SUSTAINABLE DEVELOPMENT GOALS

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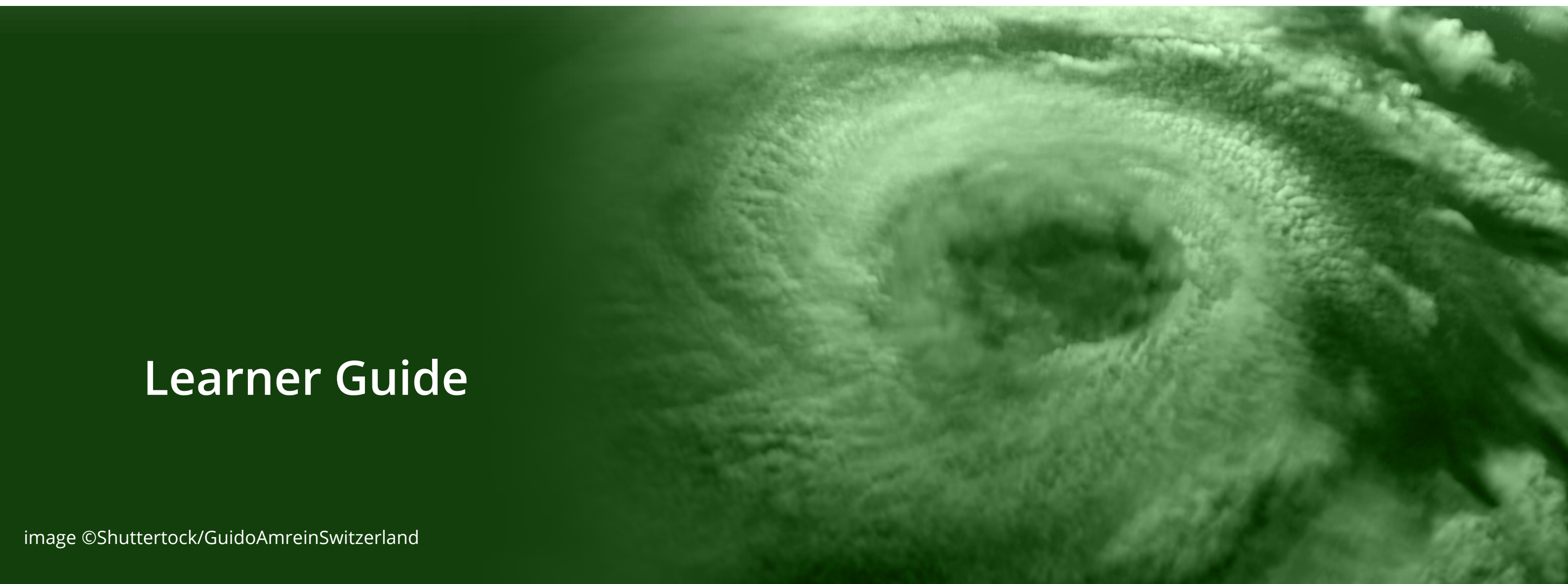
Education for Sustainable Development Kit: Impacts of Climate Change

13 CLIMATE ACTION

Sustainable Development Goal 13: Climate Action



Learner Guide

Education for Sustainable Development Kit: Impacts of Climate Change

Sustainable Development Goal 13: Climate Action

Learner Guide

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ESD KIT: IMPACTS OF CLIMATE CHANGE

Sustainable Development Goal 13: Climate Action

TABLE OF CONTENTS

ESD KIT: IMPACTS OF CLIMATE CHANGE

13 CLIMATE ACTION

Sustainable Development Goal 13: Climate Action

INVESTIGATION 1: CONSIDERING CLIMATE

Learning Outcome: Explain the difference between weather and climate to understand how each affects your community.

Materials

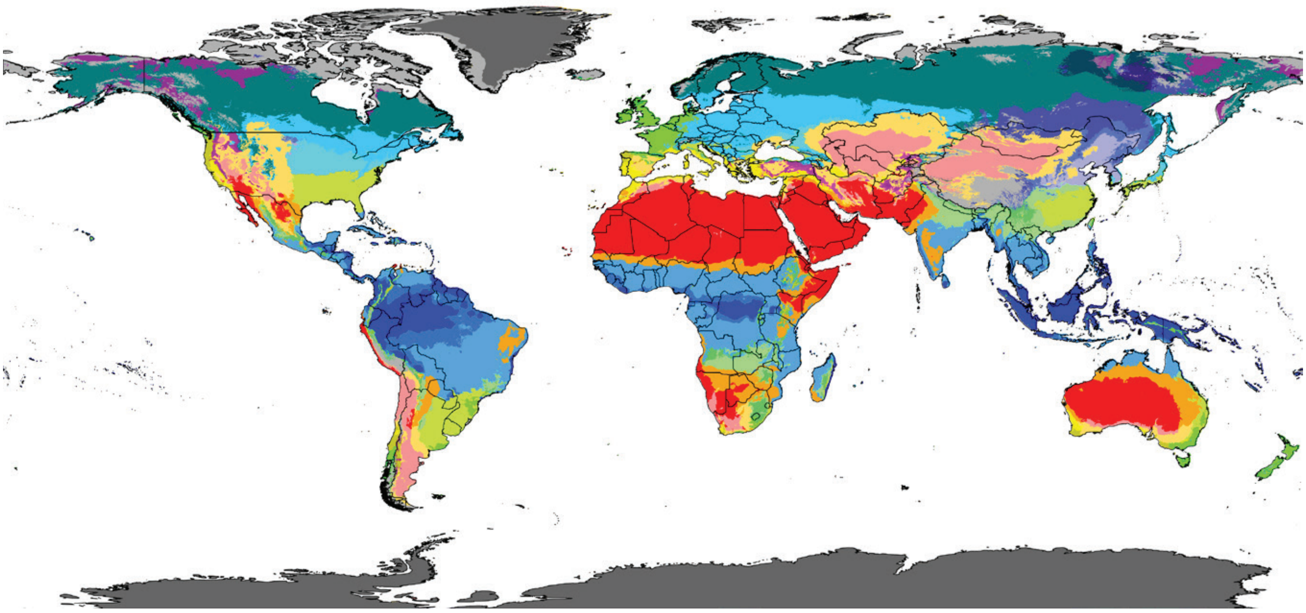
Per group:

- Handout- Maps and Graphs

What to Do

1. Look outside and describe current weather conditions.
2. Describe different weather conditions you've experienced in your area. Why does weather vary throughout the year?
3. What are the seasons like where you live? Describe any seasonal changes that occur.
4. Describe any weather conditions you have seen or heard about in other areas that do not happen where you live. Why does the weather vary from region to region?
5. Locate your region on the map and identify your region's climate

Köppen–Geiger climate classification map (1980–2016)



Credit: Beck et al., https://upload.wikimedia.org/wikipedia/commons/d/d5/K%C3%B6ppen-Geiger_Climate_Classification_Map.png

Köppen-Geiger Climate Classification Key

Tropical	Arid	Mediterranean	Subtropical	Oceanic
Rainforest; Monsoon	Hot Desert; Cold Desert	Hot Summer; Warm Summer; Cold Summer	Both are humid (a.k.a. warm temperate)	Subtropical Highland; Temperate (Mild Marine)
Savanna Dry Winter; Savanna Dry Summer	Hot, Semi-Arid; Cold, Semi-Arid			Both are Subpolar

Humid Continental	Subarctic/Subpolar/Boreal	Tundra	Ice Caps
Dry, Hot Summer; Dry Winter Hot Summer; Hot Summer, No Dry Season	Dry Summer; Dry Winter; No Dry Season		
Dry, Warm Summer; Dry Winter, Warm Summer; Warm Summer, No Dry Season	Dry Summer, Extreme Cold; Dry Winter, Extreme Cold; No Dry Season, Extreme Cold		

Credit: modified from Beck et al., https://upload.wikimedia.org/wikipedia/commons/d/d5/K%C3%B6ppen-Geiger_Climate_Classification_Map.png

6. Talk with a partner about a type of environment (desert, forest, grassland, etc.) that is common in your region given its climate. What features does it have?

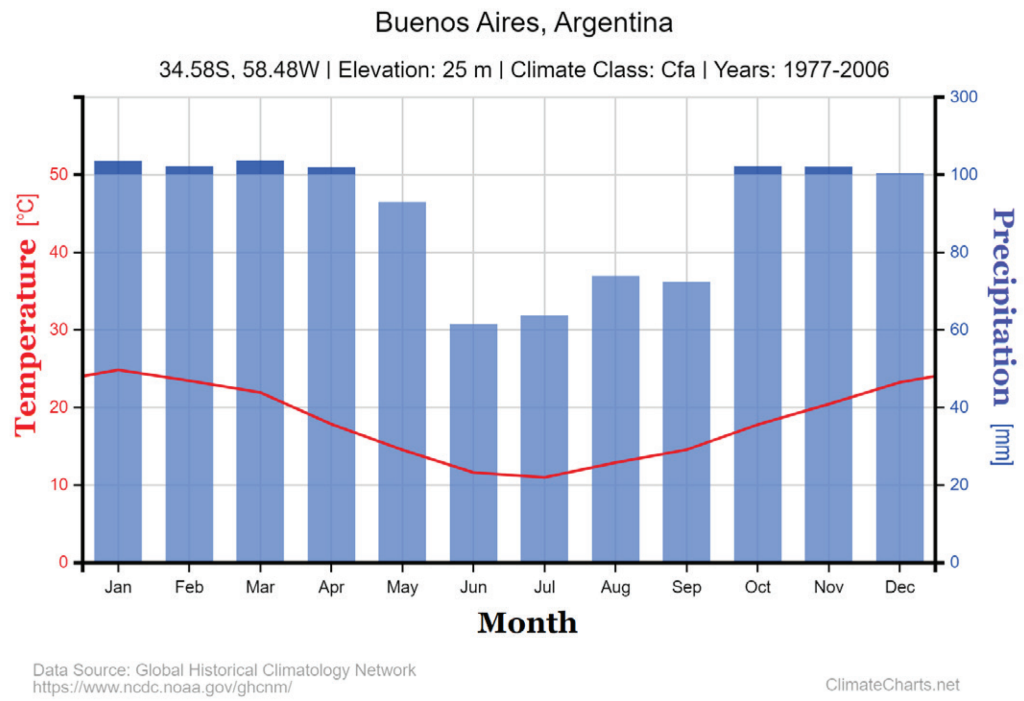
a. Draw a picture of that environment. Include some organisms you would expect to find there.

b. Describe how this environment fits the description of the climate in your area that is given on the map. What elements of the climate are not described well by the map?

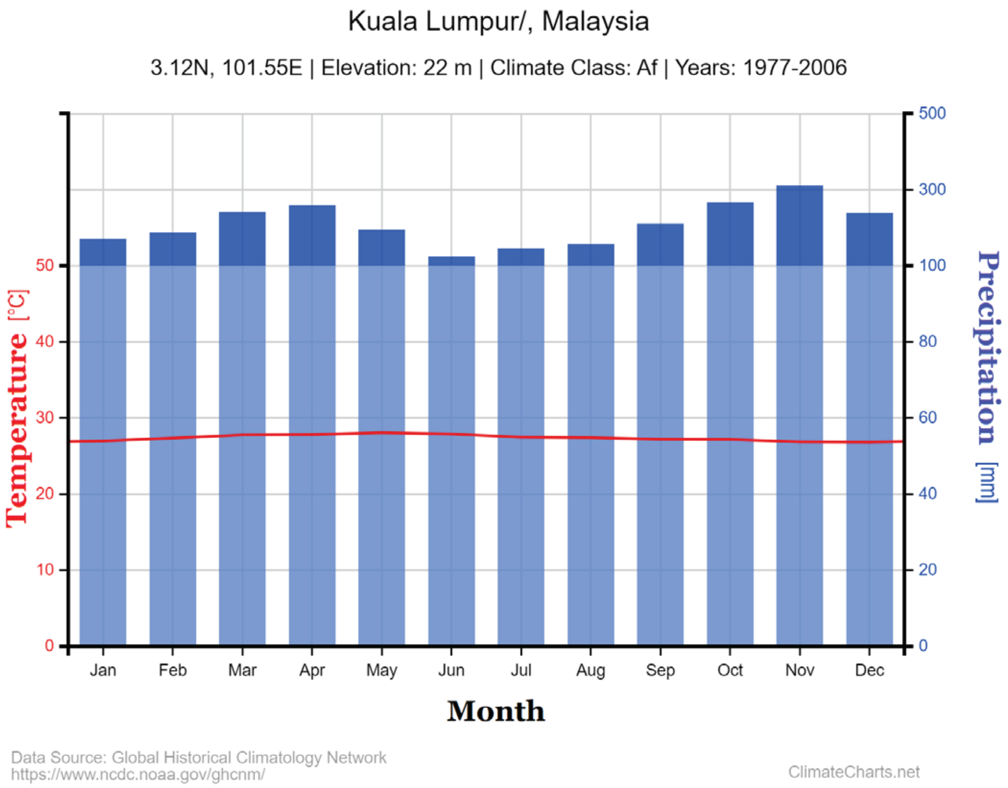
7. Describe any trends you see in the locations of different climates, identified by the colors on the map.

8. Locate the following countries on the climate map: Argentina, Malaysia, and Bulgaria. Identify their climates.

a. A climatogram includes a line graph of the average monthly temperatures in degrees centigrade (°C) and a bar graph of the average monthly precipitation in mm. Examine the climatograms below and describe each city's trends in average temperature and precipitation.



Credit listed with third graph.



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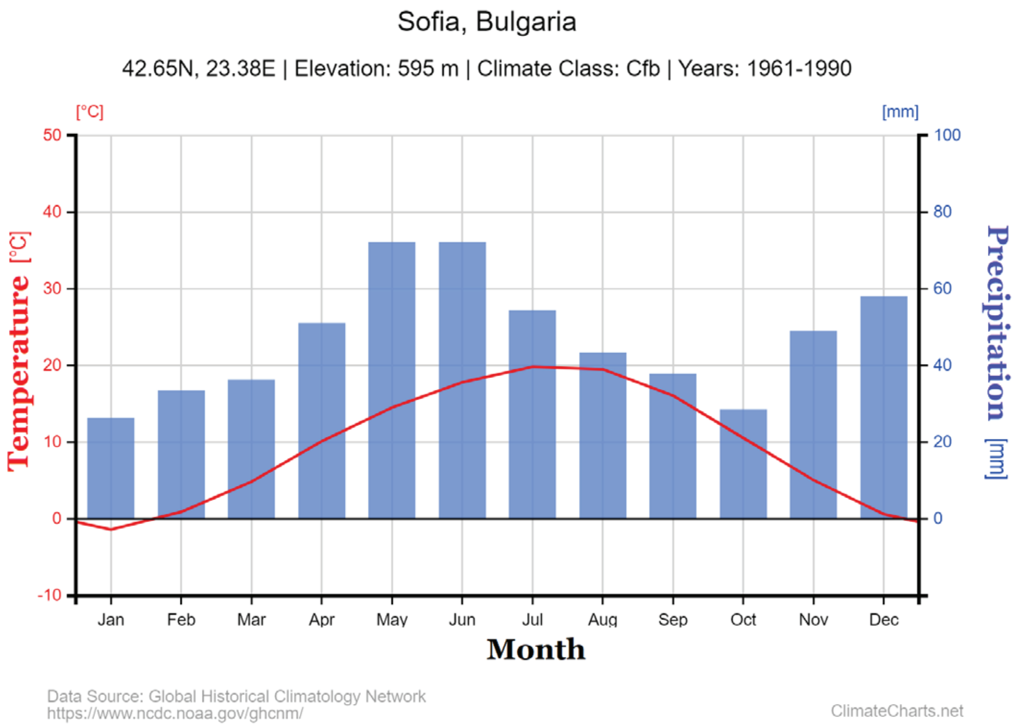


Credit: Modified from aura Zepner, Pierre Karrasch, Felix Wiemann & Lars Bernard (2020) ClimateCharts.net — an interactive climate analysis web platform, International Journal of Digital Earth, **DOI: 10.1080/17538947.2020.1829112**

b. How can the trends on the climatograms be used to describe the climate of each city?

c. Use this information to predict some other cities that you would expect to have climatograms like that of Buenos Aires, Kuala Lumpur, and Sofia.

d. Explain why climatograms cannot be used to predict weather on a particular day.

9. Sustainable Development Goal (SDG) 13 is all about climate change and the many impacts it has on the environment.

   a. What do you think about when you hear "climate change"?

   b. What do you think some of the environmental impacts of climate change are?

   c. Why do you think addressing climate change is important for people around the world?

Consider

1. Can the trends on the climatogram be used to determine the exact location of a city? Why or why not?

2. Consider the climates of the three cities, Sofia, Bulgaria, Kuala Lumpur, Indonesia, or Buenos Aires, Argentina.

   a. Do these three cities experience the same seasons at the same time? Give evidence from the climatograms to support your answer.

   b. Climatograms do not specify the type of precipitation a city receives. Do you think any of these cities get snow? What makes you think this?

   c. For each of these three cities, name the months when it would be most appropriate to wear "summer" clothing. Are they the same months for all three cities? Explain your answer.

   d. Consider outdoor activities you enjoy doing. Which of these three cities could you most likely visit or live in and be able to do these activities? Give evidence from the climatograms to support your answer.

3. Predict what a climatogram for your city would look like. Use what you know about your country's climate to describe what the trends for temperature and precipitation may look like.

Extensions

1. **Testing Variables:** Build a weather station to better understand variables involved in weather and to be able to distinguish it from climate.

2. What variables will you measure? What equipment would you need to measure each of these factors? How often would you take data? How will you analyze and use the data from your weather station?

Many automatic sensors and microcontrollers, such as micro:bit, can be used to not only sense variables related to weather, but can also log data at regular intervals set by the user. Kits are available to make a weather station using a micro:bit: https://bit.ly/microbitweatherstation and https://www.sparkfun.com/products/16274. What are the advantages of having a microcontroller log data? What might be some disadvantages?

3. **Applying Concepts:** Look at a climatogram from your city.

a. Compare your climatogram to those from Buenos Aires, Argentina, Kuala Lumpur, Malaysia, and Sofia, Bulgaria. Which of the three climatograms is most like yours? Describe the similarities and differences.

b. Which of the three climatograms is most different from yours? Why does this make sense given where in the world these countries are found?

ESD KIT:
IMPACTS OF CLIMATE CHANGE

13 CLIMATE ACTION

Sustainable Development Goal 13: Climate Action

INVESTIGATION 2: GREENHOUSE GASES AND CLIMATE

Learning Outcome: Investigate carbon dioxide as a molecule by studying the atmosphere and how carbon dioxide is exchanged between Earth's systems.

Materials

Per group:

- 9 plastic cups
- 1 marker
- water
- 100 mL graduated cylinder
- pipette
- 1 oxygen molecular model (2 tennis balls, 15 cm [6 in] flexible tubing)
- 1 carbon dioxide molecular model (3 tennis balls, 2 25 cm [10 in] pieces of flexible tubing)
- duct tape or plasticine clay

What to Do

1. The Structure of Atmospheric Gases

   a. Examine how oxygen and carbon dioxide react to solar energy using a model. Hold the model of the oxygen molecule by one end and gently shake it. The shaking represents solar energy being added to the molecules. Observe the tubing holding the tennis balls together. The tubing represents the bond between the oxygen atoms, which are represented by the tennis balls.

   b. What do you notice when you shake the model?

  - **c.** Repeat this with the model of the carbon dioxide molecule. What do you notice when you shake the model? How is it similar or different to the oxygen model?

2. Carbon Exchange with the Soil
   - **a.** Observe the experimental setup of a bottle of soil that has been running for approximately 3 days. The soil in the bottle was mixed with sugar water at the beginning of the experiment. Gases were collected from soil during those three days. The gases were funneled into a container of bromothymol blue that was mixed with water. The bromothymol blue in the small container was in its blue (neutral) state at the beginning of the experiment.
   - **b.** Use the color chart to determine the approximate pH of this solution now.

