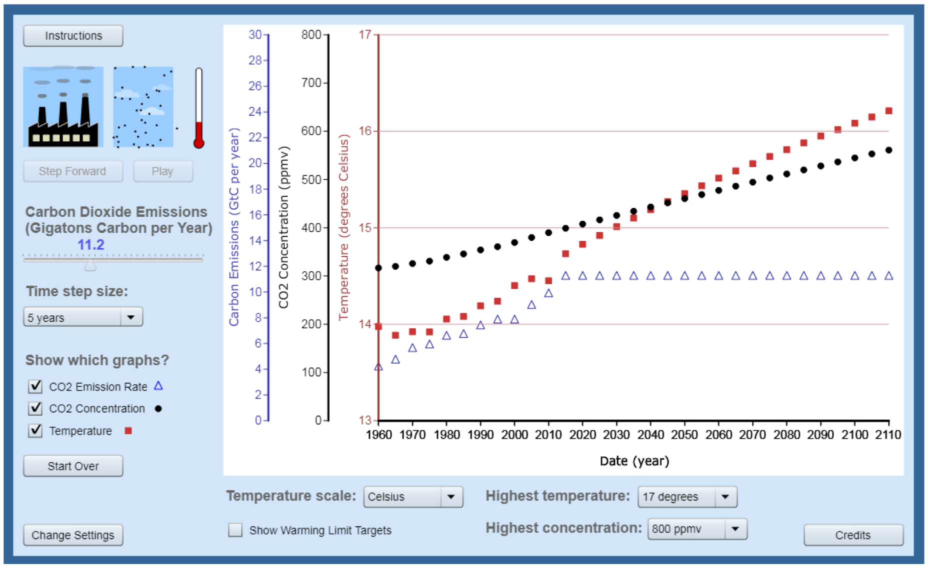
1. Click the "Start Over" button.
2. Use the slider to set the emission number <u>lower</u> than 10.5. Run through the model by clicking on "Step Forward."
3. Create a screenshot or printout of this graph (or use the copy in the kit).



Graph produced with a lower emission value (8). Source: University Corporation for Atmospheric Research Center for Science Education (UCAR SciEd): www.scied.ucar.edu/simple-climate-model

Higher CO_2 Emission Graph

1. Repeat, with the emissions number now higher than 10.5 (example graph provided is set to 11.2 GtC, similar to 2017 values from the chart below).
2. Create a screenshot or printout of this graph (or use the copy in the kit).



Graph produced with a higher emission value (11.2). Source: University Corporation for Atmospheric Research Center for Science Education (UCAR SciEd): www.scied.ucar.edu/simple-climate-model

Share and Process

As a group, carefully compare all three graphs. What is the same? What is different? What happens to CO_2 concentrations over time for each CO_2 emission value? (CO_2 concentrations increase over time with each CO_2 emission value). What happens to temperatures over time for each CO_2 emission value? (Temperatures increase over time for each CO_2 emission value.)

Generalize

If the trends in all three scenarios are the same, what is different? (If CO_2 emission values are higher, CO_2 concentrations increase more in a shorter time, and temperatures increase more in a shorter time.)

Timeframe	Average CO_2 Emissions (GtC) from fossil fuels	Average CO_2 Emissions (GtC) from deforestation	Total Average CO_2 Emissions (GtC)
2008-2017	9.4	1.5	**10.9**
2017	10.9	1.4	**11.3**

Source: www.earth-syst-sci-data.net/10/2141/2018/

The table shows CO_2 emission values based on data reported by scientists for the Global Carbon Budget 2018. What emissions value(s) did you use from the model that most closely corresponded to actual values from 2017 (which is closest to reality)?

Apply

In Activity Five you also looked at CO_2 concentrations and temperatures. How does this model compare to what was learned in that activity? Specifically:

- In Activity Five, both global CO_2 concentrations in the atmosphere and temperatures were rising. Does this model show the same? Return to the data from Activity Five. Are the values for CO_2 similar? Are the temperatures similar?
- Given what was learned about the greenhouse effect and global temperatures in Activity Five, do the outcomes of this model seem reasonable and realistic?

