4-H Weather and Climate Youth Learning Lab

Leader's Guide

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Editors

Molly Ward
Science Educator
Mountain Goat Instructional Design, LLC
Bozeman, Montana

Paul Lachapelle
Associate Professor & Extension Community Development Specialist; Department of Political Science; Local Government Center
Montana State University

With contributions from:

Jasmine Carbajal
MSU Extension FCS Agent, Hill County

Mary Louise Wood
Wyoming State University Extension Educator, 4-H/Youth

Shylea Wingard
MSU Extension Agriculture and 4-H Agent, Hill County

Todd Kesner
Director, MSU 4-H Center for Youth Development

Katherine Jaeger
Extension Field Specialist-Youth Outdoor Education, South Dakota State University

Mark Platten
Director, Teller County, Colorado State University Extension

Reviewers

Jasmine Carbajal
MSU Extension FCS Agent, Hill County

David Carlson
World Climate Research Program (former Director)

Patrick Mangan
MSU Extension Agriculture Agent, Ravalli County

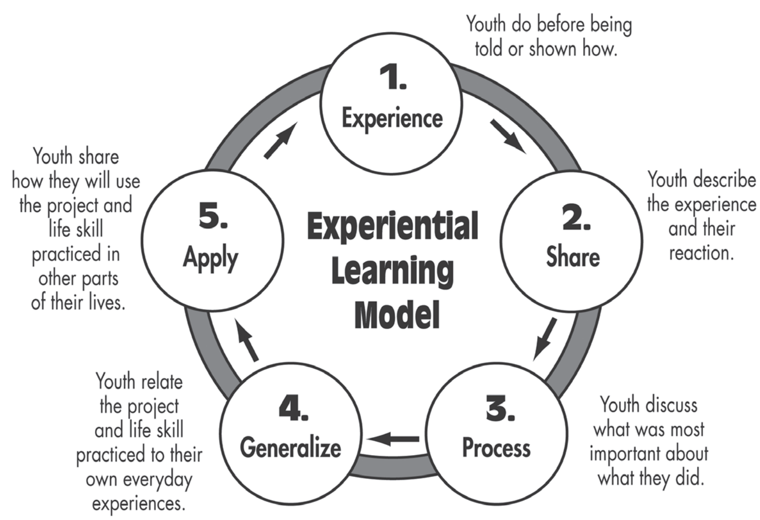
Mary Louise Wood
Wyoming State University
Extension Educator, 4-H/Youth

Design & Layout

Deborah Albin
Montana State University Extension

Table of Contents

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:

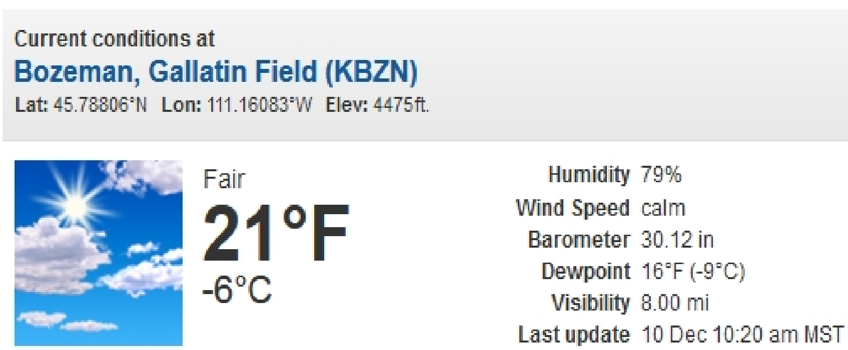
- On a phone or tablet, download a weather app and find a weather report for another location.
- Set up basic weather station (if outside).
- Set out weather report examples.
- Set out laminated weather data collection sheets and wet erase markers.

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 Four

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

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?

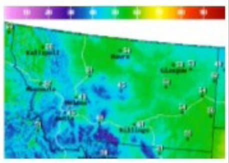
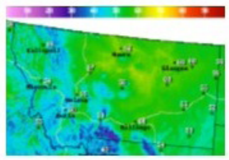
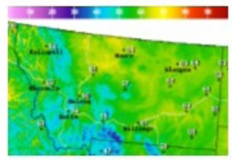
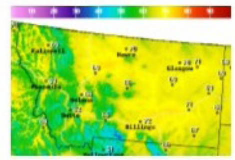
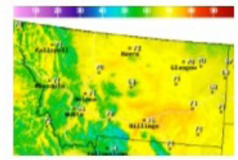
Experience

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.