3. Carbon Exchange and Plants
   - **a.** The test tubes are filled with the solutions below and have been sitting under a lamp for the last 24 hours. Observe the color of the test tubes.
     - **i.** Bromothymol Blue in water (control)
     - **ii.** Bromothymol Blue in water with carbon dioxide added
     - **iii.** Bromothymol Blue in water with carbon dioxide and a plant added
     - **iv.** Bromothymol Blue in water with carbon dioxide and a plant added, covered with foil (dark)

Consider

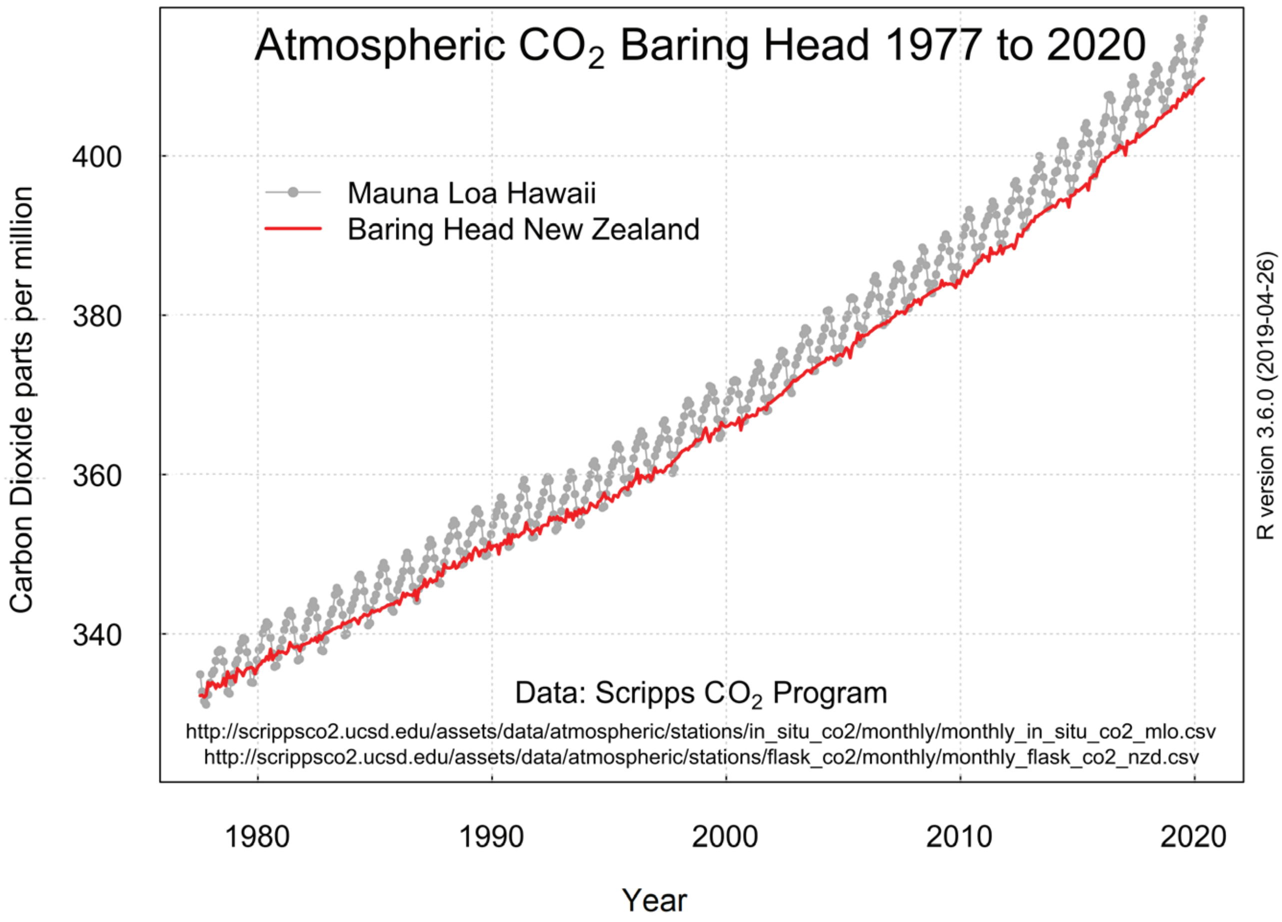
1. How did the models of oxygen and carbon dioxide react differently when shaken? How do you think the shapes of these molecules affect their ability to absorb solar energy?

2. The solution connected to the bottle of soil started out blue. Determine how much the pH changed over three days.
   - **a.** What gas did the soil give off? How can you tell?
   - **b.** How do you think carbon gets into the soil?

3. Compare the colors of each of the test tubes.
   - **a.** Describe the purpose of the test tubes i and ii.
   - **b.** Which gas does photosynthesis produce? How can you tell?
   - **c.** Which gas does cellular respiration produce? How can you tell?

4. What gas was given off by the burning candle (combustion)? How can you tell?
   - **a.** Do you think burning other materials or objects gives off the same gas?
   - **b.** What is your evidence? Or, what evidence would you need to determine this?

5. **Data Analysis:** Examine the graph “Atmospheric CO_2 Baring Head 1977 to 2020”. The graph shows carbon dioxide concentrations in the atmosphere at two locations. Describe and compare the trends shown.



Credit: Creative Commons, **https://commons.wikimedia.org/wiki/File:Baringhead_co2_v9.svg**

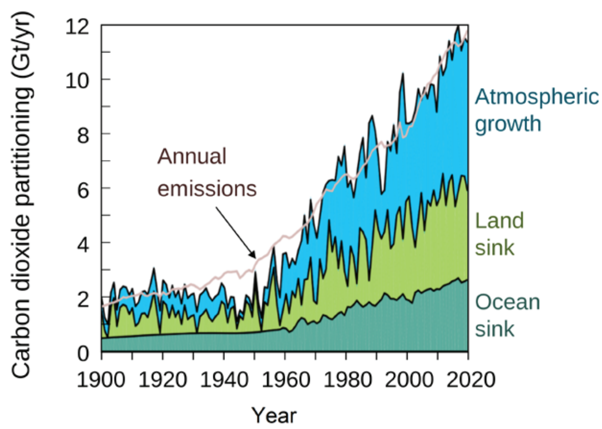
6. Data Analysis: Examine the graph, "Carbon Sink Partitioning in Relation to Annual Carbon Dioxide Emissions".

a. Describe the trend of annual carbon dioxide emissions line. What do you think is the most likely source of these emissions?

b. Carbon dioxide is held in the atmosphere, geosphere (soil and rocks), and hydrosphere (bodies of water). Which of these spheres appears to be most affected by carbon dioxide emissions? Use evidence from the graph to support your ideas.

c. Which sector shows the least variation in carbon levels over time? How do you know?

CARBON SINK PARTITIONING IN RELATION TO ANNUAL CARBON DIOXIDE EMISSIONS



Credit: Creative Commons, **https://commons.wikimedia.org/wiki/File:Carbon_Dioxide_Partitioning.svg**

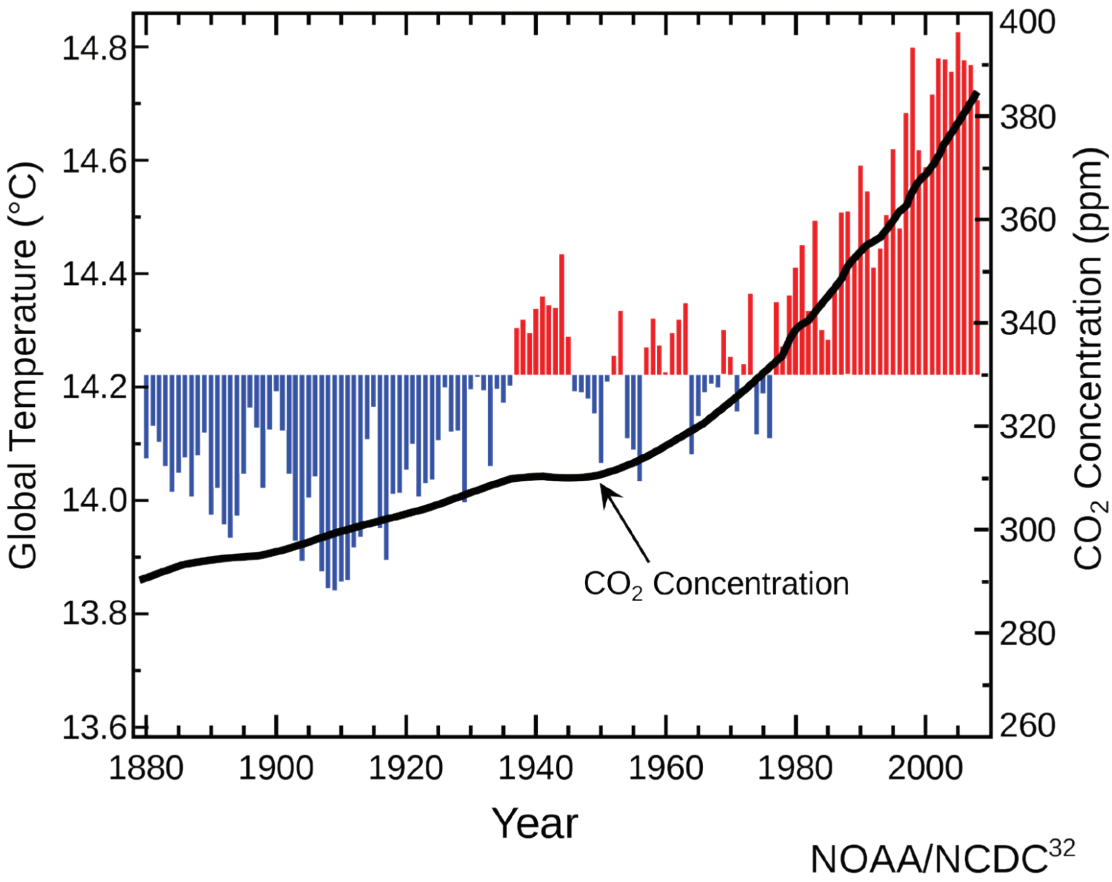
7. **Data Analysis:** Examine the graph, "Atmospheric Carbon Dioxide Concentration and Global Temperature Trends," which shows changes in Earth's temperature alongside changes in atmospheric carbon dioxide in parts per million (ppm).

   a. How much has carbon dioxide increased between 1880 and 2009?

   b. The bars on the graph show the average yearly temperature. Describe the trend in global temperature over the time period shown. How does it compare with the trend in carbon dioxide concentration?

   c. Think about the models of oxygen and carbon dioxide you built and examined at the beginning of this Investigation. How do you think the structure of these molecules contributes to carbon dioxide's effect on global temperature? Do you think oxygen would have the same effect if its concentration increased? Why or why not?

ATMOSPHERIC CARBON DIOXIDE CONCENTRATION AND GLOBAL TEMPERATURE TRENDS



Credit: Creative Commons, https://commons.wikimedia.org/wiki/File:Atmospheric_carbon_dioxide_concentrations_and_global_annual_average_temperatures_(in_C)_over_the_years_1880_to_2009.svg

Extension

1. **Testing Variables:** Test respiration in different organisms:

   a. Mix 5 germinated beans (that have been soaked in water overnight) in 25 mL of water mixed with 5 drops of bromothymol blue. Observe the color change of the solution over a 15–30 minute period.

   b. Mix 1 g of yeast with 25 mL of warm water and a pinch of sugar. Let sit for 10–15 minutes. Add 5 drops of bromothymol blue and observe the color change of the solution.

   c. Analyze your results:

   i. What gases do these organisms give off? How can you tell?

   ii. How does this differ from a green plant?

   iii. Why is it that green plants can reduce the effects of climate change, while other organisms cannot?

2. **Applying Concepts:** Compare the atmospheric gases of Earth to those of other planets. Use the data to make a representation of each atmosphere using pom poms. Based on the activity at: https://scied.ucar.edu/activity/learn/planetary-gases

			
	Venus	**Earth**	**Mars**
Carbon Dioxide (CO_2)	96.5%	0.03%	95%
Nitrogen (N_2)	3.5%	78%	2.7%
Oxygen (O_2)	Trace	21%	0.13%
Argon (Ar)	0.007%	0.9%	1.6%
Methane (CH_4)	0	0.002%	0

Credit: UCAR, https://scied.ucar.edu/activity/learn/planetary-gases

a. Label three clear plastic bags with the name of one of the planets. If your facilitator has already created a bag to represent Earth, you will only need two bags.

b. Choose a different color pom pom to represent each gas. Make sure the colors are consistent between each bag.

c. To determine how many pom poms of each color to put in each bag, read the percentages as regular numbers (round up for any decimal over .5). For example, the bag for Venus will have 97 carbon dioxide pom poms, Earth will have a small piece of one carbon dioxide pom pom, and Mars will have 95 carbon dioxide pom poms.

1. Describe the similarities and differences in the atmospheric gases of the three planets.

    a. Which planets have similar atmospheres?

    b. Which planet has the highest concentration of greenhouse gases? What effect would you expect this to have on the average temperature of the planet?

    c. Venus' atmosphere is very thick, while Mars' atmosphere is very thin. This means that there are fewer molecules of each gas type in Mars' atmosphere when compared to Venus. What effect do you think this has on Mars' average temperature?

    d. If possible, research the average temperatures or temperature ranges of each of these planets and use the information you have been given to explain their differences.

ESD KIT: IMPACTS OF CLIMATE CHANGE

Sustainable Development Goal 13: Climate Action

INVESTIGATION 3A: MEASURING CARBON DIOXIDE AND ACIDITY

Learning Outcome: Conduct tests to determine the effects of carbon dioxide on the pH of water and the effects of acids on other materials.

GROUP A:
FORMING ACID RAIN

Materials

Per group:

- 2 small cups
- water
- small cup of apple cider or white vinegar
- pH paper
- petri dish or similar clear, shallow dish with a cover
- 2 pipettes or medicine droppers
- toothpick
- bromothymol blue (or other pH indicator solution)
- stopwatch or clock with a second hand
- camera (optional)

What to Do

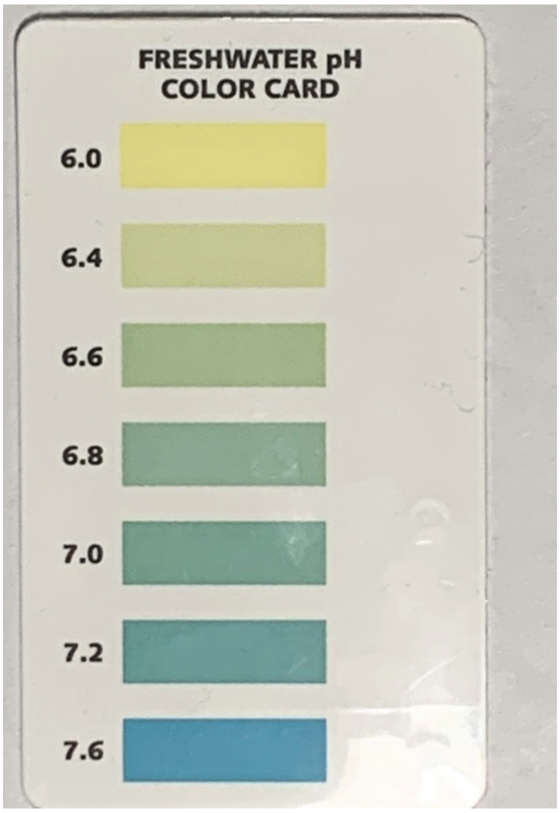
1. Use a small strip of pH paper to measure the pH of the vinegar. Use another strip to measure the pH of the water.

2. Add enough water to a small cup to fill a pipette (approximately 3 mL). Add 8–10 drops of bromothymol blue until the solution is an even blue color. Fill a pipette with this solution.

3. Use the pipette full of solution to make 6–10 drops in different areas of a petri dish. Each drop should contain 2–3 droplets of solution.

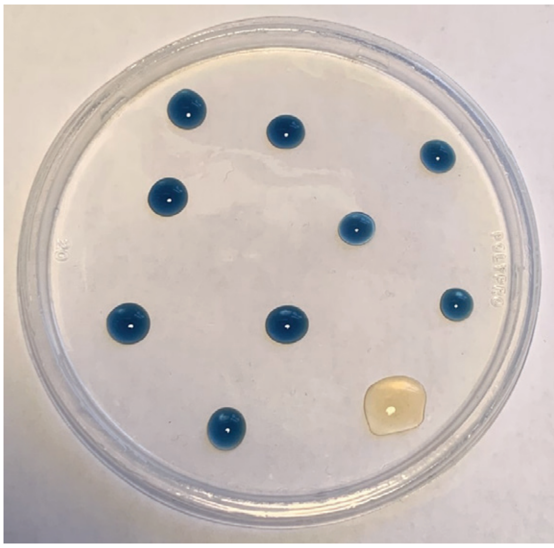
    a. Record the initial color of the drops.

    b. Compare this to the color chart that comes with the indicator. What is the pH of the drops?



Credit: L.C. Mossa

4. Use a new pipette to add 5 drops of vinegar to the petri dish. Add the vinegar along the side of the dish or in another spot where it will not come into contact with the water drops.



Credit: L.C. Mossa

5. Cover the dish. Wait one minute to observe the color of each water drop. Record the color every minute for 15 minutes.

    a. Be careful not to bump or move the dish.

    b. If possible, take pictures of the color changes.

6. After the 15 minutes of observation, add three drops of bromothymol blue to the vinegar spot in the petri dish to test its pH.

Consider

1. Compare the rate of color change in the different drops of water.

2. Describe how you think the water became more acidic (a lower pH) over time. Remember, the vinegar never touched the water drops.

3. When carbon dioxide mixes with water, it produces carbonic acid. Describe how an increase in atmospheric carbon dioxide can lead to acid rain.

Extension

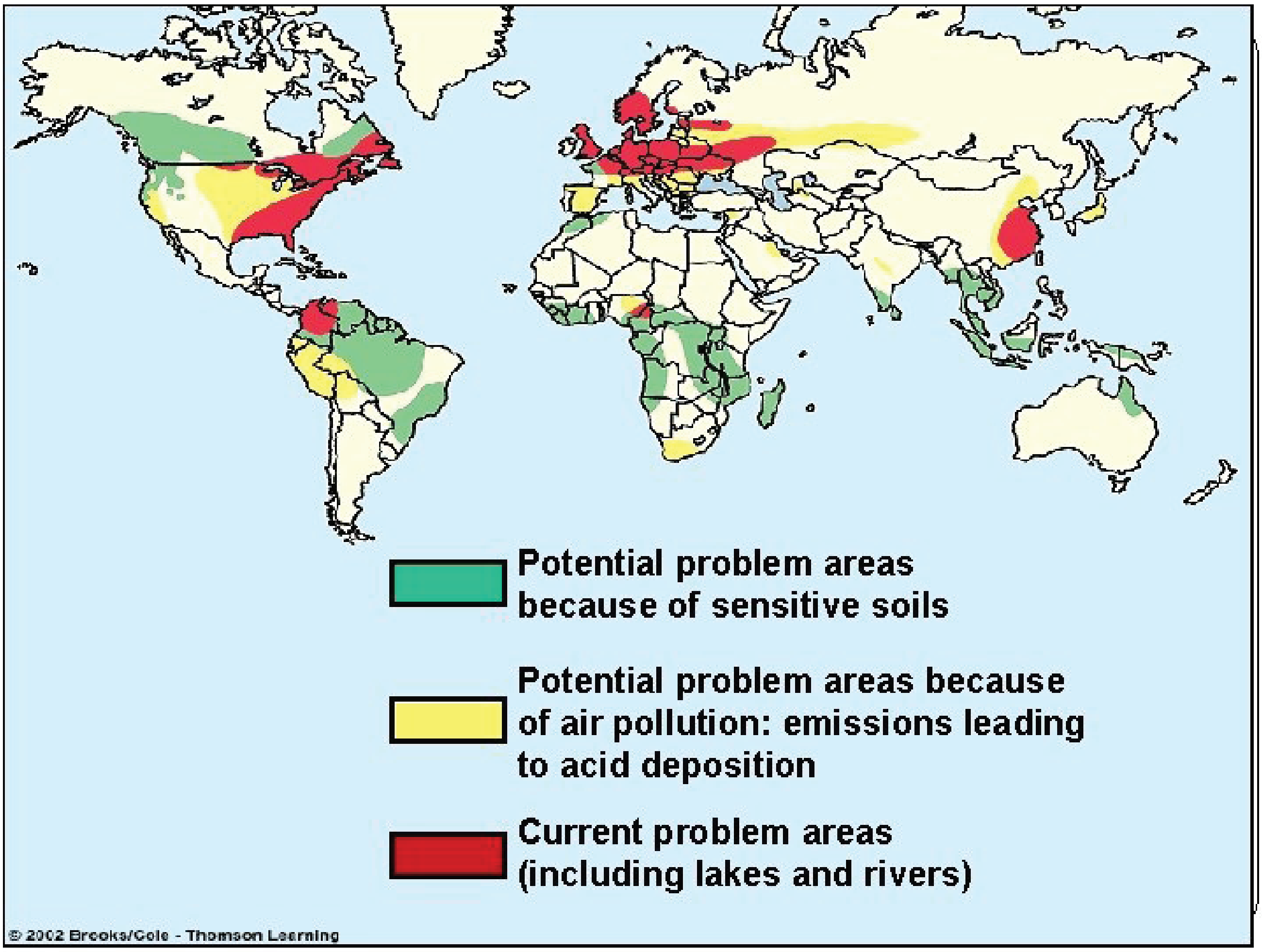
1. **Analyzing Data:** Examine the map "Potential Effects of Acid Rain". The yellow areas on the map are where emissions that can lead to acid rain are occurring. The red areas are the regions where acid rain is already causing problems in the environment.

   a. Describe the patterns with the yellow and red areas on the map.

   b. Why do you think the areas that produce emissions that cause acid rain are not the same areas that get acid rain?

   c. Are there any locations on the map that don't follow the pattern(s)? Why do you think that is?