More Challenges

- Experiment with other features of the model according to interest and time available. What other features of the model did you explore, and with what outcome(s)?
- What other features would you like to see; features that would help answer some of your other questions?
- In this activity you used one of the few interactive climate models available to the public in an online interactive format. Why?
- If, on a warmer planet, snow and ice disappear and precipitation changes, how might the features explored here—ocean salinity/density, snow and ice reflectivity, and global air temperature response to CO_2—also change? If these ocean, snow and ice and global features change, will they change independently or interactively? Can you identify feedback loops, such as how changes in one feature might slow down or accelerate changes in another feature?
- This activity explored large-scale global processes operating on scales of years to decades. How might these processes influence local weather?

Activity Resources

Earth System Science Data: www.earth-syst-sci-data.net/10/2141/2018/

Salinity-Density Demonstration: www.youtube.com/watch?v=bp7-xYG1D6s&feature=youtu.be

University Corporation for Atmospheric Research Center for Science Education (UCAR SciEd):
www.scied.ucar.edu/simple-climate-model

Additional Resources

Climate Science Resources

Rutgers University Global Snow Lab: https://climate.rutgers.edu/snowcover/

Global Carbon Budget 2018: www.earth-syst-sci-data.net/10/2141/2018/

Center for Climate and Energy Solutions, Climate Basics for Kids:
www.c2es.org/content/climate-basics-for-kids/

Common Sense Education, 4 Free Tools to Teach About Climate Change:
www.commonsense.org/education/blog/4-free-tools-to-teach-about-climate-change

Modeling Resources

Climate Literacy and Energy Awareness Network, Very, Very Simple Climate Model in the Classroom:
www.cleanet.org/resources/41874.html

NASA Climate Kids, Climate Time Machine:
https://climate.nasa.gov/interactives/climate-time-machine\

STEM Learning, Modelling Climate Change:
www.stem.org.uk/resources/elibrary/resource/26878/modelling-climate-change

Oceans and Climate Resources

NASA Climate Kids, What is happening in the ocean?: www.climatekids.nasa.gov/ocean/

NOAA: www.oceanexplorer.noaa.gov/facts/climate.html

Climate.gov: www.climate.gov/news-features/featured-images/2017-state-climate-ocean-heat-content

Activity Eight

Where Does the Carbon Go?

By tracing carbon, we can understand how much comes in (sources) and how it is stored (sinks) in the ocean, land, and atmosphere.

Learning Outcomes

Participants will:

- Understand basic processes of the global carbon cycle.
- Model a simple carbon budget.
- Explore carbon inputs and outputs within a model carbon budget.

Content Skill: Understand basic processes related to the global carbon cycle.

Life Skill: Thinking

Educational Standards: 4-ESS3-1, 5-PS1-2, 5-LS2-1, 5-ESS2-1; 2d, 2f, 3e, 4g, 6c, 7d

Success Indicator: Successful modeling of a simple carbon budget.

Background

Carbon is an element that occurs naturally on planet Earth. It is found just about everywhere—in the atmosphere, soil, rocks, trees, animals, and even in you. As you learned in Activity Five, a certain amount of carbon (in the form of CO_2) in the atmosphere is normal, but too much leads to warming. In this activity participants explore the carbon cycle—how carbon moves from place to place on, in, and around our planet, and where it goes when there is excess.

Participants will have learned about atmospheric CO_2 in Activity Five. Recent additions to the natural carbon cycle come from human activities, primarily combustion of fossil fuels. Approximately 25% of that additional carbon goes into the ocean, 25% goes to land processes and the remaining 50% accumulates in the atmosphere. When we calculate CO_2 inputs from fossil fuels—our "income" in this carbon budget—we find that we have too much income (CO_2) and not enough places (land and ocean) to "spend" (or store) it. As a consequence, almost half of the inputs remain in the atmosphere. In this activity, participants will model the carbon cycle—and find no place other than the atmosphere to deposit the excess carbon. By repeating cycles representing annual inputs, participants will recognize that CO_2 inevitably builds up in the atmosphere. They will also realize the impacts of changing land use like deforestation and the reasons for increases in ocean acidity. Along with Activities Five and Seven, Activity Eight should prepare participants for the carbon footprint exercise in Activity Nine (Weather and Climate Together, Now and in the Future).

Carbon Income and Expense

In a personal financial budget, income should roughly balance expenses. Any excess income over expenses will accumulate as savings. Likewise for the global carbon cycle; CO_2 "income," the input of CO_2, should balance carbon uptake processes of land and ocean (CO_2 "expenses") with any excess accumulating in the atmosphere. In a financial budget, one can presumably spend as much as one pleases on food, rent, transportation, clothing, etc. and thereby reduce one's savings. In the carbon budget of our planet, land and ocean can take up only a limited amount of CO_2 each year, so any excess carbon must stay in the atmosphere. In other words, we cannot "spend" more carbon in the land or ocean to reduce how much we "save" in the atmosphere.