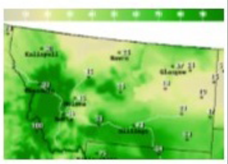
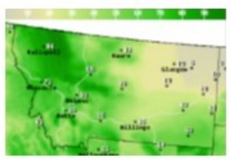
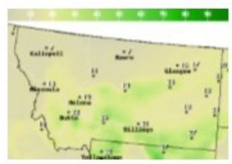
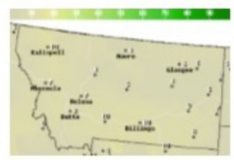
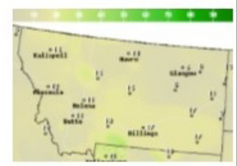
Other questions to think about:

- 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 Six

Photo: Deborah Albin

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 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.

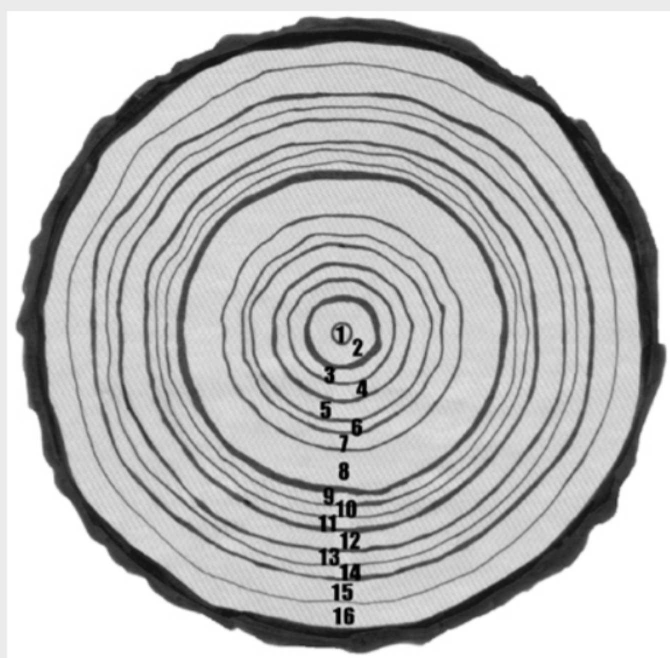
During the event:

- 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?



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

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?

- 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 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.

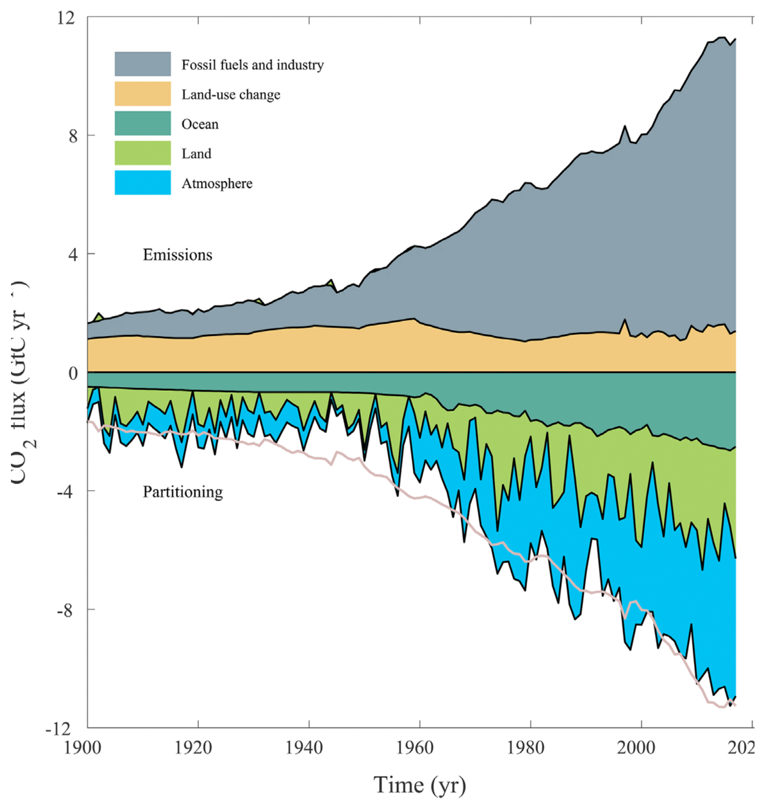
Inputs/Sources		**Expenses/Sinks**
carbon from fossil fuels + carbon released during deforestation	=	new carbon stored in oceans + new carbon stored on land + carbon accumulating in atmosphere

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

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.