POTENTIAL EFFECTS OF ACID RAIN



Credit: Brooks and Cole, Thomson Learning

GROUP B:
CARBON DIOXIDE AND pH

Materials

Per group:

- water (tap or distilled)
- salt water (7 g salt per 200 mL water)
- straw
- 2 small plastic cups (less than 240 mL [8 oz])
- bromothymol blue (available in many aquarium water test kits)

What to Do

1. Fill one cup halfway with cold water.
   a. Add 12 drops of bromothymol blue. Gently stir using the straw until the color is evenly distributed. Record this initial color. Examine the pH color chart that came with the indicator and record the pH of the water.
2. When you inhale, what gases do you breathe in? When you exhale, what gases do you breathe out?
3. Predict what will happen to the pH of the water when you exhale into it. Explain why you think so.
4. Use the straw to very gently blow bubbles (exhale) into the water in the cup. Start a timer when you start blowing bubbles and keep it running. Note the time when the solution turns green, and again when it turns yellow. Stop when the solution is yellow.

Caution: *Remove the straw from your mouth while inhaling, so you do not ingest the bromothymol blue. Pause the timer whenever you stop to inhale.*

   a. Keep your bubbles and the liquid in the cup. Be sure not to exhale too hard that causes the cup to overflow.
5. Note any color changes that occur in the cup.
6. Make a prediction as to what will happen with each of the following setups. Will the temperature and salt content of the water affect how long it takes to change pH (color)? Repeat this procedure with each setup:
   a. Warm fresh water
   b. Cold salt water
   c. Warm salt water

Consider

1. One of the gases you exhale is carbon dioxide. What effect did it have on the pH of the water?
   a. Compare the pH test results between freshwater and saltwater over time.
   b. Compare the pH test results between colder and warmer water over time.
2. Consider carbon dioxide and bodies of water, such as lakes, rivers, and oceans.
   a. How might carbon dioxide get into bodies of water? Where does it come from?

b. Can carbon dioxide also leave bodies of water? If not, explain why. If yes, describe where it goes.

3. The amount of atmospheric carbon dioxide is increasing. Describe what effect this will have on the pH of rain and bodies of water.

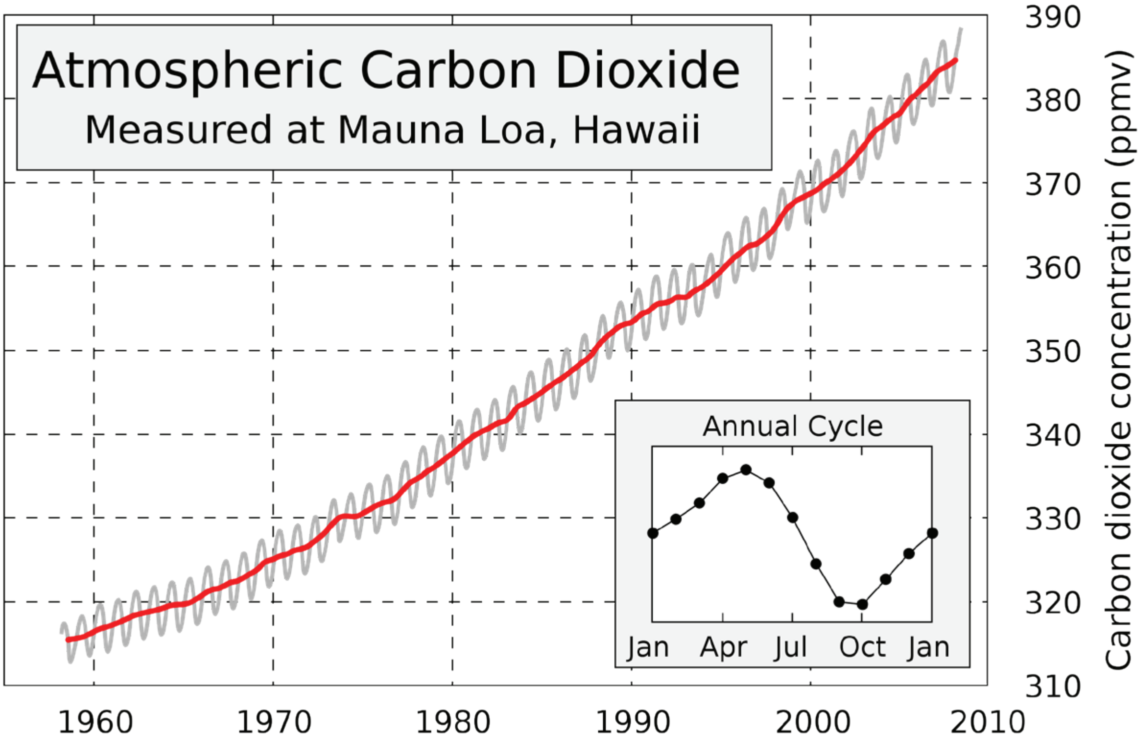
Extension

1. **Analyzing Data:** Examine the graph, "Atmospheric Carbon Dioxide". It shows atmospheric carbon dioxide levels between 1958 and 2008. The grey line is of the actual data, while the red line is the average trend.

   a. Describe the annual cycle of atmospheric carbon dioxide (grey line and inset).

   b. Describe the trend of the graph (red line).

   c. Predict the likely effect of this trend on the pH of oceans.



Credit: Robert A. Rohde, https://commons.wikimedia.org/wiki/File:Mauna_Loa_Carbon_Dioxide-en.svg

GROUP C: TEMPERATURE AND DISSOLVED CARBON DIOXIDE

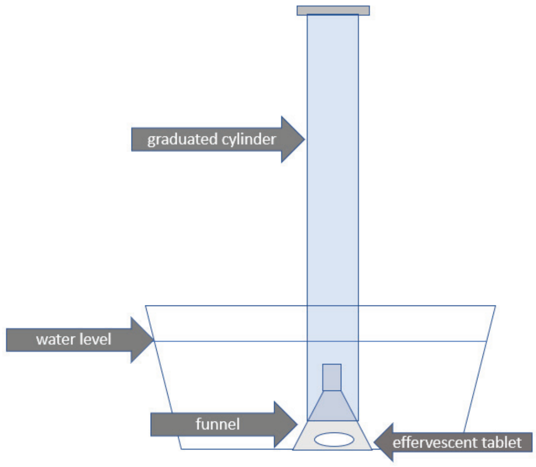
Materials

Per group:

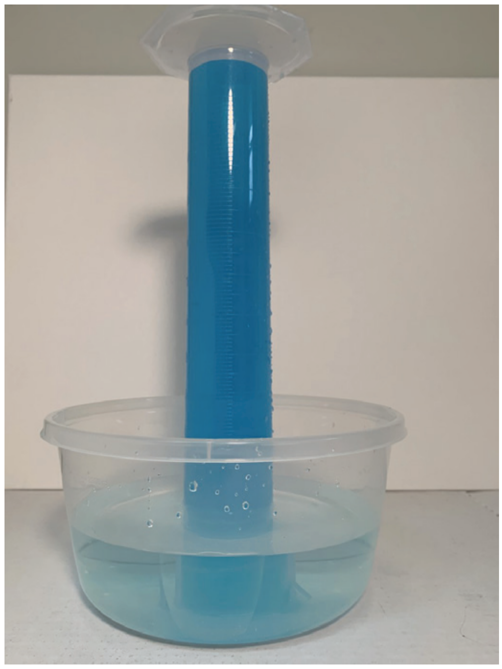
- 500 mL graduated cylinder or clear water bottle
- plastic funnel with a short stem
- plastic bin or bowl (10–15 cm [4–6 in] deep)
- cold water (approximately 10°C [50°F])
- warm water (approximately 20°C [68°F])
- hot water (approximately 30°C [86°F])
- sodium bicarbonate tablets (effervescent antacids, such as Alka-Seltzer®)
- tape
- food coloring (optional)

What to Do

1. Place the funnel near the center of the bin so that the smaller opening is turned upward.
2. Fill the bin about halfway with cold water. The funnel should be fully submerged. If not, add more water.
3. Fill the graduated cylinder all the way with cold water. Add 5–10 drops of food coloring if you have it.
4. Place your hand over the top of the graduated cylinder and quickly invert it so that your hand and the top of the cylinder are in the bin of water.
5. There can be a small air bubble in the graduated cylinder, but it is ideal if there is no air. If some air does get inside, use tape to mark where it is on the cylinder.



Credit: E.C. Robeck



Credit: L.C. Mossa

6. Keeping the cylinder underwater, move it so it is on top of the funnel. Hold the cylinder to keep it from falling over.

7. Carefully tilt the graduated cylinder and funnel and place an effervescent tablet under the funnel. Quickly stand the funnel and graduated cylinder up straight to trap the gas coming from the tablet.

8. Take observations of what you see happening.

9. Once the tablet has completely dissolved, measure the gas pocket that has formed in the top of the cylinder. Also note how much the water in the bowl has changed color, if you used food coloring.

10. Predict what would happen if you used warmer water. Repeat the procedure with warm water, and then with hot water.

Consider

1. Compare the results from the different water temperatures. The effervescent tablet released carbon dioxide. Each of the tablets started the same size, so how can you explain any differences that occurred with the different temperatures of water?

2. Oceans are considered carbon sinks, which means that they hold a large amount of carbon in the form of dissolved carbon dioxide.

    a. Describe how an increase in water temperature would affect the ability of the oceans to act as a carbon sink.

    b. What effect would this have on the atmosphere and air temperatures? Explain.

Extensions

1. **Testing Variables:** Predict how your results would differ if you tested saltwater instead of freshwater. If there is time, test your prediction (35 g of salt per 1000 mL of water would be similar to ocean water).

2. **Testing Variables:** Predict what would happen if you used more than one tablet at a time. If there Is time, test your prediction.

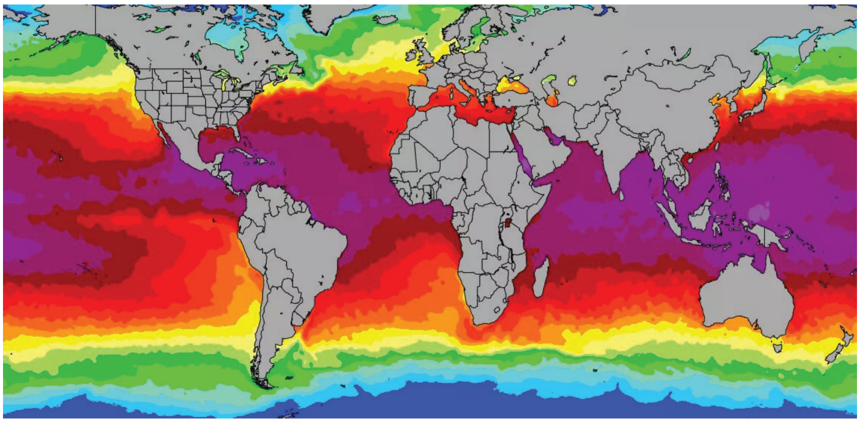
3. **Analyzing Data:** Examine the world map "Sea Temperature Readings".

    a. Describe any patterns you observe in sea temperatures.

    b. Where would you expect there to be the highest levels of dissolved carbon dioxide?

    c. Would you expect the pH of these areas to be higher or lower than areas with less dissolved carbon dioxide? Explain.

SEA TEMPERATURE READINGS



°C	0	1	3	5	7	9	11	13	15	17	19	21	24	27	30	35

°F	32	34	37	41	45	48	52	55	59	62	66	70	75	80	86	95

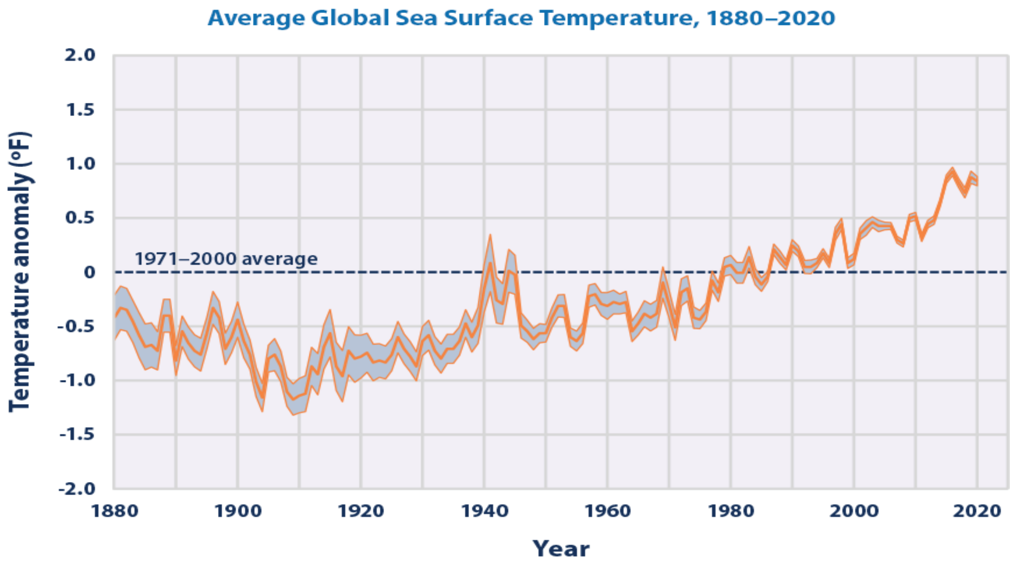
Credit: https://www.seatemperature.org/

4. Analyzing Data: Examine the graph, "Average Global Sea Surface Temperature, 1880–2020". The average was taken by using values from 1971 to 2000, and the graph shows any differences between this average (set at 0) and the average global sea temperatures each year.

a. Describe the trend of the graph.

b. Predict how the amount of dissolved carbon dioxide in oceans has likely changed.

c. Predict how the pH of oceans has changed over time.



Data source: NOAA (National Oceanic and Atmospheric Administration). 2021. Extended reconstructed sea surface temperature (ERSST.v5). Accessed February 2021.
www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Credit: EPA, Data Source: NOAA

GROUP D:
EFFECTS OF pH

Materials

Per group:

- apple cider or white vinegar
- pipette or medicine dropper
- chalk (cannot be dustless chalk or molded chalk)
- mortar and pestle (or another tool that can safely crush the chalk)
- petri dish or plastic food container
- jars containing vinegar and an item (eggshell, leaves, paper clips, apple slice, etc.)

What to Do

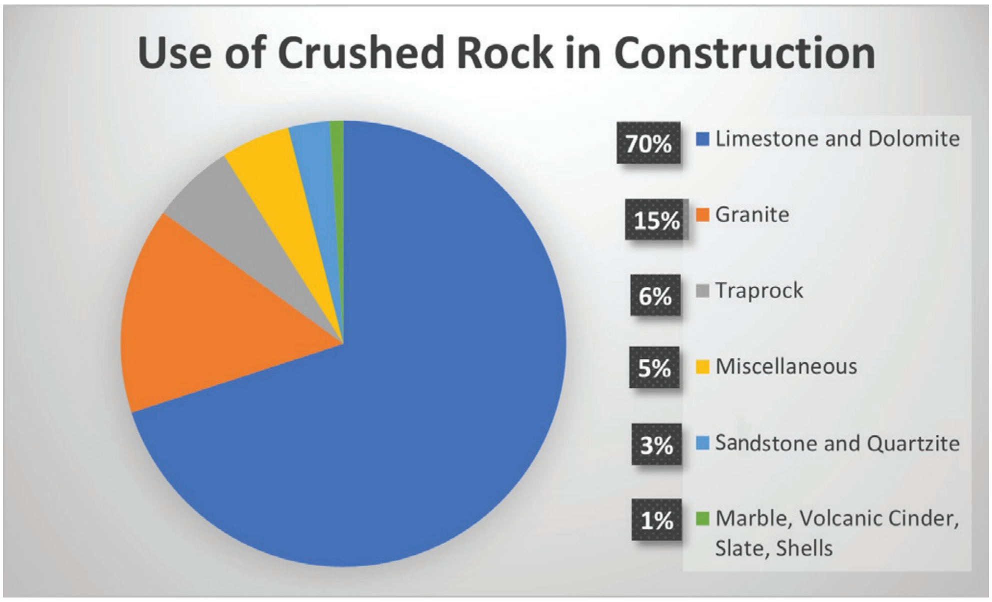
1. Test the pH of the vinegar.
2. Place a small piece of chalk into a petri dish.
3. Using a pipette, put 5 drops of vinegar on the chalk. Record your observations for one minute.
4. Add 5 more drops of vinegar to the chalk and make observations for one more minute.
5. After the minute, take the pH of the vinegar that has reacted with the chalk.
6. Rinse and dry the petri dish.
7. Crush a piece of chalk into a powder and place it in the petri dish.
8. Using a pipette, put 5 drops of vinegar on the chalk. Record your observations for one minute.
9. Add 5 more drops of vinegar to the chalk and make observations for one more minute.
10. After the minute, take the pH of the vinegar that has reacted with the chalk.
11. Observe the items that have been left in jars of vinegar. Record observations, noting how long the items have been sitting in the vinegar.

Consider

1. Compare your observations from the experiment using a piece of chalk and crushed chalk. Describe differences between your results.
2. Coral and shelled marine animals build their shells using calcium carbonate that is dissolved in seawater.
   a. Calcium carbonate is the same molecule that makes up chalk. Use this information to predict how oceans becoming more acidic will affect coral and shelled marine animals.
   b. More acidic water is able to hold less dissolved calcium carbonate. How do you think oceans becoming more acidic will affect the growth of shelled organisms?
3. Rank the items soaked in vinegar from most to least affected. Describe what evidence you used to put the items in the order you did.

Extension

1. **Analyzing Data:** Examine the graph, "Use of Crushed Rock in Construction". It shows the use of different types of rocks in construction materials for roads and buildings. Limestone and Dolomite are made of calcium carbonate. How do you think acid rain affects buildings and roads?



Credit: L.C. Mossa, Produced from data from USGS, 2020, https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-stone-crushed.pdf

SUSTAINABLE DEVELOPMENT GOALS

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INVESTIGATION 3B: ANALYZING GREENHOUSE GAS EMISSIONS

Learning Outcome: Analyze data to explain greenhouse gas emissions and the major contributors to their accumulation in the atmosphere.