Photo: David J. Moorhead, University of Georgia, Bugwood.org

A Simple Carbon Budget

We can express an annual carbon budget for our planet in very basic income and expenditure terms. Instead of dollars, the carbon budget is measured in gigatons per year. Carbon income (inputs or sources) includes carbon released due to the use of fossil fuels plus carbon released due to removal of trees and plants which would otherwise store carbon. Carbon expenditures (expenses or sinks) include carbon absorbed by the ocean, carbon absorbed into the land, plus the remaining excess carbon in the atmosphere.

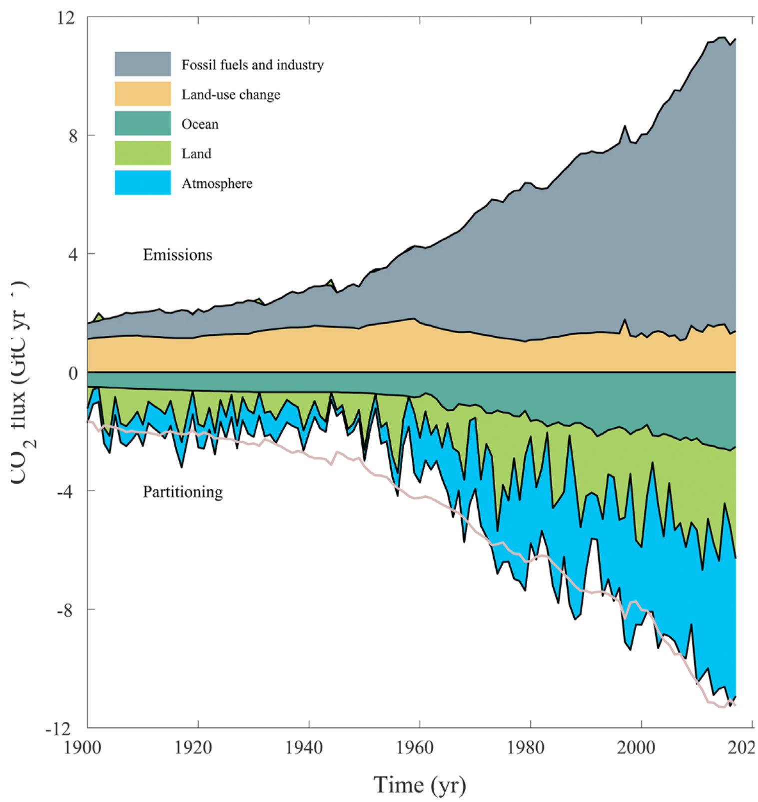
Inputs/Sources		**Expenses/Sinks**
carbon from fossil fuels + carbon released during deforestation	=	new carbon stored in oceans + new carbon stored on land + carbon accumulating in atmosphere

Consider the numbers from the *Very, Very Simple Climate Model* used in Activity Seven. For 2017, these budget numbers were (in rounded units of gigatons of carbon per year):

10 (fossil carbon) + 1 (land-use change) = 2 (ocean) + 4 (land) + 5 (atmosphere)
11 GtC input = 11 GtC expenses

How have the budget numbers changed with time? With careful analysis of records and data, scientists can reconstruct an accurate carbon budget for the past and present. The graph on the right shows the five categories: fossil fuel (fossil carbon) and deforestation (land-use change) on the income (positive or upper) side and ocean, land and atmosphere on the expenditure (negative or lower) side for the past 117 years.

The increase in fossil fuel emissions (gray) is clear. The graph also shows the other sources and sinks used in this activity: land-use change (such as deforestation) as a steady source of carbon; with ocean (sink) as a gradually increasing uptake, land (sink) as a variable but slightly increasing uptake, and atmosphere (as an increasing sink).



Source: Global Carbon Budget 2018:
https://www.earth-syst-sci-data.net/10/2141/2018/

How Do Carbon Inputs Impact the Ocean?

Adding additional CO_2 to the oceans causes a shift in ocean chemistry: the oceans become more acidic. Research shows that acidification happens sooner and with larger effect in colder waters, and that a wide range of carbonate-shelled organisms (such as oysters and clams) may suffer from this chemical change in larval or adult stages.

What happens On Land?

You may have noticed that land is categorized as both a source of and a sink for carbon on the graph. Since the start of agriculture, humans have played a large role in modifying land surfaces. In the present-day carbon budget, land changes as a carbon source (for example, on the income side) represent the net of human-induced land use impacts with deforestation the largest impact. Land changes on the uptake side represent changes due to CO_2 increases, including CO_2 fertilization of plant growth and longer growing seasons, particularly in northern parts of the northern hemisphere. If one chose to lump all land change processes that affect CO_2 into a single number, for example, roughly one gigaton lost combined with four gigatons gained, land will still represent a net uptake (sink).

Time Needed: 1 hour

Materials

- 60 (or more) identical paper tickets or equivalent small item.
- Timer (included in Activity Five)
- Notebook (not included)

What To Do

Experience

In this activity, participants explore sources and sinks of carbon by modeling how carbon moves between land, ocean and atmosphere annually. To start the activity, assign the following roles to participants (based on up to 10 participants):

- Ocean (1 participant): can only receive 2 tickets in each annual exchange cycle;
- Land (1 participant): can receive up to four tickets in each annual exchange cycle;
- Atmosphere (1 participant): can receive an unlimited number of tickets;
- Carbon Mover (all others): one ticket per participant or a few participants each holding several tickets, for a total of 10 tickets at the start.

Situate the Ocean, Land and Atmosphere ticket collectors at one side of the room (tell them how many tickets they can receive, but don't inform the Carbon Movers). Line the other participants up single-file, facing them. Depending on size of the group and space available, set a time limit for ticket exchanges. For small groups, 2-3 minutes will usually prove sufficient. Prior to starting, set the timer for 2-3 minutes. As each Carbon Mover takes their turn, they should run across and choose to give their tickets to either the Ocean, Land or Atmosphere. For each ticket received, ocean shouts "acidification," land says nothing, and atmosphere says "warmer." See above for how many tickets each can accept. Tickets refused by ocean or land must go to atmosphere.

After they distribute their ticket(s), each Carbon Mover returns to the line, where the instructor gives the Carbon Movers a second set of 10 tickets, representing the next annual cycle. Before the second round starts, Land returns one of its first four tickets to the Carbon Movers, giving them now 11 rather than 10. As before, the clock starts and the Carbon Movers again attempt to turn in all their tickets to the land, ocean and atmosphere. This cycle and the addition of 10 new tickets (plus one returned from the land) each round, can be repeated as many times as the group would like, or at least 5 rounds (50+ tickets).

Participants can change roles in each cycle but tickets accumulated should remain with each depository (ocean, land or atmosphere).

Share and Process

Gather the participants and discuss:

- Which location accumulated the most tickets – ocean, atmosphere or land?
- Why and what happened as a result? (Mostly atmosphere, because the ocean and land were limited in the amount of CO_2 they could absorb. Ocean gains some tickets and becomes more acidic.)
- If each cycle represented a year, did the CO_2 inputs over a year (tickets) equal collections (outputs)? (No, the total number of tickets per year increased by 1 and ends up in the atmosphere.)

In the real world, fossil fuel emissions have increased steadily for at least 50 years. If you redid this experiment with increased emissions (starting each annual cycle with one more additional ticket), but with no other changes, where (to which location) would those additional tickets go? (Atmosphere.)

In some years, deforestation increases substantially. How would such an increased loss of forests affect these ticket exchanges? (The land could absorb less CO_2.) What if you decrease the number of tickets land can take by one? (Atmosphere will end up with more.)

Frozen land, called permafrost, can hold a lot of carbon. If carbon from permafrost emerges as CO_2, where will that carbon accumulate as frozen soils start to thaw? (The land releases CO_2 and is also not able to absorb as much CO_2.) What if you decrease tickets land can take by one? (Atmosphere will end up with more.)

Generalize and Apply

Ask participants to consider, has our carbon budget model considered all major sources (income) and sinks (expenses) of carbon, or have we missed something?

What can we learn about the carbon cycle from this activity? (Carbon cycles between its sources, land, ocean and atmosphere over time; the land, ocean, and atmosphere can store extra carbon. The amount of carbon the land and ocean can store is limited. Excess carbon that cannot be stored in the land or ocean ends up in the atmosphere.)

What happens to the atmosphere as CO_2 increases (participants should recall what they observed in Activity Five)? How is the carbon cycle related to global warming and the greenhouse effect?