Materials

Per group:

- copies of graphs within the Investigation

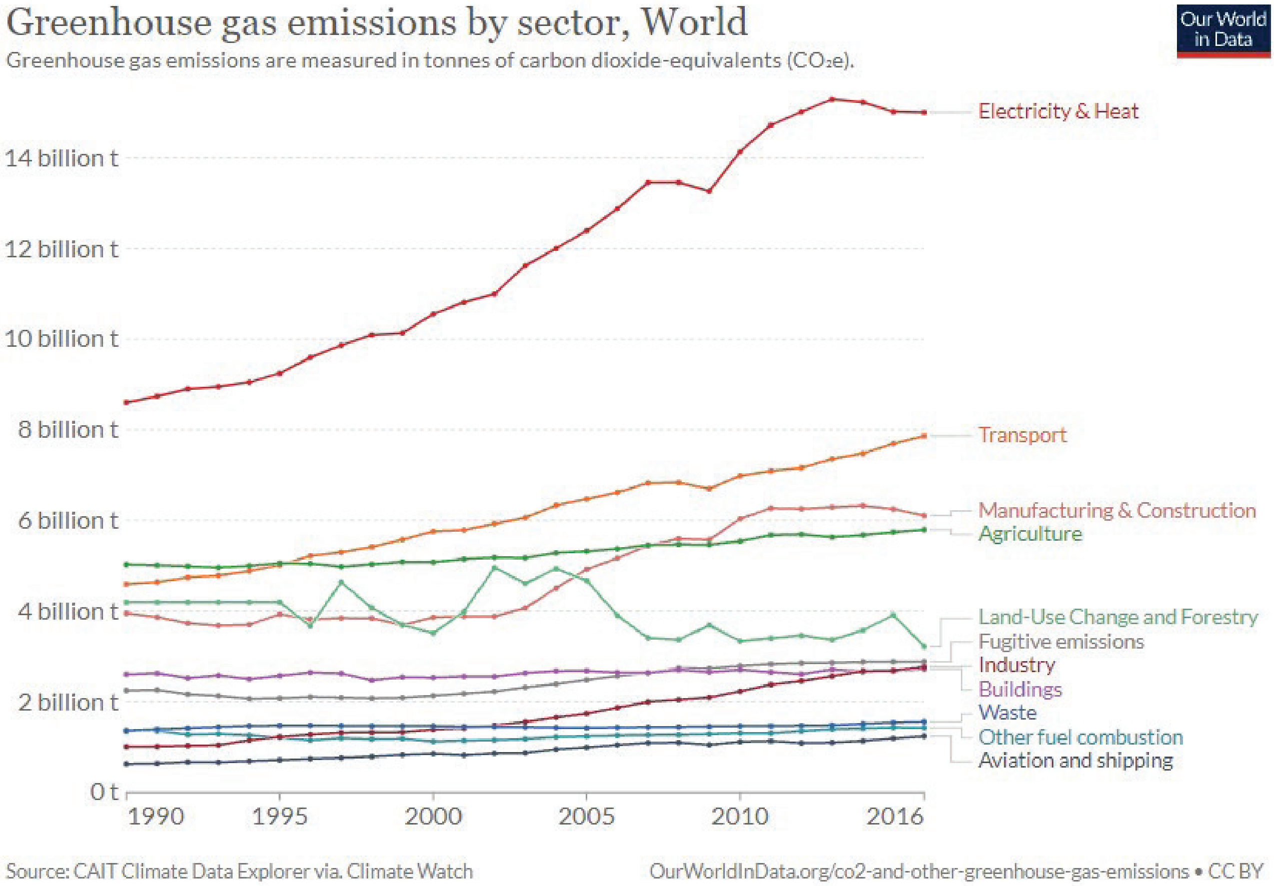
What to Do

1. Examine the graph "Greenhouse gas emissions by sector, World".

   a. Which two sectors had the greatest increases in emissions from 1990 to 2016? Why do you think this is?

   b. Which sectors decreased in emissions from 1990 to 2016? Why do you think this is?

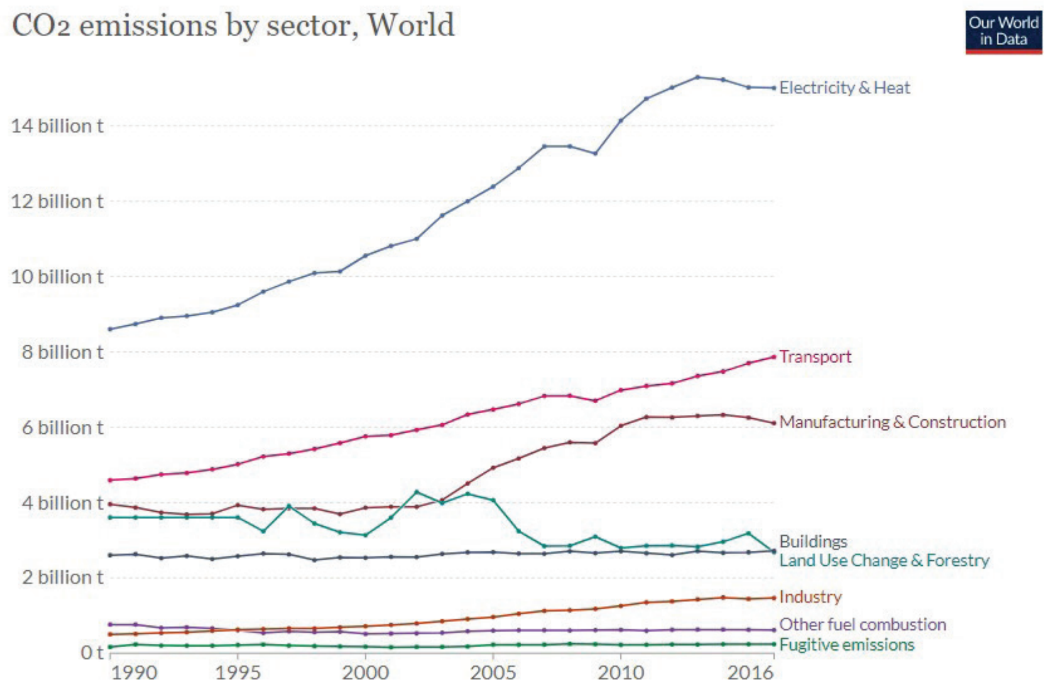
   c. Do you think all countries contribute equally to greenhouse gas emissions? Why or why not?



Credit: Our World In Data, https://ourworldindata.org/emissions-by-sector

2. Examine the graph, “CO_2 emissions by sector, World”. This graph looks only at carbon dioxide emissions.

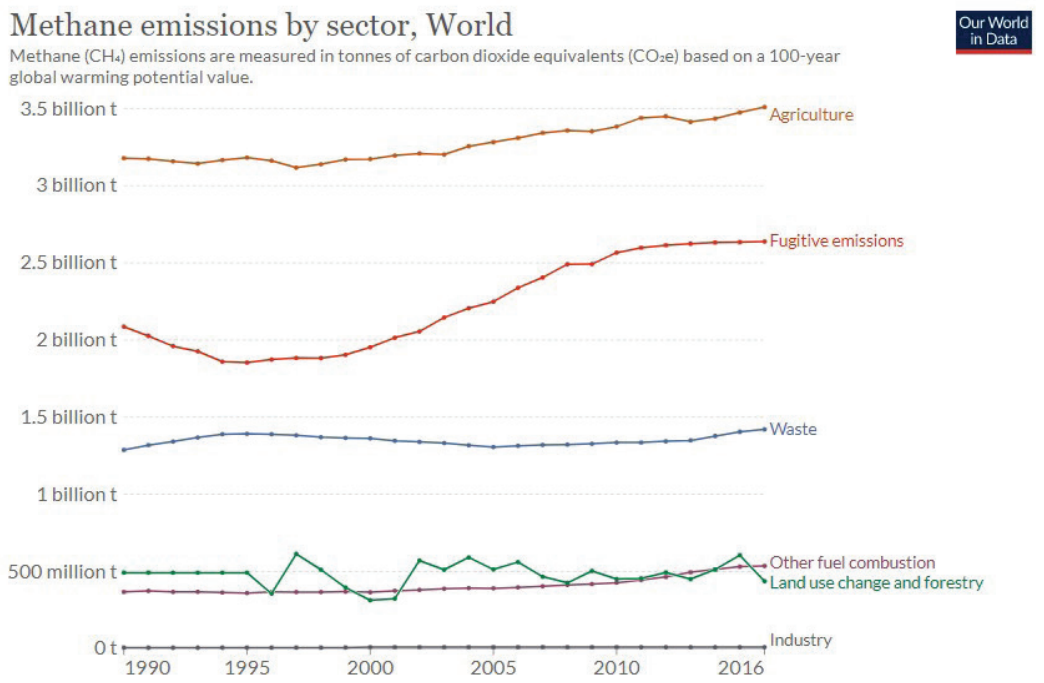
   a. Compare the trends on this graph to the trends on the total emissions graph. Describe some similarities and differences. Why do you think there are differences?



Credit: Our World In Data, https://ourworldindata.org/emissions-by-sector

3. Examine the graph, "Methane emissions by sector, World".

a. Compare the trends on this graph to the trends on the total emissions graph. Describe some similarities and differences. Why do you think there are differences?



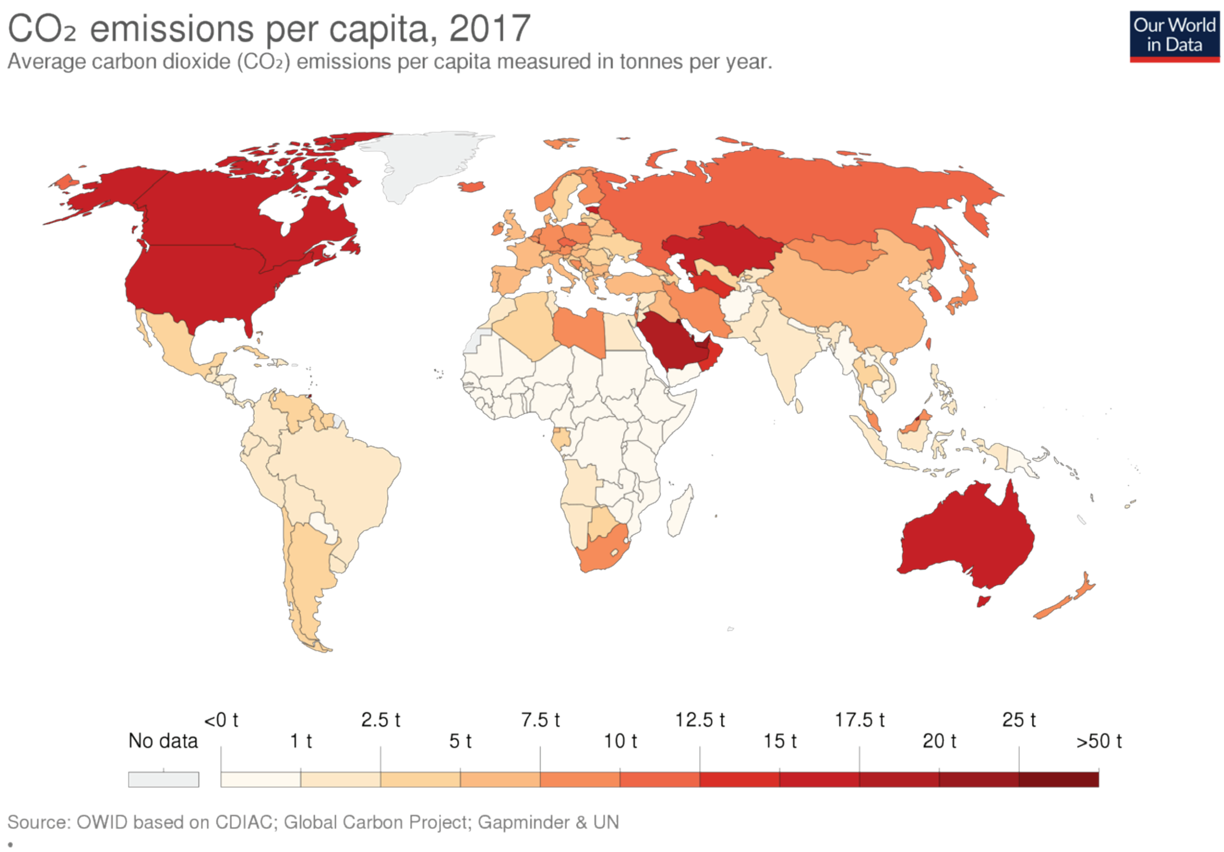
Credit: Our World In Data, https://ourworldindata.org/emissions-by-sector

Consider

1. Examine the graph, “CO_2 emissions per capita, 2017”. This map shows each country’s contribution to carbon dioxide emissions.

   a. How many countries are identified as having high carbon dioxide emissions?

   b. What are some factors that might cause a country to have greater carbon dioxide emissions than others?



Credit: Our World In Data, Creative Commons

Extensions

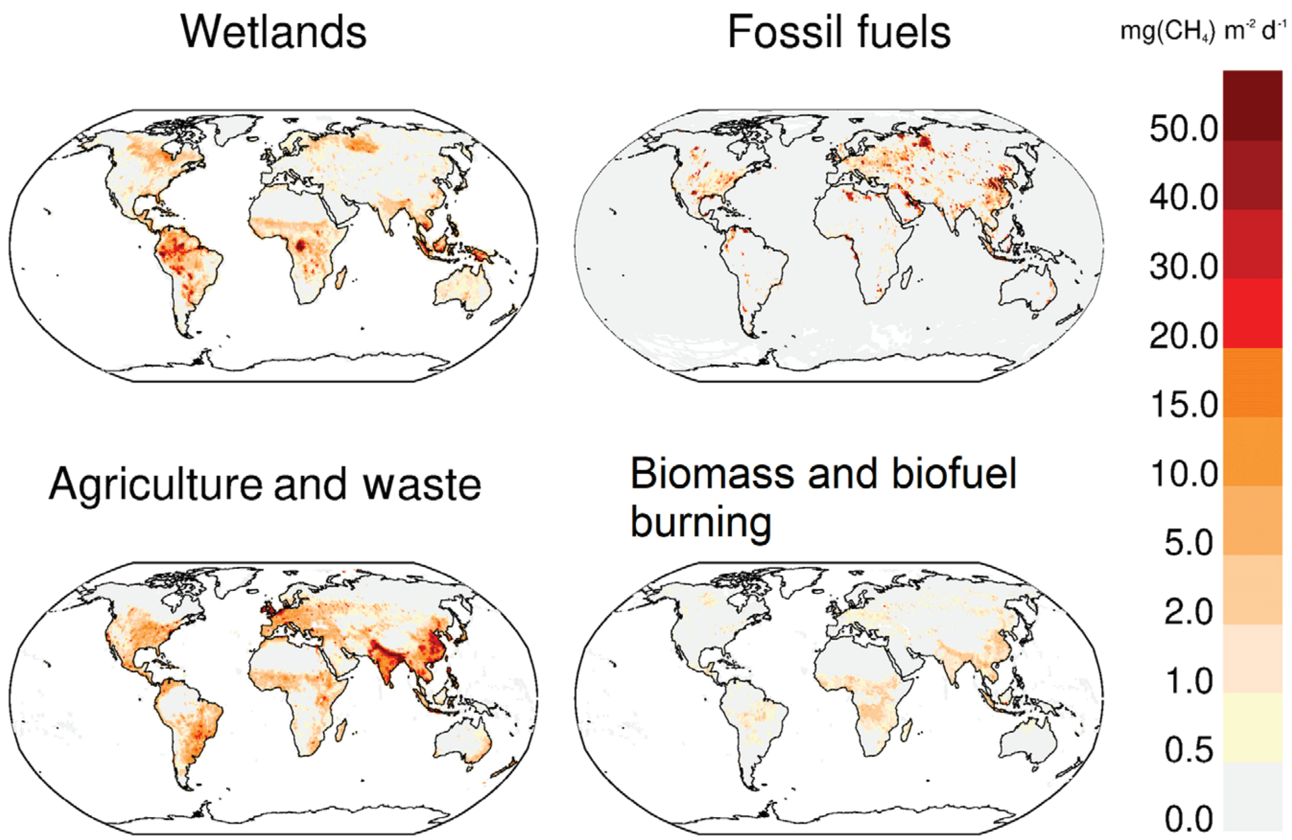
1. **Analyzing Data:** There are several sources of methane (CH_4) emissions. As shown in the map, “Methane Emissions by Sector,” these include Wetlands; Fossil Fuels; Agriculture and waste; and Biomass and biofuel burning. Examine the maps comparing methane emissions from various industries and natural sources around the world.

   a. Which sector(s) appear to contribute the most methane to the atmosphere?

b. Which industry has methane emissions most similar to carbon dioxide emissions? Explain your reasoning using evidence from the maps.

c. Wetlands are natural sources of methane. Why are methane emissions of concern if methane is produced naturally?

METHANE EMISSIONS BY SECTOR

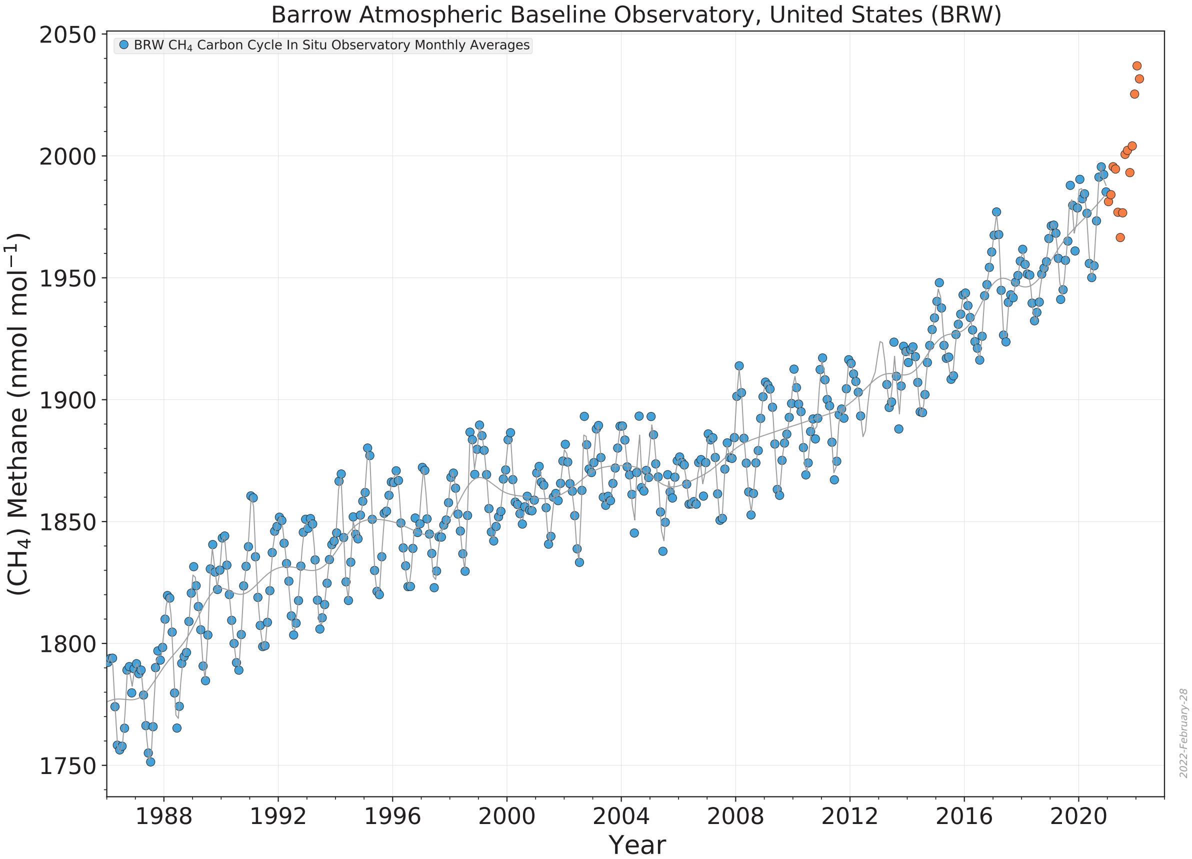


Credit: Modified from Creative Commons, **https://commons.wikimedia.org/wiki/File:Map_of_methane_emissions_from_four_source_categories.png**

2. **Analyzing Data:** Permafrost is land near the North Pole where the ground stays frozen year-round. Permafrost holds large stores of methane left over from decomposition that was occurring in the soil before the land froze over. As the Earth's climate warms, permafrost has started to thaw.

   a. Use the graph, "Atmospheric Methane Levels near Barrow, Alaska," to describe the effect of permafrost thawing on atmospheric methane levels.

Atmospheric Methane Levels near Barrow, Alaska



Credit: NOAA, **https://gml.noaa.gov/dv/iadv/graph.php?code=BRW&program=ccgg&type=ts(**

b. What effect do you think this methane will have on further thawing of the permafrost? Why do you think this?

ESD KIT: IMPACTS OF CLIMATE CHANGE

13 CLIMATE ACTION

Sustainable Development Goal 13: Climate Action

INVESTIGATION 4A: TESTING THE HEAT CAPACITY OF LIQUIDS

Learning Outcome: Test the heat capacity of different liquids to understand that the temperature of bodies of water changes slowly compared to air and land.

Materials

Per group:

- 1 250–500 mL (1–2 cup) heat-resistant glass measuring cup (or beaker)
- plate or tray to carry measuring cup
- 100–250 mL (½-1 cup) water, oil (e.g., vegetable, olive, peanut), and liquid soap
- 1 alcohol thermometer
- 1 hotplate (or microwave)
- boiling stones (if using a microwave, to prevent superheating)
- oven mitts
- safety goggles
- small towel

What to Do

1. Fill a heat-proof glass measuring cup (or beaker) halfway with water. Measure and record the initial temperature of the water.
2. Place the measuring cup on a hotplate. Set the hotplate to medium.
   a. If using a microwave, place a boiling chip in the water.

3. Measure and record the temperature of the water. When taking the temperature, carefully hold the thermometer near the middle of the volume of water. Do not let the thermometer sit on the bottom of the measuring cup as that will record the temperature of the glass rather than the temperature of the liquid.

   a. If using a hot plate, measure and record the temperature every 2 minutes for 10 minutes.

   b. If using a microwave, heat the water with boiling stones in 10 second increments for 1 minute 30 seconds. Measure and record the temperature every 10 seconds.

4. Use an oven mitt to carefully remove the measuring cup from the hot plate or microwave and place the measuring cup on the small towel. If using a hotplate, turn it off.

Caution: *Do not touch the glass with your bare hands. Be sure to place the measuring cup on the towel. Do not place the measuring cup on a cold surface, or the glass may shatter.*

5. Measure and record the temperature of the water every 2 minutes for another 10 minutes.

6. Repeat this procedure with each liquid provided.

Consider

1. Graph your results on the same axes. Be sure to include axis labels, a descriptive title, and a key.

2. Consider the rate at which water changes temperature versus the other liquids you tested. Make a hypothesis to describe the relative rate at which each liquid will cool down. Do you think that liquids that take longer to heat up also take longer to cool down? Why or why not?

3. How might Earth be different if a liquid other than water made up our oceans, lakes, and rivers?

   a. How might the temperature change of oceans, lakes, and rivers affect the organisms living in them?

   b. Large bodies of water moderate the climate of nearby lands, meaning being nearby an ocean, bay, or large lake helps keep the temperature of the nearby land relatively stable. How might this change if the bodies were made of something other than water?

Extensions

1. **Testing Variables:** Predict how your results might change if you used salt water instead of fresh water. Test your prediction and compare the results to that of fresh water.

2. **Testing Variables:** Predict how your results might change if you tested a larger volume of each liquid. Test your prediction and compare your results to the original volume you tested.

3. **Analyzing Data:** Go to: https://earthobservatory.nasa.gov/global-maps/MYD28M/AMSRE_SSTAn_M

   a. Before viewing the animation, study the Sea Surface Temperatures color key.

b. Play the animation and observe the Sea Surface Temperatures animation. Describe any yearly patterns or trends you see in sea surface temperature. It may help to focus your attention on a part of the ocean near where you live, or someplace else that interests you.

c. Study the color key for the Sea Surface Temperature Anomaly map.

d. Play the animation and observe the Sea Surface Temperature Anomaly animation. It may help to focus your attention on a part of the ocean near where you live, or someplace else that interests you.

e. What is happening to average sea surface temperatures? Describe any changes or trends you see over time.

f. How do the two maps compare?

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INVESTIGATION 4B: COASTAL STORMS

Learning Outcome: Design and evaluate the effectiveness of seawalls as a mitigation strategy for coastal storms.

Materials

Per group:

- clear plastic bin (approximately 35 cm x 25 cm (14 in x 10 in) and 10–15 cm (4–6 in) deep)
- water
- small dowels, toothpicks, popsicle sticks, small rocks, or other materials that can be used to build a seawall
- empty 500 mL (16.9 oz) water bottle
- ruler
- construction paper
- tape
- washable markers (different colors)
- metronome (or recording of a steady beat)
- modeling clay
- fine-grained sand (Group A)
- pebbles or coarser sand (Group B)

What to Do

(Directions follow for 2 different study groups.)

GROUP A

1. In a plastic bin, build a model beach by piling moist, fine-grained sand in a plastic bin.

   a. The highest point of the sand should be along one of the bin's shorter walls. The sand should be a little over half the height of the bin and should have a relatively flat surface along the short side of the bin.

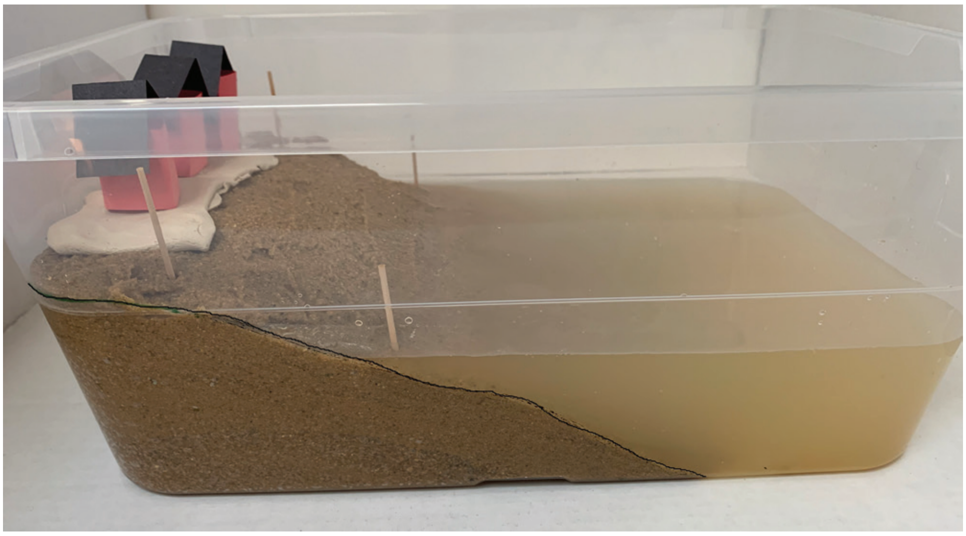
   b. Make a "hill" by angling the sand down toward the middle of the bin.

2. Use a washable marker to make an outline of the shape of the sand on the outside of the bin.

3. Add water to the bin until it comes about halfway up the sand. Push a toothpick or small dowel into the sand at the water line to mark where the exposed model beach starts.

4. Place a layer of modeling (plasticene) clay at the top of the beach to model paved surfaces, and also to prevent the houses from getting wet before waves are generated.

5. Build 2–4 small houses from construction paper. Place them on the layer of clay. Place a toothpick or small dowel to mark the location of the front of the houses



Credit: L.C. Mossa

6. Make waves using an empty water bottle.

   a. Gently lay the bottle on its side in the water, as far from the beach as possible.

   b. Push the bottle down approximately 2 cm to make a wave, then let it float up. Repeat this to make more waves at a steady rate.

   c. Using a metronome will help to keep a constant rhythm for your waves.

   d. Continue bobbing the bottle for 2 minutes to see the effects the waves have on the beach and houses.

7. Analyze the new sand profile.
    a. Use a different color marker to trace the new sand profile.
    b. Make observations of how the beach has changed, if the location of the beach has changed (i.e., how high up the water meets the sand), and if the houses have gotten wet or moved.
8. Reset the sand to its original position.
    a. Reset the toothpick indicating the water line and house locations.
    b. Replace any houses that got wet.
9. Use the available supplies to build a wall that will prevent the beach from changing. This will be a model seawall for your coastal community.
10. Make waves for another two minutes, then make observations on any changes that occurred.
11. Based on your results, determine what modifications could be made to your seawall that could make it more effective. Test one possible modification, being sure to reset the beach to its original location before testing.
12. Make waves for another two minutes, then make observations on any changes that occurred.
13. Share your design and results with the whole group.

Consider

1. Once you built the seawall, how did the changes that occurred compare to the changes in your original test?
    a. After listening to other seawall designs, what modifications would you make to your design? Why?
2. Compare the results of Group A and Group B. Did the same style of seawall work for both beaches? Why do you think this is?
3. Is your area affected by coastal flooding? If so, are there any areas in your community that would benefit from a seawall? If there are already seawalls near you, what modifications could be made to improve them?
4. Look at a map of your country. What coastal places do you visit or consider interesting? Do you think they would benefit from a seawall? How could you find out?
5. Besides building a seawall, what other variables could be changed to keep the water from flooding the houses?

Extensions

1. **Testing Variables:** Predict which is more effective: a thicker seawall or a taller seawall. Test different designs to see their effects on erosion of the beach. Be sure to rebuild the original beach before testing each time.
2. **Testing Variables:** Living seawalls are a more natural means of preventing coastal flooding and erosion. The image shows a mangrove forest on a beach in Zanzibar that acts as a seawall.

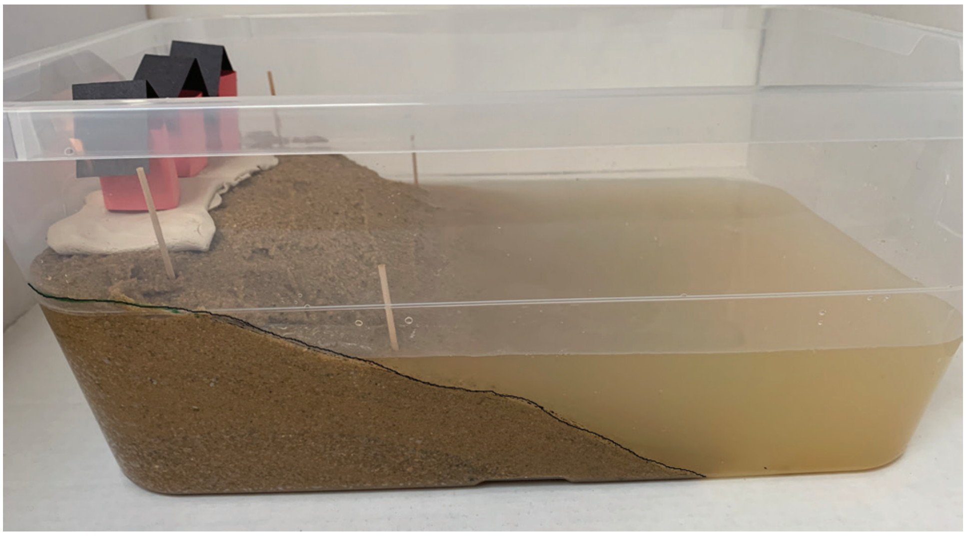
Credit: Flickr/GRID-Arendal resources library photo by Rob Barnes, CC BY-NC-SA 2.0 DEED. https://www.grida.no/resources/8701

a. How do you think plants help prevent flooding and beach erosion?

b. Use small plastic aquarium plants to construct a seawall for your beach. How does it compare the seawalls you designed in terms of preventing erosion and flooding?

GROUP B

1. In a plastic bin, build a model beach by piling moist, coarse-grained sand or pebbles in a plastic bin.
   a. The highest point of the sand should be along one of the bin's shorter walls. The sand should be a little over half the height of the bin and should have a relatively flat surface along the short side of the bin.
   b. Make a "hill" by angling the sand down toward the middle of the bin.
2. Use a washable marker to make an outline of the shape of the sand on the outside of the bin.
3. Add water to the bin until it comes about halfway up the sand. Push a toothpick or small dowel into the sand at the water line to mark where the exposed model beach starts.
4. Place a layer of modeling (plasticene) clay at the top of the beach to model paved surfaces, and also to prevent the houses from getting wet before waves are generated.
5. Build 2–4 small houses from construction paper. Place them on the layer of clay. Place a toothpick or small dowel to mark the location of the front of the houses



Credit: L.C. Mossa

Make waves using an empty water bottle.

   a. Gently lay the bottle on its side in the water, as far from the beach as possible.
   b. Push the bottle down approximately 2 cm to make a wave, then let it float up. Repeat this to make more waves at a steady rate.
   c. Using a metronome will help to keep a constant rhythm for your waves.
   d. Continue bobbing the bottle for 2 minutes to see the effects the waves have on the beach and houses.

6. Analyze the new sand profile.
   a. Use a different color marker to trace the new sand profile.
   b. Make observations of how the beach has changed, if the location of the beach has changed (i.e., how high up the water meets the sand), and if the houses have gotten wet or moved.
7. Reset the sand to its original position.
   a. Reset the toothpick indicating the water line and house locations.
   b. Replace any houses that got wet.
8. Use the available supplies to build a wall that will prevent the beach from changing. This will be a model seawall for your coastal community.
9. Make waves for another two minutes, then make observations on any changes that occurred.
10. Based on your results, determine what modifications could be made to your seawall that could make it more effective. Test one possible modification, being sure to reset the beach to its original location before testing.
11. Make waves for another two minutes, then make observations on any changes that occurred.
12. Share your design and results with the whole group.

Consider

1. Once you built the seawall, how did the changes that occurred compare to the changes in your original test?
2. After listening to other seawall designs, what modifications would you make to your design? Why?
3. Compare the results of Group A and Group B. Did the same style of seawall work for both beaches? Why do you think this is?
4. Is your area affected by coastal flooding? If so, are there any areas in your community that would benefit from a seawall? If there are already seawalls near you, what modifications could be made to improve them?
5. Look at a map of your country. What coastal places do you visit or consider interesting? Do you think they would benefit from a seawall? How could you find out?
6. Besides building a seawall, what other variables could be changed to keep the water from flooding the houses?

Extensions

1. **Testing Variables:** Predict which is more effective: a thicker seawall or a taller seawall. Test different designs to see their effects on erosion of the beach. Be sure to rebuild the original beach before testing each time.
2. **Testing Variables:** Living seawalls are a more natural means of preventing coastal flooding and erosion. The image shows a mangrove forest on a beach in Zanzibar that acts as a seawall.

Credit: Flickr/GRID-Arendal resources library photo by Rob Barnes, CC BY-NC-SA 2.0 DEED. https://www.grida.no/resources/8701

a. How do you think plants help prevent flooding and beach erosion?

b. Use small plastic aquarium plants to construct a seawall for your beach. How does it compare the seawalls you designed in terms of preventing erosion and flooding?

ESD KIT: IMPACTS OF CLIMATE CHANGE

13 CLIMATE ACTION

Sustainable Development Goal 13: Climate Action

INVESTIGATION 5A: ICE MELTING, THERMAL EXPANSION, AND SEA LEVEL RISING

Learning Outcome: Determine how heat and ice melting can contribute to sea level rise by observing and testing variables.

Materials

Per group:

- plastic bin [approximately 35 cm x 25 cm (14 in x 10 in) and 10–15 cm (4–6 in) deep]
- closed cell foam block (approximately half the height and length of the bin)
- desk lamp
- saltwater [35 g salt/L of water (1/3 cup of salt per 4 1/3 cup of water)]
- large ice block containing food coloring
- washable marker
- ruler
- weight (optional)
- mass scale (optional)

What to Do

(Directions follow for 2 different study groups.)

GROUP A: GLACIERS

In this Investigation, you will model a glacier.

1. Place a foam block at one end of the plastic bin.
2. Measure the length, width, and height of the ice block. If you have a scale, take the mass of the ice block
3. Place the ice block on top of the foam block.
4. Fill the bin with saltwater so it comes about halfway up the foam block.
5. Mark the water level on the foam block and on the side of the bin. Measure the water level using a ruler.
6. Set up the lamp so that it is directly over the block of ice.
7. Take measurements every 5 minutes for 30 minutes.
    a. Mark the water level.
    b. Measure the length, width, and height of the ice block. If you have a scale, take the mass of the ice block and quickly return it to the foam block. Observe any changes in shape.
    c. If the ice contains food coloring, observe where the water from the ice goes.
8. Discuss your results with the whole group. As groups share, consider differences between the results of the iceberg compared with the glacier.

Consider

1. Graph the water height over time. Make sure your graph has a descriptive title and labeled axes.
2. Compare the results from glaciers and icebergs.
    a. Which melted faster? Why do you think this is?
    b. Which contributed more to a rise in water level? Why do you think this is?

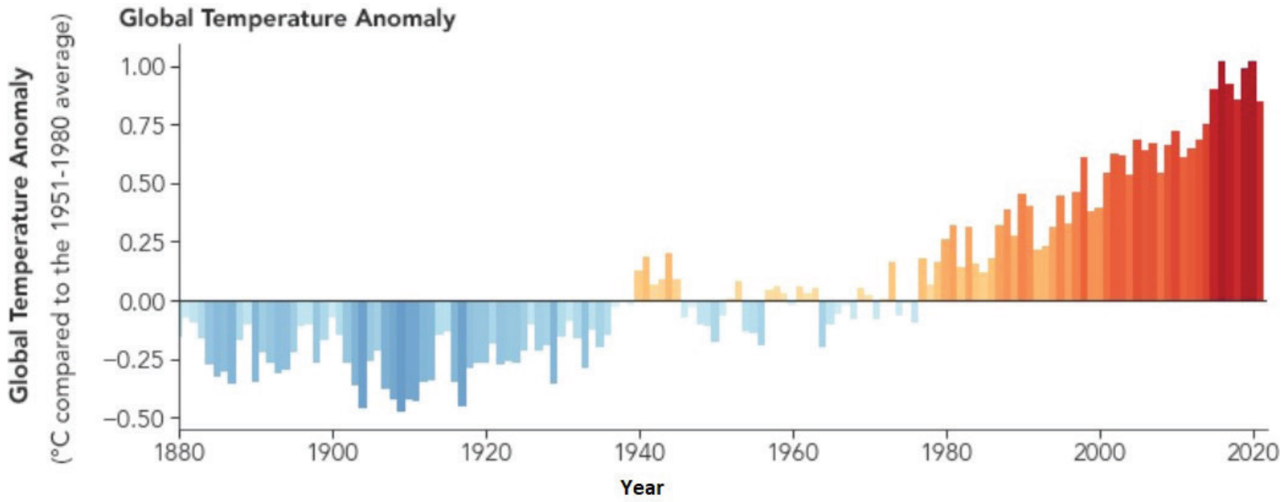
Extension

1. **Analyzing Data:** The graph “Global Temperature Anomaly” represents Earth’s average temperature (taken between 1951 and 1980) as the x-axis, while the bars show how much Earth’s average temperature deviated from that average each year. The graph “Cumulative Mass Change of Glaciers Over Time” shows the total change in mass of glaciers found on different landmasses in meters of water equivalent (m w.e), a unit that shows mass loss. Meters of water equivalent represents the volume of water that would be obtained from the melting snow or ice and is used to compare different glaciers to normalize measured thicknesses for different snowpack densities.
    a. Describe the trend in Earth’s average temperature from 1940–2020.
    b. Which glaciers have been most affected by the change in Earth’s average temperature between 1940–2020? How can you tell? Use evidence from the graph to support your answer.

c. Which glaciers have been least affected by a rise in Earth's average temperature? Use evidence from the graph to support your answer.

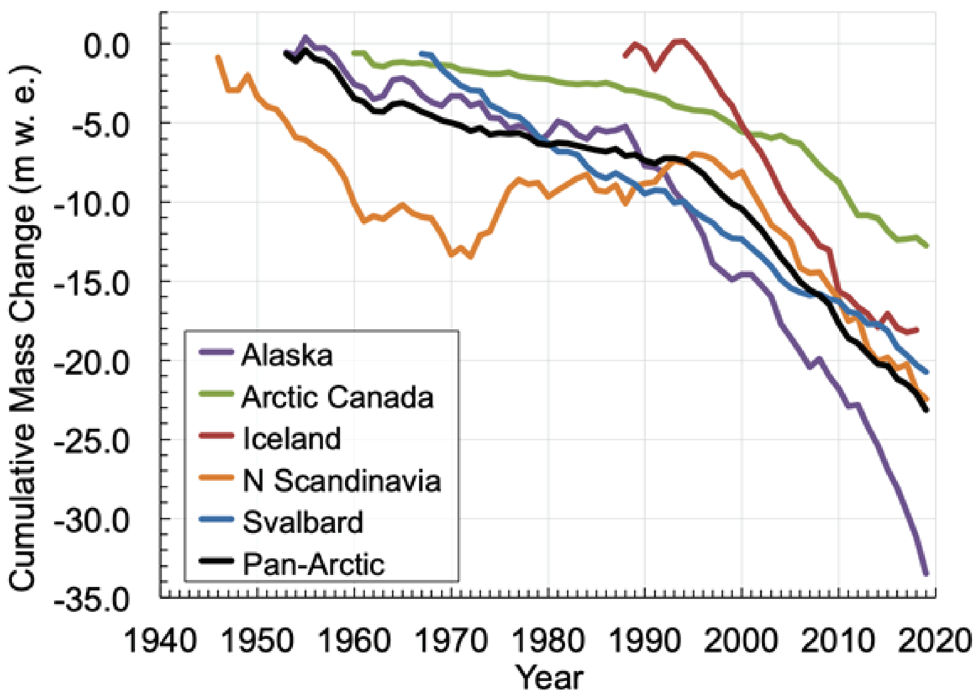
d. The rate of change of the glaciers is shown by how steep the lines are. Why do you think not all glaciers are melting at the same rate?

e. Glaciers are found on land. How does their melting contribute to sea level rising?



Credit: NASA, https://earthobservatory.nasa.gov/images/147794/2020-tied-for-warmest-year-on-record

CUMULATIVE MASS CHANGE OF GLACIERS OVER TIME



Credit: NOAA, https://arctic.noaa.gov/Report-Card/Report-Card-2020/ArtMID/7975/ArticleID/906/Glaciers-and-Ice-Caps-Outside-Greenland

GROUP B: ICEBERGS

In this Investigation, you will model an iceberg.