More Challenges

If participants have a grasp of this concept and exercise, ask them to consider the following: CO_2 lasts 200 or more years in the atmosphere. Assuming carbon inputs to the atmosphere are at least five gigatons per year, how much additional carbon will accumulate in the atmosphere over the next 100 years? (500 gigatons.) The current atmosphere holds 870 gigatons of carbon (this is the equivalent to 410 ppm, from Activity Five). Assuming the land and ocean sinks remain stable, how much carbon (in gigatons) will the atmosphere hold 100 years from now? (1370 gigatons.) What might this amount of carbon in the atmosphere lead to? What might happen if the land and ocean lose uptake efficiency (can't absorb as much as they do now)? (Even more CO_2 will end up in the atmosphere.)

Additional Resources

Earth System Science Data: www.earth-syst-sci-data.net/10/2141/2018/

Our World, United Nations University: https://ourworld.unu.edu/en/climate-changes-evil-twin-ocean-acidification

Activity Nine

Weather and Climate Together, Now and in the Future

Participants monitor carbon impacts and explore needs for weather and climate information.

Learning Outcomes

Participants will:

- Find and use various carbon footprint monitors.
- Imagine future weather and climate scenarios.
- Understand potential workforce needs and career opportunities in the coming decades.

Content Skill: Understand the interaction between weather and climate in the present and beyond.

Life Skill: Thinking

Educational Standards: 4-ESS3-1, 5-ESS3-1; 6b, 6c, GPa, GPb, GPd, GPe, GPg

Success Indicator: Competency in understanding carbon footprint calculators and various scenarios in the future.

Background

If participants have completed the eight preceding activities in this Learning Lab, they will have gained experience and knowledge of the data, patterns, and forecast or prediction tools of weather and climate. From Activity Three they will have learned about extreme weather/climate events. They will have developed some sense of the importance of water for our four-state region and of the importance of the levels of carbon, CO_2 in particular, to present and future climate. In Part I, this activity will introduce them to some of the online tools available to monitor different carbon "footprints." A carbon footprint provides individuals and communities with an estimate of the net carbon impact they have or will have by their energy, transportation, housing and food choices. They will then consider, in Part II, one energy and one transportation scenario which might play out in coming decades. Information and discussions in this activity should provide participants with ideas about future classes, community actions, and possible career opportunities, which they'll think about in Part III.

Reducing Carbon Footprints

Despite scientific evidence and public education, carbon emissions and atmospheric concentrations of CO_2 continue to increase. Much of this increase comes from updated living conditions in China and India (leading to increased CO_2 emissions, see Figures 1 and 2) but any individual, community, or national investments in high-carbon emission tools and systems add to our cumulative impact on our planet's climate. In the U.S., our national average carbon emissions per person remain far above those of any other population in any country (see Figure 2).

As a first step toward reducing carbon emissions, many citizens and communities assess their carbon footprints: the amount of carbon released by various actions taken by that individual or community. Most carbon emission calculators report carbon footprints on an annual basis—tons of carbon per person or household per year, for example—based on location, energy use, transportation choices, etc. Useful carbon footprint calculators for U.S. citizens come from several U.S. federal agencies, particularly the

Photo: Howard F. Schwartz, Colorado State University, Bugwood.org

Environmental Protection Agency (EPA) and the National Renewable Energy Laboratory (NREL), or from U.S. universities. Some of these sources have developed specialized versions relevant to agriculture, transportation, buildings, etc. Several sector-specific links are included in the resource section to allow participants to explore more detailed emission analyses. The availability of carbon impact calculators has stimulated a substantial commercial application—by using free calculators, a user can then purchase carbon-related services or carbon offsets. A carbon offset is a decrease in the emissions of carbon dioxide or other greenhouse gases that acts to balance out emissions made elsewhere. Leaders can help participants recognize which sites advertise carbon offset services.