1. Place the foam block at one end of the plastic bin.
2. Fill the bin with saltwater so it comes about 1/3 up the foam block. You may need to place an object on the foam block to prevent it from floating.
3. Measure the length, width, and height of the ice block. If you have a scale, take the mass of the ice block.
4. Place the ice block in the water.
    a. Observe the water level as you place the ice block into the water.
    b. If needed, add more saltwater until it comes halfway up the foam block.
    c. Mark the level of the water on the foam block and on side of the bin. Measure the water level with a ruler.
    d. Measure how much of the ice block is above the water.
5. Set up the lamp so that it is directly over the block of ice. Be careful not to bump the bin so that the ice stays directly under the lamp.
6. Take measurements every 5 minutes for 30 minutes.
    a. Mark the water level on the foam block and on the side of the bin.
    b. Measure the length, width, and height of the ice block. If you have a scale, take the mass of the ice block and quickly return to the water under the light. Observe any changes in shape.
    c. Measure how much of the ice block is above the water.
    d. If the ice contains food coloring, observe where the water from the ice goes.
7. Discuss your results with the whole group. As groups share, consider differences between the results of the iceberg compared with the glacier.

Consider

1. Graph the water height over time. Make sure your graph has a descriptive title and labeled axes.
2. Compare the results from glaciers and icebergs.
    a. Which melted faster? Why do you think this is?
    b. Which contributed more to a rise in water level? Why do you think this is?

Extension

1. **Analyzing Data:** Antarctica and Greenland are both covered by ice sheets, also known as continental glaciers. The graphs “Land Ice in Antarctica” and “Land Ice in Greenland” show the change in mass of each in Gigatons (Gt) from 2002–2022. The gap in the graphs represents a time when there was no data collection taking place.
    a. Which ice sheet has lost more mass over this 20-year period? Use evidence from the graph to support your answer. Why do you think that location has lost more ice mass?

b. Why do you think the lines have small peaks and valleys?

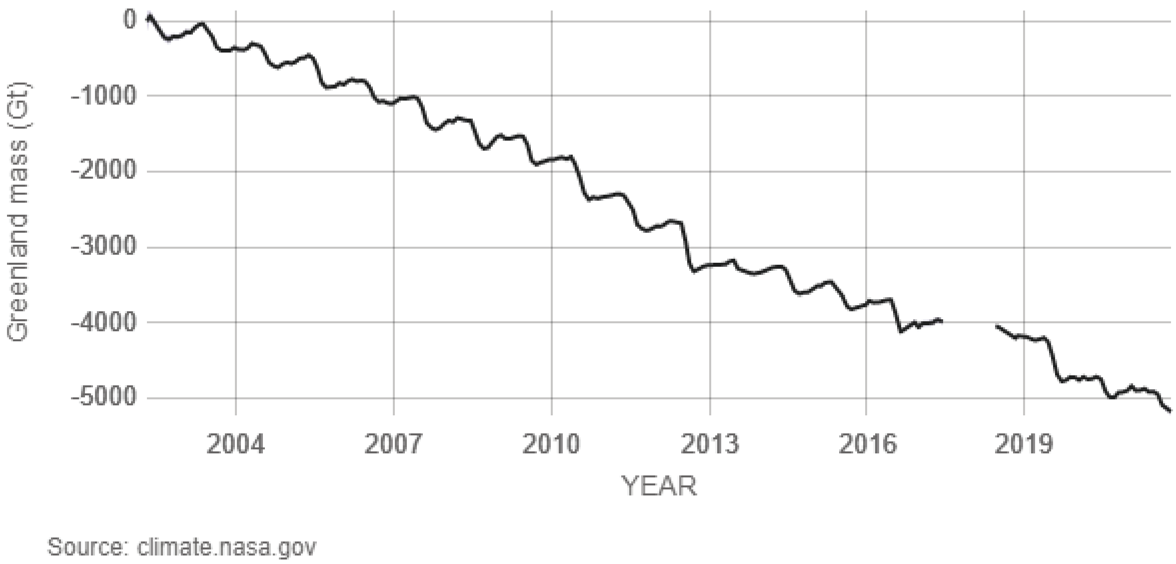
c. Predict what the graphs might look like during the period when data was not being collected. Why do you think this?

d. Given these trends, predict how a graph of the number of icebergs around Greenland and Antarctica over time might look. Explain your answer.

LAND ICE IN ANTARCTICA

Credit: NASA, https://climate.nasa.gov/vital-signs/ice-sheets/

LAND ICE IN GREENLAND



Credit: NASA, https://climate.nasa.gov/vital-signs/ice-sheets/

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INVESTIGATION 5B: MITIGATION OF COASTAL FLOODING

Learning Outcome: Analyze data and maps on coastal flooding to understand the impact this environmental change will have on people in the future.

Materials

Per group:

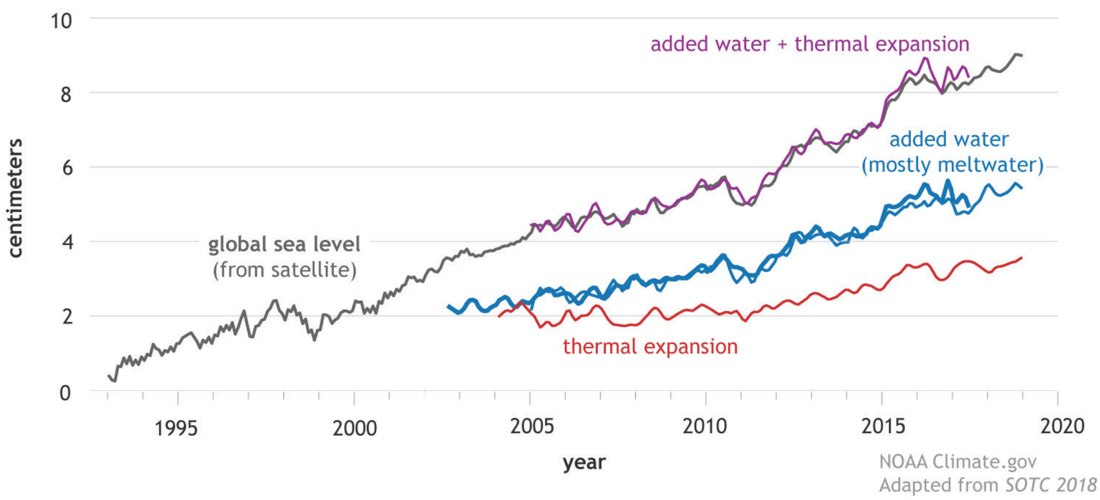
- graphs
- maps
- calculator (optional)

What to Do

1. Examine the graph, "Contributors to global sea level rise (1993–2018)". It shows how sea level has changed due to thermal expansion and meltwater. Which factor had the greatest contribution to sea level rise? How can you tell?

2. Notes for the Facilitator: Meltwater has contributed more to sea level rise than thermal expansion. The line for meltwater has a steeper slope and so a greater increase (2 cm to almost 6 cm) in the same time that thermal expansion has contributed less than 2 cm to sea level rise.

Contributors to global sea sea level rise (1993-2018)



Credit: NOAA

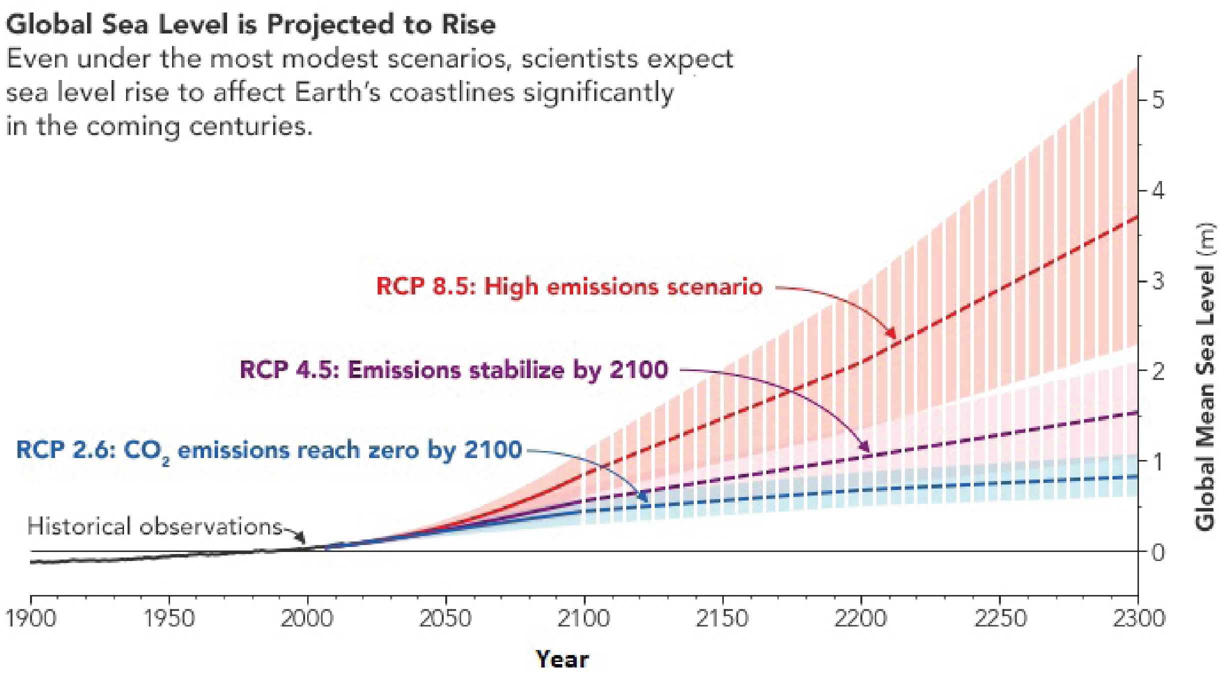
3. Examine the graph, "Global Sea Level is Projected to Rise". It shows projected sea level rise based on different scenarios.

  a. What do you think the striped areas around each line on the graph represent? What information do these areas give you that the line alone does not?

  b. Approximately how much is sea level expected to rise if carbon dioxide emissions are eliminated?

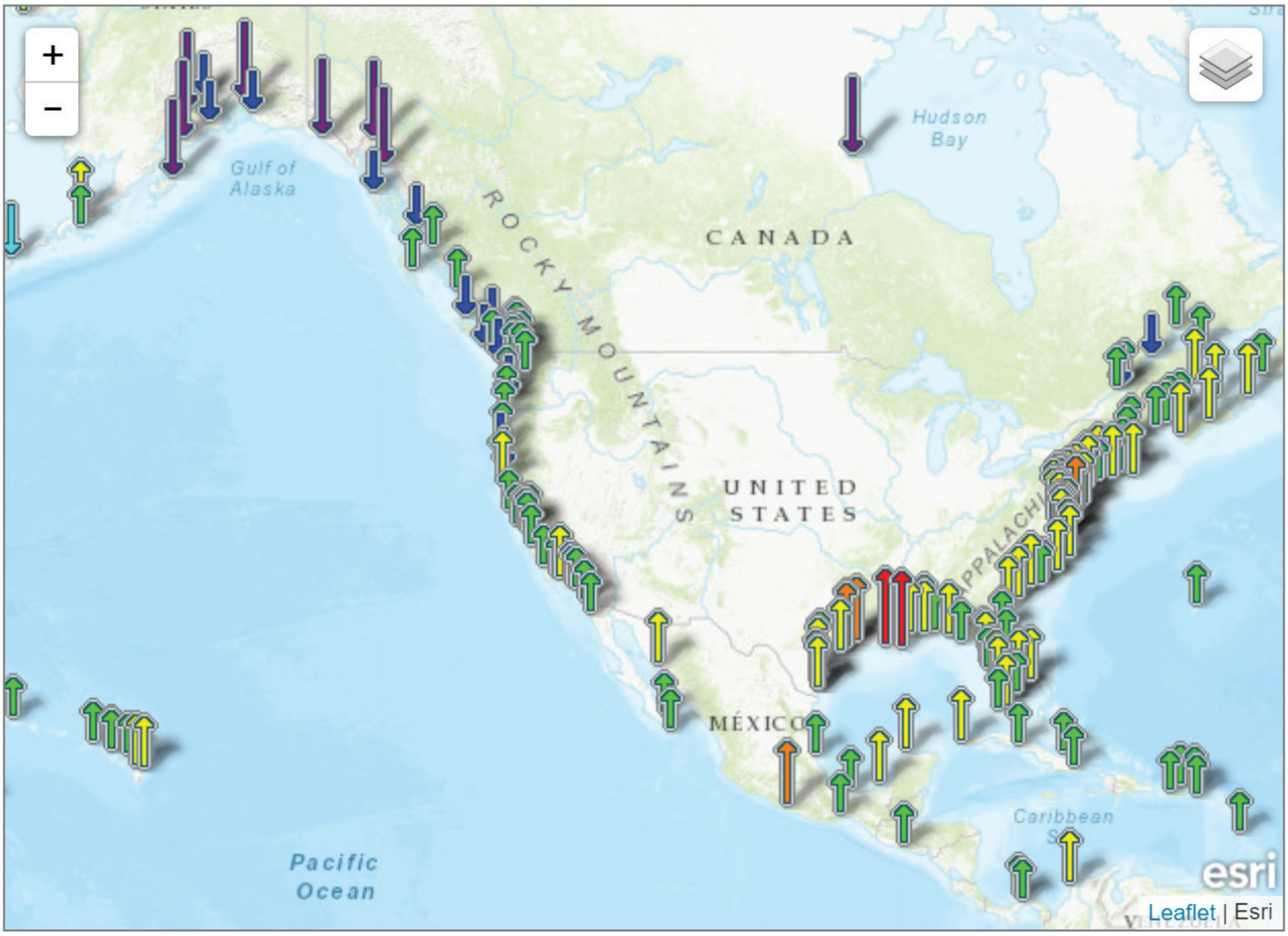
  c. Approximately how much is sea level expected to rise if carbon dioxide emissions are reduced?

  d. Approximately how much is sea level expected to rise if carbon dioxide emissions remain high?



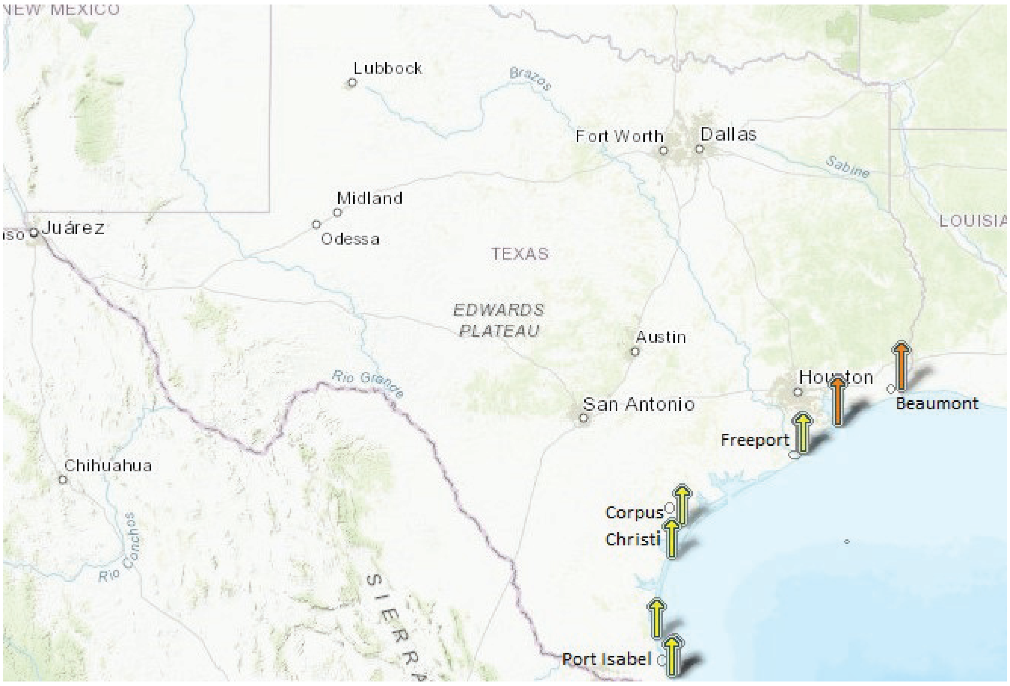
Credit: Modified from NOAA

4. The map shows how the coastline of the United States is being affected by sea level rise. These measurements were taken using a tide gauge since 1992. The arrows indicate the amount of change that has occurred in the tide gauge readings. Which coast is more negatively affected: East or West? How can you tell?

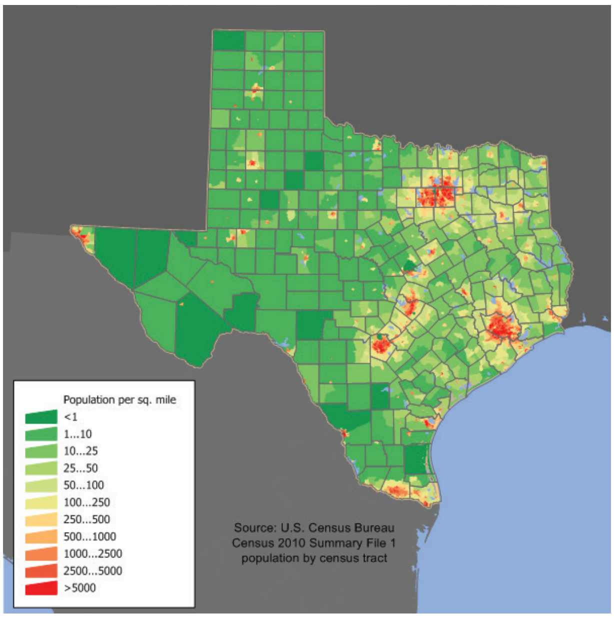


Credit: NOAA

5. Zooming in on the state of Texas, we see predicted sea level rise. The second map shows the population of Texas. Are there heavily populated areas that will be affected by coastal flooding as sea level rises? What effects will coastal flooding have on the more heavily populated areas?



Credit: Modified from NOAA



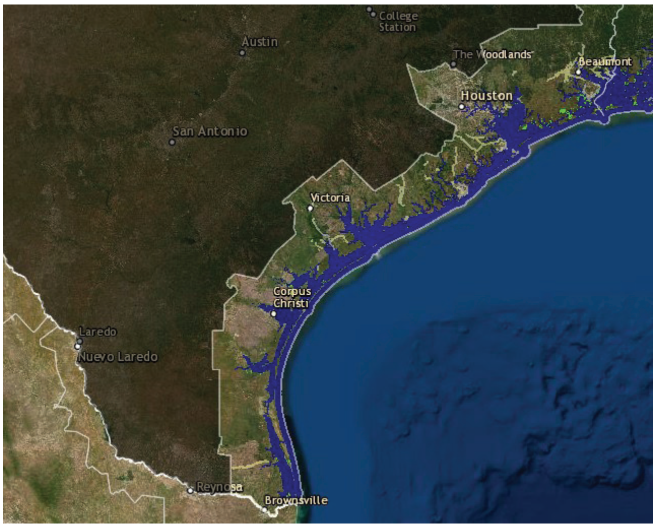
Credit: Creative Commons, https://commons.wikimedia.org/wiki/File:Texas_population_map.png

6. Compare the following maps, "Current Sea Level" and "Predicted Sea Level if Carbon Dioxide Emissions are Reduced". Current water levels are shown in blue, while predicted moderate sea level rise (1.5 m (5 ft)) is shown in light blue.

    a. What areas are currently most affected by a rise in sea level?

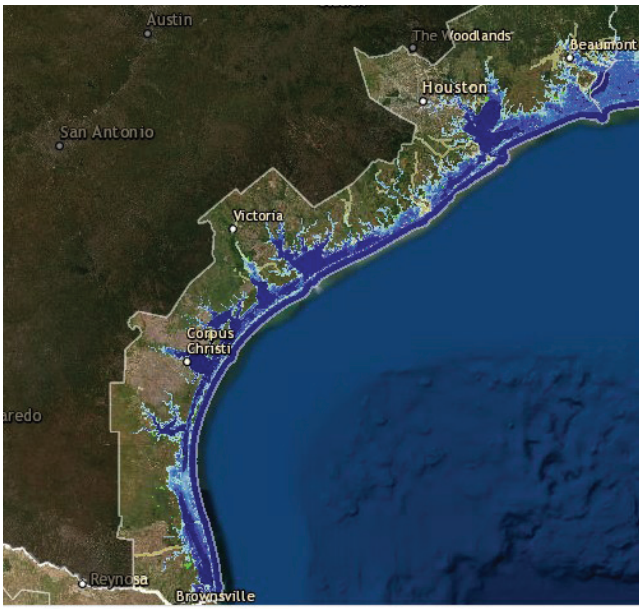
    b. Are these heavily populated areas? How might sea level rise affect heavily populated areas versus smaller towns or rural areas?

CURRENT SEA LEVEL



Credit: NOAA

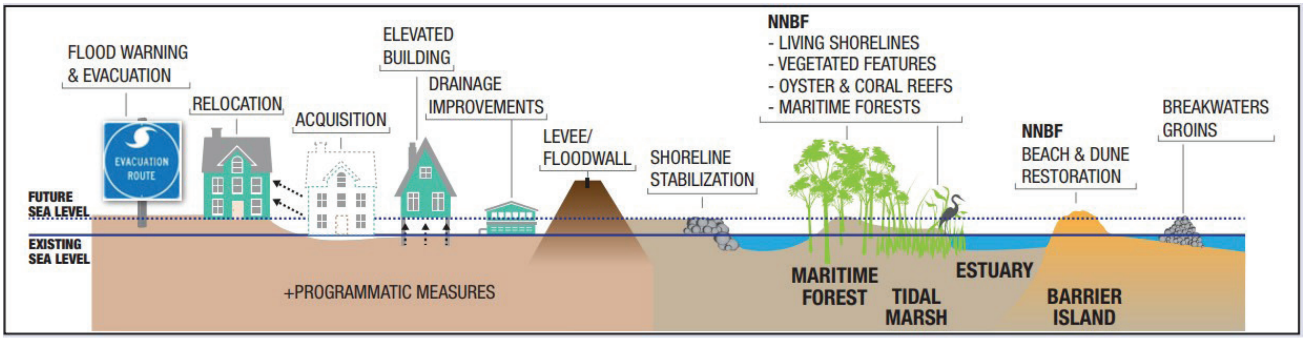
PREDICTED SEA LEVEL IF CARBON DIOXIDE EMISSIONS ARE REDUCED, ESTIMATED +1.5M ABOVE CURRENT SEA LEVEL



Credit: NOAA

Consider

1. Cities in Texas have focused on Structural Measures to adapt to more frequent coastal flooding. This includes acquisition and relocation, as well as elevated dwellings and drainage improvement, shown in the image below.
   a. Why are these considered adaptation strategies rather than mitigation strategies?
   b. Would the other strategies shown in the image be adaptations or mitigation strategies? Explain why you think so.



Source: U.S. Army Corps of Engineers, North Atlantic Coast Comprehensive Study: Resilience Adaptation to Increasing Risk, January 2015, p. 7, https://www.nad.usace.army.mil/Portals/40/docs/NACCS/NACCS_main_report.pdf

Extensions

1. **Testing Variables:** In Investigation 4, you looked at some strategies for mitigating coastal storm damage.
   a. Which of those strategies could also be used for coastal flooding mitigation?
   b. If there is time, test some other strategies shown in the diagram above, or test your own ideas. Use the procedure from Investigation 4.
   c. Compare the results to determine which strategies seem most effective.
2. **Applying Concepts:** Use this site to analyze current or potential effects of sea level rise on an area near you: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool
3. Using *Scratch*®: *Scratch*® project on sea level rise: https://scratch.mit.edu/projects/585163046/
   It uses data from climate.gov; learners can remix it and/or use the data for their own visual representation of sea-level rise.

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13 CLIMATE ACTION

Sustainable Development Goal 13: Climate Action

INVESTIGATION 6A1: ALBEDO

Learning Outcome: Measure temperature change of different colored materials to describe the effect of albedo on heat absorption versus reflection.

Materials

Per group:

- 3 pieces of paper (white, black, and another color)
- foil
- 4 pieces of cardboard
- 4 alcohol bulb thermometers
- sunny area (or desk lamp)
- light meter (such as: https://amzn.to/3NkLwXz)
- timer
- tape (optional)

What to Do

1. Cut 15 cm (6 inch) squares of foil, white paper, black paper, and colored paper.
2. Cut four 15 cm (6 inch) squares of corrugated cardboard.
3. Place all four pieces of cardboard near each other in a sunny area (alternatively, you can position a lamp directly over them so that it is equidistant from the four setups).
4. Set a thermometer on each piece of cardboard so that the bulb rests in the middle of it.
   a. Be sure that the numbers on the thermometer are facing up so they can be read easily.

  b. You may need to use tape to hold the thermometer in place.

5. Place one of the squares of paper or foil on top of each piece of cardboard.

6. Take the initial temperature of each setup and start the timer.

7. Use the light meter to get a reading of how much light is being reflected by each paper. Hold the light meter 2 cm (1 in.) above the paper to take the reading. Be sure to avoid casting a shadow from the light meter onto the paper as you take the reading.

8. Take the temperature of each setup every 3 minutes for 15 minutes.

Consider

1. Graph your results. Be sure to label the axes and provide a descriptive title for your graph.

2. Which setup warmed the fastest? The slowest? Why do you think this is?

3. Why do you think we placed cardboard under the papers? How might the results have been affected if we set the papers directly on the ground?

4. What other factors could affect the temperature of a material besides color?

5. How might the albedo of materials on a building affect the temperature of the building's interior?

6. How might the albedo of surfaces on the Earth affect the temperature of the atmosphere?

Extensions

1. **Testing Variables:** Identify at least three outdoor surfaces for which you could safely test the effect of albedo on surface temperature. The surfaces need to be flat so that you can set an ice cube on each. Use the light meter to measure how much light each reflects. Make sure all three surfaces get the same amount of sunlight.

   a. Predict which surface would cause an ice cube to melt the fastest. Explain why you think this. Place ice cubes of the same size on each surface and time how long it takes each to melt. Analyze your data in terms of how much light each surface reflected versus how long it took for the ice cube to melt.

   b. If you have an infrared thermometer, take the temperatures of each surface before you test it. Alternatively, you can touch each surface to see if there is a noticeable difference in temperature.

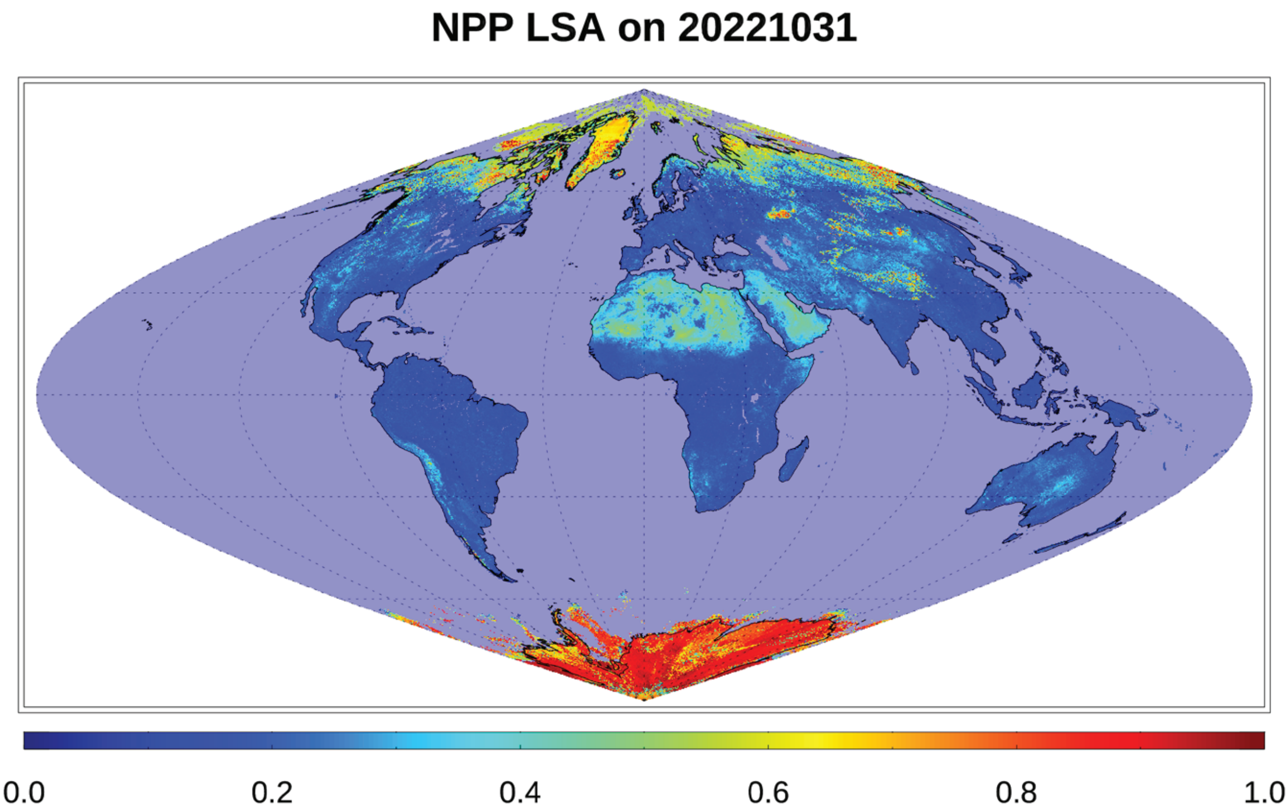
2. **Analyzing Data:** Examine the map, "Suomi NPP VIIRS Global Land Surface Albedo".

   a. What parts of the world have the highest albedo? Consider the type of environment in these locations. Discuss why the albedo in these places might higher than other places.

   b. What parts of the world have the lowest albedo? Consider the type of environment in these locations. Discuss why the albedo in these places might be lower than other places.

   c. Choose two areas for which there is no data. Predict the albedo for these areas. Explain your choices and your predictions.

d. The data to make this map was taken in February. Predict what areas might have a different albedo if the data were taken in July. Why do you think this?



Credit: NOAA, https://www.ospo.noaa.gov/Products/land/lsa/index.html

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INVESTIGATION 6A2: LOGGING TEMPERATURE AUTOMATICALLY USING A MICRO:BIT

Learning Outcome: Log the temperature change of different colored materials to describe the effect of albedo on heat absorption versus reflection.

Materials

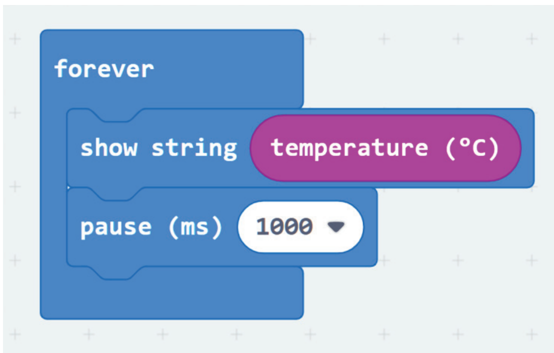
Per group:

- 3 pieces of paper (white, black, and another color)
- 3 pieces of cardboard
- 1 micro:bit V2 (some other micro:bits do not support data logging)
- 1 3 V battery pack for the micro:bit
- laptop or computer to program the micro:bit (can be shared by groups)
- sunny area (or desk lamp)
- light meter (such as: https://amzn.to/3NkLwXz)
- timer
- tape (optional)

What to Do

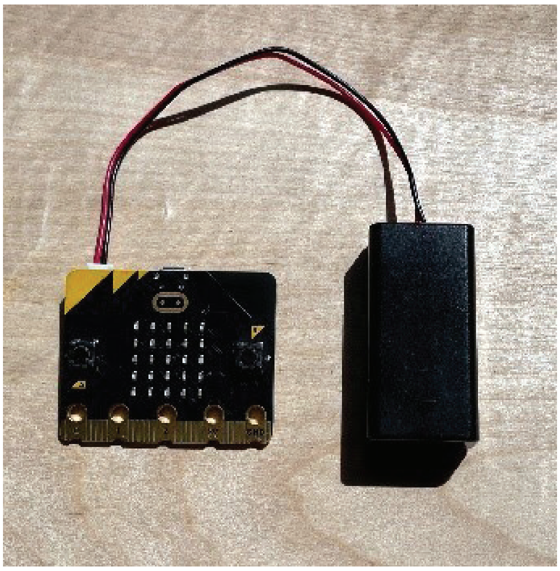
1. The micro:bit has a temperature sensor built in. Before setting up the Investigation, the micro:bit needs a program to collect temperature data. Go to the MakeCode site: https://makecode.microbit.org/

   a. Start with a short sample program to test the micro:bit. Write this code in MakeCode. Connect the micro:bit to the computer using a USB cable to download the program.



Credit: MakeCode, https://makecode.microbit.org/

   - Attach a 3 V battery pack so that you can disconnect the micro:bit from your computer while still allowing the program to continue to run.

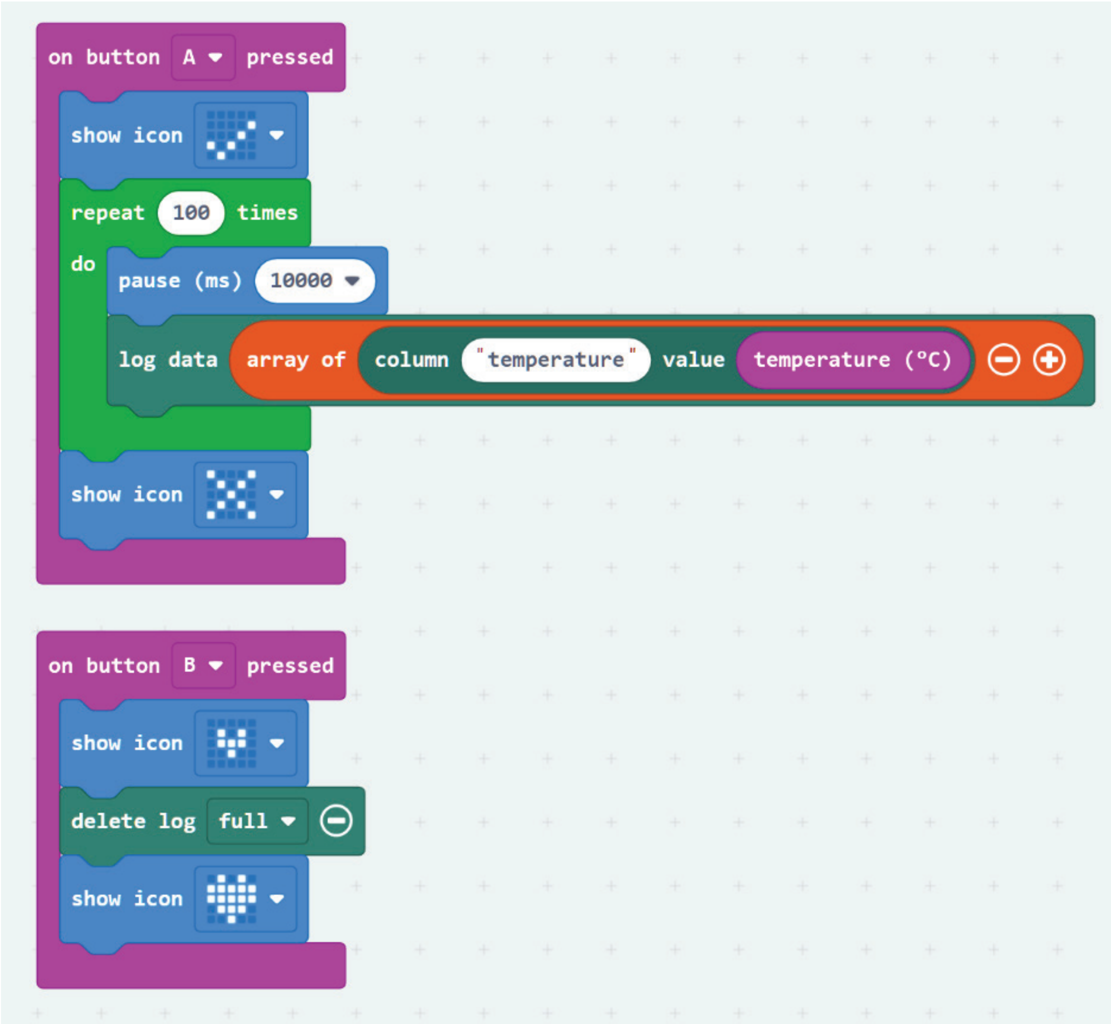


Credit: Logo Foundation

- The temperature of the room will display on the LED screen.
- The temperature being measured will most likely be a two-digit number, which cannot fit on the micro:bit screen. Instead, the digits scroll by one at a time.
- Where could you place the micro:bit to get different temperature readings? Predict how the temperature reading would change for each of these locations. Test some locations and compare the results to your predictions. Be careful not to place the micro:bit anywhere it could get wet.

b. To log temperature data, the micro:bit will need a more detailed MakeCode program. Access the program the micro:bit needs to log temperature data: **https://makecode.microbit.org/_C89gV5V9YhEW**

- This program is set to record data every 10 seconds (10,000 milliseconds). You can lengthen or shorten this interval by changing the number in the "pause(ms)" block.
- The program records 100 data points. You can increase or decrease this by changing the number in the "repeat __times" block
- The program also includes code to delete the data log from the micro:bit. If you don't do this before logging data, new data will be added to any data that is already on the micro:bit.



Credit: MakeCode, https://makecode.microbit.org/

c. Download the program to the micro:bit. Disconnect the micro:bit from the computer.

d. Plug the micro:bit into the 3 V battery pack.

e. On the micro:bit

- Press **button B** to delete any previous data on the micro:bit. You will see a small heart icon on the micro:bit display. After a moment, you will see a heart on the micro:bit display. This indicates that any old data has been deleted.
- Press **button A** on the micro:bit to start logging data
- A check icon appears to indicate that data logging has begun. An X icon will appear when data logging is completed. Cut 15 cm (6 inch) squares of white paper, black paper, and colored paper.

2. Cut one 15 cm (6 inch) square of corrugated cardboard.

3. Place the cardboard in a sunny area. Alternatively, you can place the cardboard under a lamp. The lamp should be approximately 15 cm (6 inch) above the cardboard.

4. Set a timer for the approximate total time the data logging will take.

a. The code as written above will take about 17 minutes, which was calculated by multiplying 100 repeats by 10 seconds and dividing by 60.

b. If you make changes to the number of repeats or the length of the pause, you will need to calculate how long the micro:bit will log data. Do this by multiplying the number of repeats by the duration of the pause and dividing by 60.

c. The micro:bit displays an X when the data logging is completed, but you won't be able to see this until you lift the piece of paper. Note the time when the data logging begins and do not disturb the set up until enough time has passed that the data logging will have stopped. Be sure to not lift the paper until the timer has stopped.

5. Set the micro:bit on the piece of cardboard.

6. Start data logging on the micro:bit as described above and immediately place one of the squares of paper on top of the micro:bit.

7. Use the light meter to get a reading of how much light is being reflected by each paper. Hold the light meter 2 cm (1 in.) above the paper to take the reading. Be sure to avoid casting a shadow from the light meter onto the paper as you take the reading.

8. When the micro:bit has finished logging data, remove it from the sunny area or turn off the lamp.

9. Connect the micro:bit to the computer and open the file MY_DATA.HTM. You should see something like the chart below. You should download the data to your computer. It is best to do this as a .csv file, which can then be opened in Excel, *Scratch*®, or another application so that you can use it to create a graph or other visualization.

10. Make sure to delete the data log after downloading the data so that the micro:bit is ready to log the next batch of data.