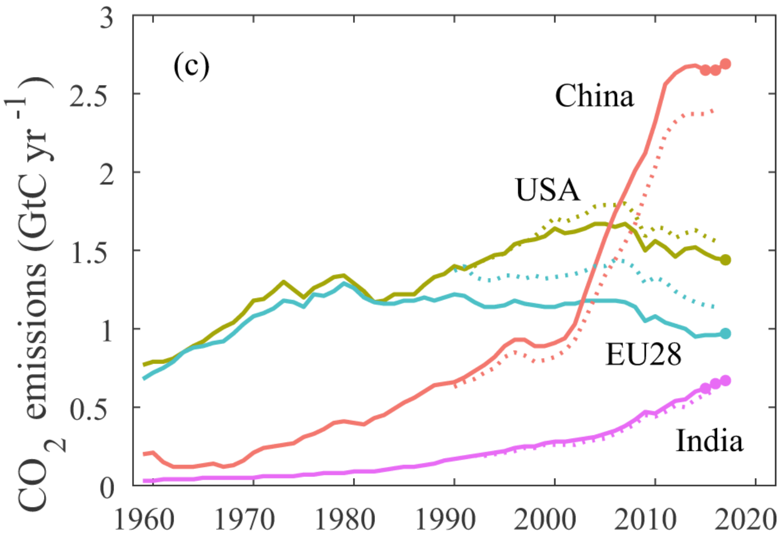


FIGURE 1. From annual and historical carbon budgets at https://www.earth-syst-sci-data.net/10/2141/2018/. Dashed lines indicate CO2 emissions calculated by consumption rather than by production, for example, emissions from China go down but emissions for USA and Europe go up if one tracks carbon by where it is consumed rather than by where it is produced.

The "Smart" Energy Future

Leaders and participants may have encountered the term "smart" here and in many articles and products. The term has—rightly or wrongly—become a convenient short-hand to imply efficiency, innovation, convenience, and connectedness. The term misses the need for a well-trained, highly-capable, "smart" workforce to confront and solve future weather and climate challenges. That workforce will need specific skills, as well as general awareness. Specific professions may include engineers, scientists, software engineers, technology specialists, communication experts, economics and energy modelers, etc., plus those with skills and specialties not yet envisioned. A general awareness should inform businesses, policy makers, community planners, and individual consumers. Participants should browse the resources provided. Because those mostly focus on actions individual and communities can take now, leaders and participants should shift the focus from the present to the weather and climate scenarios proposed. Viewing future weather and climate situations from a "smart" workforce point of view can provide participants with interesting options for future course work, professional training, and information sources.

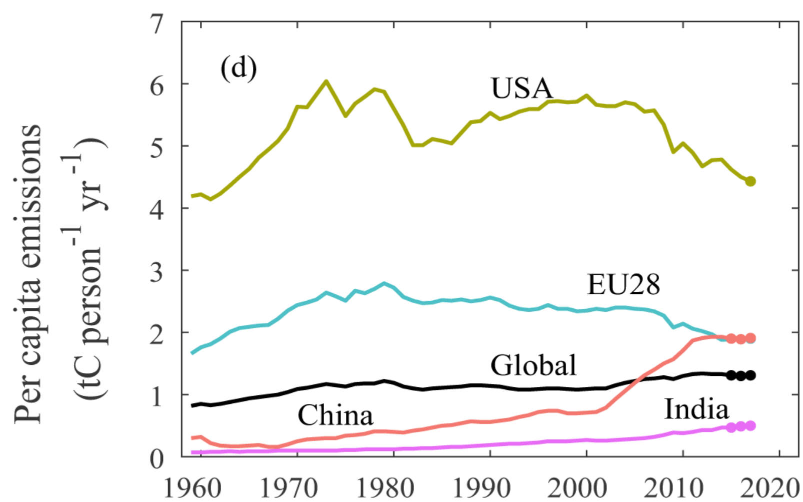


FIGURE 2. From annual and historical carbon budgets at https://www.earth-syst-sci-data.net/10/2141/2018/. CO2 emissions per person for the major emitting countries.

Activity Nine: Weather and Climate Together, Now and in the Future

Time Needed: 1 hour

Materials

PART I

- Access to online carbon footprint calculators, such as U.S. EPA Carbon Footprint Calculator found at www3.epa.gov/carbon-footprint-calculator/
- Laminated example copy of carbon footprint report
- Laminated copy of *How Can I Reduce My "Carbon Footprint"?* from NASA Kids

PART II and PART III

- Science Notebooks

What To Do

PART I: Carbon Footprints

Participants explore questions, responses and outcomes by using a carbon footprint calculator.

Experience

If no computer/device/internet is available - use the printed and laminated carbon footprint provided in the Learning Lab. Or, prior to the activity, access the carbon footprint calculator you choose to use (this activity follows the U.S. EPA Carbon Footprint Calculator found at www3.epa.gov/carbon-footprint-calculator/) and follow the instructions to calculate your personal carbon footprint and print it out for use during this activity.

Or, if possible and participants are of appropriate age, gather participants where they can access individually, in small groups, or as one large group, a screen showing the carbon footprint calculator. As a group, or with a leader assisting participants, follow the instructions to create as accurate a carbon footprint as possible (participants will likely not know the answers to some questions). Generate, and if possible, print your carbon footprint.

Share

Discuss the following:

- Did you find the calculators easy to use? (These calculators require information that is likely difficult for participants to know without input from leaders.)
- Would this calculator be easier to use if you were working through it with an adult family member? (Yes, adults will have access to some of the difficult information.)
- What factors (location, income, house size, travel, etc.) seemed most important to the carbon calculators?

Process

Now discuss:

- How did your carbon footprint values compare to the U.S. averages? Were yours more or less? Were you surprised?
- What factors seemed to hold highest priority? Why? How do these factors compare to the recommendations for lowering one's carbon footprint?
- What information or factors did you find useful or helpful?

Generalize

Replay the EPA calculator using different numbers or try one of the alternate footprint calculators from the NREL. Discuss the following:

- If you modified answers, which modifications had large impacts?

Apply

Focus on the "Planned Actions" section of the report. Discuss with participants:

- What types of actions reduce carbon emissions?
  (Driving less, turning heat/AC down, recycling.)
- What actions can participants commit to taking to reduce their own carbon footprints?

Have participants read *How Can I Reduce My "Carbon Footprint"?*, found at www.climatekids.nasa.gov/review/how-to-help/ and also included in the Learning Lab.

More Challenges

If participants have an understanding of the carbon footprint calculators and how they work, explore other carbon footprint calculators (possibly including specialty calculators such as food, transportation, agriculture, etc. to see how their questions differ from or require more detail than the EPA or other calculators). Discuss the following:

- Did these calculators appear to work on the basis of similar information in each case?
- Assuming that you completed these calculations as an individual or family, what similar or different factors did you observe or would you expect for a community, a building owner, a restaurant operator, etc.?

PART II: Future Scenarios in Weather and Climate

Participants explore future situations related to weather and climate.

Experience

Use the following scenarios for this activity:

SCENARIO ONE: Transportation and Weather

This scenario asks participants to imagine a future dominated by electric self-driven (autonomous) vehicles. Ask participants if they can think of current systems that combine sensors and software to control, navigate, and drive the vehicle (for example, cruise control). Ask them to imagine "smart" vehicles that do not require a driver but carry passengers or may not have any people in them at all (for example, vehicles delivering cargo). Suggested questions include:

- What weather hazards exist in your area that could affect a "smart" vehicle and how should those vehicles and their occupants respond?
- Will those vehicles "know" about specific local events (flooding, bridge damage, blowing snow, heavy traffic, etc.) and where will weather information for self-driving cars come from (National Weather Service, vehicle manufacturer, etc.)?
- Are different types of self-driven vehicles needed in different regions or seasons? Why?
- Will a smart vehicle know when to visit a service center to switch to snow tires?
- What options/roles should the customer have in weather/season-related situations?

Leaders and participants can imagine many interesting questions related to local roads and trips. Could one imagine a self-driven electric school bus? At some point in this discussion, perhaps at the suggestion of leaders, it could be considered that roads would need to change, from passive travel surfaces to information corridors.

SCENARIO TWO: Energy and Climate

In scenario two, participants take into account climate as they imagine future energy systems. Rather than privately-owned, regional, centralized utility systems as we largely have now, (in which private entities own and operate both the energy source and the distribution networks), consider a future with small wind and solar energy sources across the landscape where energy can be stored locally and used as part of a larger network as needed-locally, nationally or even internationally. Suggested questions include:

- How could a new energy system like this take advantage of favorable energy production conditions (such as wind or sunshine) in a certain region or at a certain time to meet higher energy usage in a different region or at a later time?
- What additional energy storage options will our future energy networks need and use?
- Could a person with good access to solar or wind energy invest in and provide reliable energy to immediate neighbors? How will a "smart" energy network such as this recognize, work with and take advantage of multiple small, local energy sources?
- A positive renewable energy future for our four states would consist mostly of wind (more than 50% of total energy use) and solar (30%), with a smaller amount of hydro-electric (10%). How might our flexible energy system of the future adapt to these sources?

Participants need only recognize that such questions exist today or will become more important in the near future; a longer list of questions could represent a very positive outcome of this activity.

Divide the overall group into two smaller groups, one to address the transportation/weather scenario and the other to address energy/climate. Read the appropriate scenarios above, including the suggested questions, to each group. Add any additional questions of your own. For transportation/weather, perhaps focus on a local road. For energy/climate, perhaps focus on a local renewable power installation (such as nearby wind turbines or solar panels). Help each group work through the set of questions in detail, providing at least preliminary answers or raising additional questions. Develop and record some answers or recommendations and report to the larger group.

Share

Did you find these scenarios realistic or far-fetched? How might any of these scenarios play out locally for you or within our four-state region? Did you come up with reasonable answers or more questions?

Process

What kind of systems do we use now to find out about the weather before or while driving a car? (TV, online and radio forecasts.) What systems do we use to find out about the climate of somewhere we are going to visit? (Online searches, maps, books and talking to others who have visited.) How do you think people might find information about weather and climate in the future? Do the scenarios and new ideas for information systems seem like something you will encounter in your lifetimes?

Generalize and Apply

Have participants consider changes that have taken place in the last 20 years (growth of the internet, speed of computers). How might the next 20 years progress? What jobs might be available as a result?

More Challenges

If participants have a grasp on the material, ask them the following questions:

- If hundreds of thousands of consumer-owned electric vehicles use on average only one-third of their battery-stored energy per trip or per day, how can the other two-thirds of available mobile battery capacity serve as a reliable energy storage system? (it could be used for other purposes in the house like supplementing electricity that is needed when the car is parked but many appliances are being used).
- Will electric self-driving vehicles offer similar down-time energy storage options in their batteries?

PART III: A "Smart" Workforce

Based on information gathered from Parts I and II, participants should develop and share their impressions of future workforce needs and career opportunities.

Experience

Gather participants for a discussion. Ask them, based on the carbon footprint and scenario activities, what are some jobs that might exist in the future that don't exist now?

- Make and share a guess about two or three jobs in the future related to weather and climate.
- Discuss the steps you might take in middle and high school and perhaps in college that would encourage you to be prepared for these types of jobs in the future.

What jobs did you identify? Are these jobs similar to existing careers and is the training needed similar? Did you identify new types of jobs needed to face new challenges? What features of a future workforce seemed interesting or daunting?

Share and Process

Does the idea of a "smart" workforce seem plausible for you or for people you know? If you want to play a role in that "smart" workforce, do you think you will be able to find the necessary opportunities and training? How might the knowledge gained through these weather- and climate-focused activities prove helpful?

Generalize and Apply

The steps and challenges encountered throughout this activity, for carbon footprints, future climate or weather information, and career opportunities, tended to focus on the individual making choices and pursuing various education options.

Do you think your community is moving towards having a "smart" workforce? Why or why not? What jobs and systems do you see in your community that are headed in the directions you learned about in this activity? What opportunities for future change do you see in your community?

Activity Nine: Weather and Climate Together, Now and in the Future

Activity Resources

U.S. EPA Carbon Footprint Calculator: https://www3.epa.gov/carbon-footprint-calculator/

Additional Resources

Earth System Science Data: www.earth-syst-sci-data.net/10/2141/2018/

Conservation International Carbon Footprint Calculator:
www.conservation.org/act/carboncalculator/calculate-your-carbon-footprint.aspx#/

The Nature Conservancy Carbon Footprint Calculator:
www.nature.org/en-us/get-involved/how-to-help/consider-your-impact/carbon-calculator/

The National Renewable Energy Laboratory Carbon Footprint Calculator:
www.nrel.gov/climate-neutral/planning-tool/

BBC Carbon Footprint Calculator: www.bbc.com/news/science-environment-46459714

Massachusetts Institute of Technology Carbon Counter: www.carboncounter.com

World Resources Institute Calculation Tools: www.ghgprotocol.org/calculation-tools

CoolClimate: https://coolclimate.org/business-calculator

Natural Resource Ecology Lab at Colorado State University: http://cometfarm.nrel.colostate.edu/

NASA Climate Kids: www.climatekids.nasa.gov/review/how-to-help/

The Guardian: www.theguardian.com/environment/2017/jan/19/how-to-reduce-carbon-footprint

Earth System Science Data Annual and Historical Carbon Budgets: www.earth-syst-sci-data.net/10/2141/2018/

The USDA, Agricultural Research Service's Climate Hub Program in
Fort Collins, Colorado, provided funding to South Dakota State University
for this project through a Non-Assistance Cooperative Agreement.