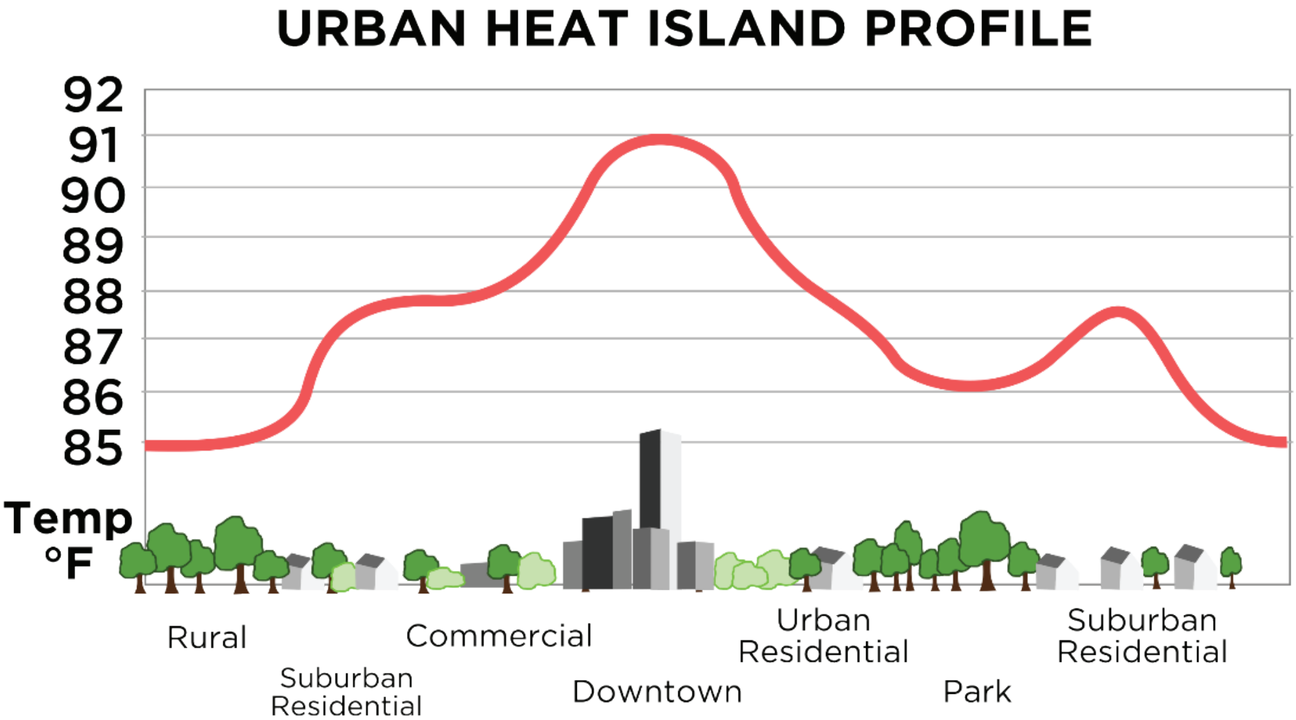
11. Allow the micro:bit to cool down in the shade for about ten minutes. Repeat the data logging with the black paper and colored paper or share data with other groups that have tested the other papers.

Consider

1. Graph your results. Be sure to label the axes and provide a descriptive title for your graph.
2. In Investigation 3A1, temperature was recorded every 3 minutes, while the micro:bit logged data every 10seconds.
   - **a.** If you completed both Investigations 3A1 and 3A2, did you see the same temperature trend? Describe them.
   - **b.** If you did not complete both Investigations, describe the temperature trend from the micro:bit data. Would you expect to see the same trends if the data was instead taken with a thermometer? Why or why not?
   - **c.** What is one benefit of recording data more frequently?
   - **d.** What is one benefit of logging data automatically?
3. Consider how atmospheric temperature is monitored on Earth.
   - **a.** Why do you think we monitor Earth's temperature?
   - **b.** What technologies do you think scientists use to regularly monitor temperature on Earth?
   - **c.** How often and at how many locations do you think data should be taken to get an accurate picture of Earth's average temperature?

INVESTIGATION 6B: ALBEDO ENHANCEMENT

Learning Outcome: Test the albedo of natural surfaces and construction materials to understand the extent to which the overall albedo of cities differs from natural environments and how this could contribute to climate change.



Credit: EPA, https://www.epa.gov/heatislands/learn-about-heat-islands

Materials

Per group:

- pieces of construction material (brick, concrete, wood, roofing, siding)
- natural materials (sand, soil, grass, leaves)
- shallow tray or pan
- infrared thermometer
- desk lamp with an incandescent bulb (preferably 100 W)

- light meter
- cardboard (optional)
- sunny area (optional)

What to Do

1. Observe all the materials being tested. List them according to your prediction of how much light they will reflect. Rank them from lowest albedo (does not reflect much light) to highest albedo (reflects a lot of light).
2. Use the infrared thermometer to take the final temperature of the surface of each of the materials. Record these temperatures.
3. Place the lamp approximately 15 cm from the surface of one of the materials. Angle the lamp so it does not cast a shadow on the material.
4. Use the light meter to collect a reading of how much light the surface is reflecting.
    a. Read the instructions for your specific light meter, but most will work well if used 2 cm from the surface of the material being tested.
    b. Be sure to face the bulb of the light meter down toward the material being tested, not toward the lamp.
    c. Repeat this for each material being tested.
    d. Compare your readings to your predictions. Rearrange your list of materials as needed so they are in order from lowest albedo (lowest light level reflected, using the units given on your light meter) to highest albedo (most light reflected).
5. Turn off the lamp. Use the infrared thermometer to take the final temperature of the surface of each of the materials. Record these temperatures.
6. Predict what will happen to the temperature of each material when they are placed in the sun or under a lamp for 15 minutes.
7. Place all the materials in an area with direct sunlight. Alternatively, arrange the lamp so it is approximately 5 cm from the surface of one of the materials.
    a. If using sand, soil, grass, or leaves, prepare a shallow pan of one of these materials.
    b. If using a lamp, you will need to test each material separately. Make sure that all materials tested are on the same surface (carpet, desk, etc.) If this is not possible, place cardboard under all materials so they are all resting on the same type of surface.
8. After 15 minutes, use the infrared thermometer to take the temperature of the material. If using a lamp, turn it off, and measure the temperature at the spot of the material that was closest to the lamp. Record this temperature.
9. Consider the similarities and differences in temperature and light meter readings between the different materials. If your group didn't test all the materials, share your results with other groups and listen to their results.

Consider

1. Graph your results. Make sure to include a descriptive title and axis labels.

2. Compare the temperatures of the construction materials to the natural materials.

   a. Which material had the greatest temperature change? Why do you think this is?

   b. How would you expect each material to affect the surrounding air temperature?

   c. Use this information to explain the Urban Heat Island Profile.

   d. In what parts of the world would it be most beneficial for people to use building materials with low albedos?

Extensions

1. **Testing Variables:** Investigate the albedo of alternative construction materials or green infrastructure materials that have been developed for the purpose of reducing the effect of urban areas on the environment.

   a. What are some different types of alternative construction materials? How do you think they reduce the urban heat island effect of urban areas?

   b. Explain other ways these materials could reduce a building's environmental impact.

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Sustainable Development Goal 13: Climate Action

INVESTIGATION 7A: ASSESSING SOIL HEALTH

Learning Outcome: Conduct soil tests to observe the components of soil and analyze the health of different soils.

Materials

Per group:

- locally sourced soil (approximately 100 mL (1 cup) per group)
- bagged garden soil (approximately 100 mL (1 cup) per group)
- annual plant or grass grown in local soil with roots intact
- 1 small plastic bin or paper plate
- tap water
- distilled water
- vinegar
- baking soda
- teaspoon
- pint-sized glass jar with a lid (filled with water and soil)
- magnifying glass
- plastic cups [with a volume of ~200 mL (1 cup)]
- 4 plastic water bottles (or other clear, narrow containers)
- sand
- gravel

- trowel
- spray bottle filled with water
- bucket
- ruler
- 100 mL graduated cylinder
- soil testing kit (for nitrogen, phosphorous, and potassium, such as Luster Leaf Rapitest)
- pH test paper (if not included with the soil testing kit)
- safety goggles

What to Do

1. Tilth of the soil:
   a. Use a trowel to collect a large scoop of soil. Place it in a plastic bin or onto a paper plate where there is room to examine the sample.
   b. Use your hands to break apart the soil. Observe whether it is difficult or easy to break apart.
   c. Describe the relative shape and size of the pieces that break off.
   d. Take half a handful of soil and lightly mist it with water from a spray bottle (or faucet, but do not get the soil too wet).
   e. Squeeze the soil into a tight ball. Gently set the ball in your bin or on your paper plate.
   f. Observe whether the ball of soil falls apart or stays together as you set it down.
   g. Gently poke the ball with your finger until it breaks apart. Observe whether this was easy or if it took some force to get the soil to break apart.
   h. Repeat this procedure for each soil or compare your results with groups that tested different soils.
2. Test soil stability:
   a. Healthy soil contains pockets of air. What do you think would happen if healthy soil is dropped in water?
   b. Fill a plastic cup ¾ full of water.
   c. Take a clump of soil that has been left out to dry and gently drop it into the cup of water. Start a timer.
   d. Once the soil settles to the bottom, make observations about what you see. When the soil stops changing, stop the timer.
   e. Repeat this procedure for each soil or compare your results with groups that tested different soils.
3. Test the pH:
   a. Place a spoonful of soil into a plastic cup.
   b. Mix the soil with enough distilled water to make a mixture that is thinner than mud.
   c. Let the mixture stand undisturbed for 5 minutes.
   d. Hold the bag up and open it so you can get to the water at the top. To measure the pH, touch a test paper to the top of the liquid. Only touch a small portion of the strip to the liquid in so the color difference from the original color of the pH paper is still visible.

   e. Repeat this procedure for each soil or compare your results with groups that tested different soils.

4. Particle sizes:

   a. Observe a sample of soil that has been prepared in a glass jar. The soil was mixed with water, and the sediment has been allowed to settle for the past 24 hours.

   b. Without disturbing the jar, measure the height of the soil in the jar in centimeters.

   c. Measure the height of each layer within the soil in millimeters.

   d. Divide the height of each layer by the total height of the soil. Multiply by 100 to get what percentage of the soil each layer of sediment makes up.

5. Soil test kit:

   a. Use a pipette to fill the nitrogen testing box with the water your soil has been soaking in for 24 hours. Be sure to only take a sample of the water, not the soil.

   b. Break open a nitrogen testing capsule and pour the powder from it into the reference chamber.

   c. Cap the nitrogen testing box and shake thoroughly.

   d. Let the solution sit for exactly 10 minutes, then match the color of the solution to the comparator chart. This is best done in natural, but not direct, light.

   e. Repeat this procedure for both potassium and phosphorous, making sure to use the appropriate testing boxes and capsules.

   f. Repeat this procedure for each soil or compare your results with groups that tested different soils.

6. Soil porosity:

   a. Fill three plastic bottles ¾ full: one with sand, one with gravel, and one with soil from your area. Be sure each bottle is filled up to the same height.

   b. Make observations of the size of the grains that make up each material and the pore space between the grains. Predict which material will hold the most water.

   c. Use the graduated cylinder to fill a fourth plastic bottle with water. Record the total amount of water used to fill the bottle.

   d. Slowly pour the water into the sand until water reaches the top of the sand. As you pour the water, make observations about how long it takes for water to go through the sand.

   e. Use the graduated cylinder to measure how much water is left in the bottle. Subtract this from the initial amount of water to see how much water was used.

   f. Refill the water bottle using the same method as before. Repeat the procedure with gravel, and then with your soil sample.

   g. Repeat this procedure for each soil or compare your results with groups that tested different soils.

7. Root development:

   a. Observe the roots of the annual plant that has been dug from the soil.

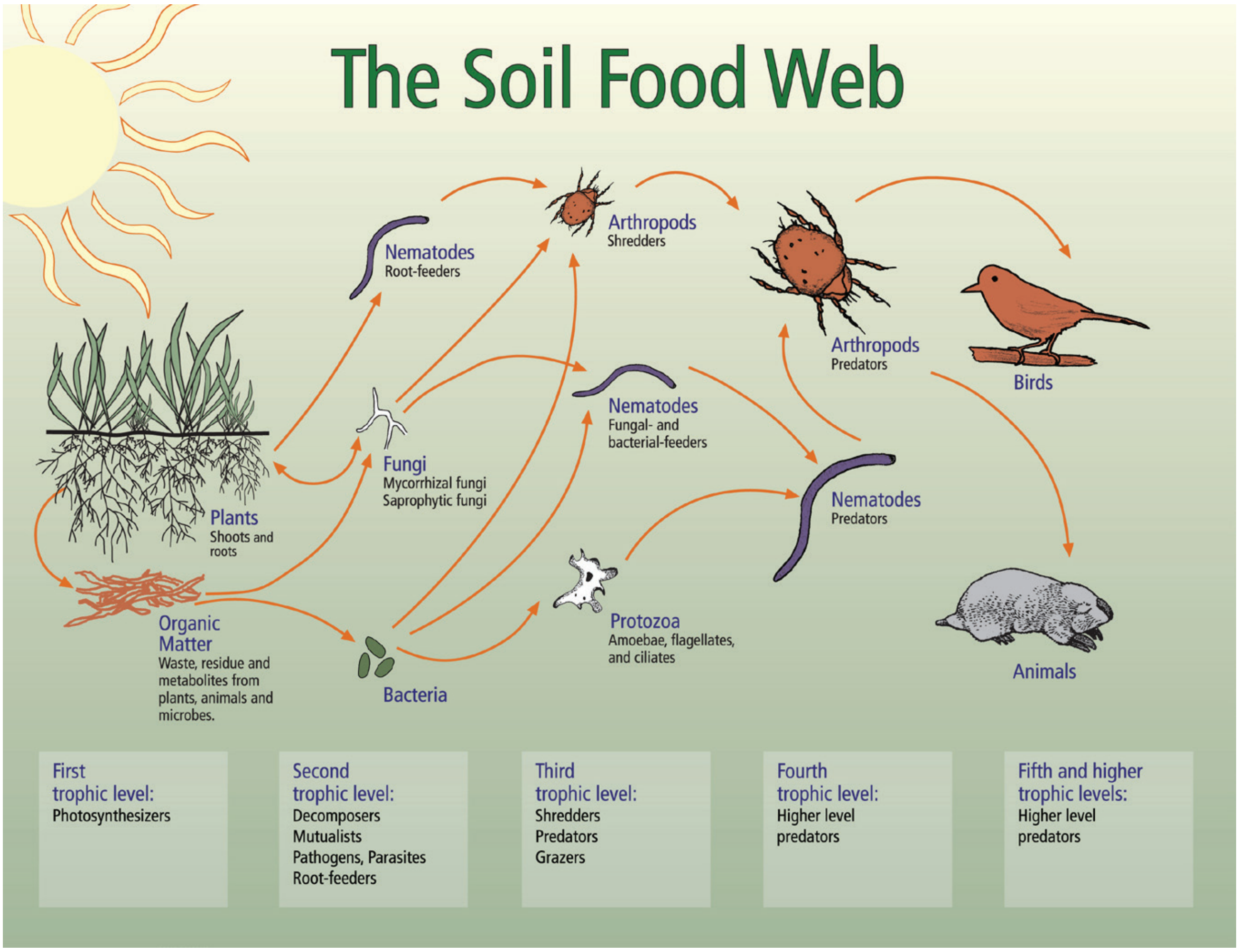
   b. Make note of their color and texture, as well as anything else you notice about them.

Consider

1. Answer this set of questions for each soil that was tested: How easy was it to break apart the soil while doing the tilth and stability tests? During the tilth test, did it fall apart on its own or only after you pressed on it? How long did it take to break apart in water? Do you think this means that the soil is healthy or not healthy?
2. Many farms till their soil, meaning they use equipment to mix up the top layer of soil where they are going to plant crops. Tilled soil tends to fall apart easily when a tilth or stability test is run on it. Given what you now know about tilth testing, does tilling help make a soil healthier? Why or why not?
3. Compare the pH of the different soils tested. Are they acidic, neutral, or basic? Which do you think is ideal for plant growth? Why?
4. If you tested multiple local soil samples, which one seems to be the healthiest? Why do you think this?
5. Are there many farms near where you live? Use the soil conditions to explain why or why not.
6. How could the soil in your area be improved?

Extensions

1. **Testing Variables:** Healthy soils should allow for moderate drainage of water through the soil. With permission, go outside and test your soil's drainage:
   - **a.** Remove both ends of a small (about 350 mL [12 oz.]) food can.
   - **b.** Dig a hole about 2 cm deep in the ground that is big enough to be able to place the end of the can into the hole. Press down on the can enough to seal around the edge with soil, but no further.
   - **c.** Fill the can halfway with water and time how long it takes to drain.
2. **Testing Variables:** With permission, go outside and dig a hole about the size of a coffee canister (about 10 cm [4 in.] wide and 14 cm [5.5 in.] deep). Observe the hole for 30 minutes and count the number of living organisms you see. What do you think the number and diversity of living organisms you observed tells you about the soil's health?
3. **Applying Concepts:** Unhealthy soils cannot support plant growth as well as healthy soils. However, plants can help make soils healthier, especially mosses. Think about when you have seen moss in nature. Where does it typically grow? What does it look like? Think about some of the properties of mosses. How do you think moss could help make soil healthier?
4. **Applying Concepts:** One factor that determines soil health is its carbon content. The carbon in soil is typically in an organic form (unlike carbon dioxide, which is inorganic). Converting carbon dioxide to organic carbon and storing it in soil is called drawdown.
   - **a.** Describe how the different types of organisms shown in the Soil Food Web Diagram can contribute to the carbon content of soils.
   - **b.** Which level do you think contributes most to drawdown? Why do you think this?



Credit: https://www.mdpi.com/2571-8789/5/2/32/htm#

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INVESTIGATION 7B: SUSTAINABLE FARMING PRACTICES

Learning Outcome: Analyze data that shows sustainable farming practices can increase soil health and make connections to atmospheric carbon dioxide levels.

Materials

Per group:

- copies of graphs from the Investigation

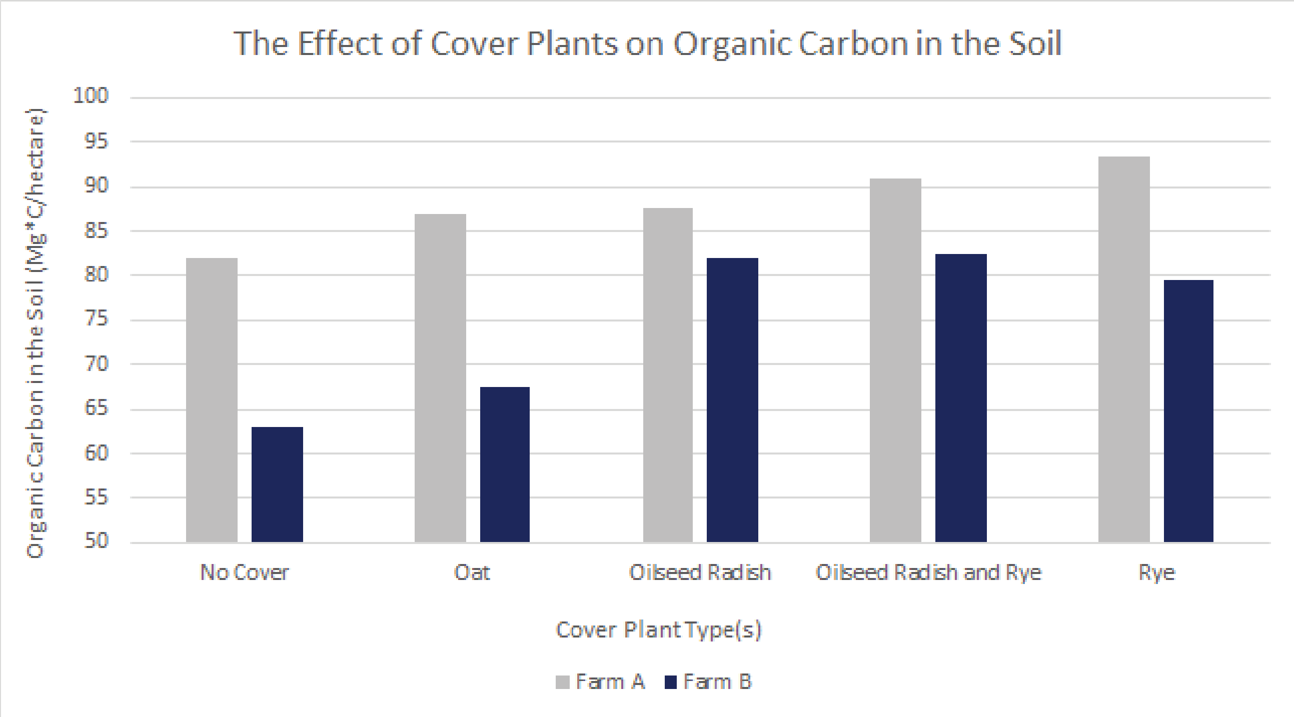
What to Do

1. Two farms were studied in regard to the use of cover crops and their effect on the carbon-content of the soil. The results are displayed in the graph "The Effect of Cover Plants on Organic Carbon in the Soil".

   a. Compare the two farms when no cover crops were used. How does this compare to when cover crops are used? Use evidence from the graph to support your answer.

   b. What effect does crop cover seem to have on soil health? Why do you think this is?

   c. Which cover crop would you plant if you wanted to increase the amount of carbon in the soil? Use evidence from the graph to support your answer.

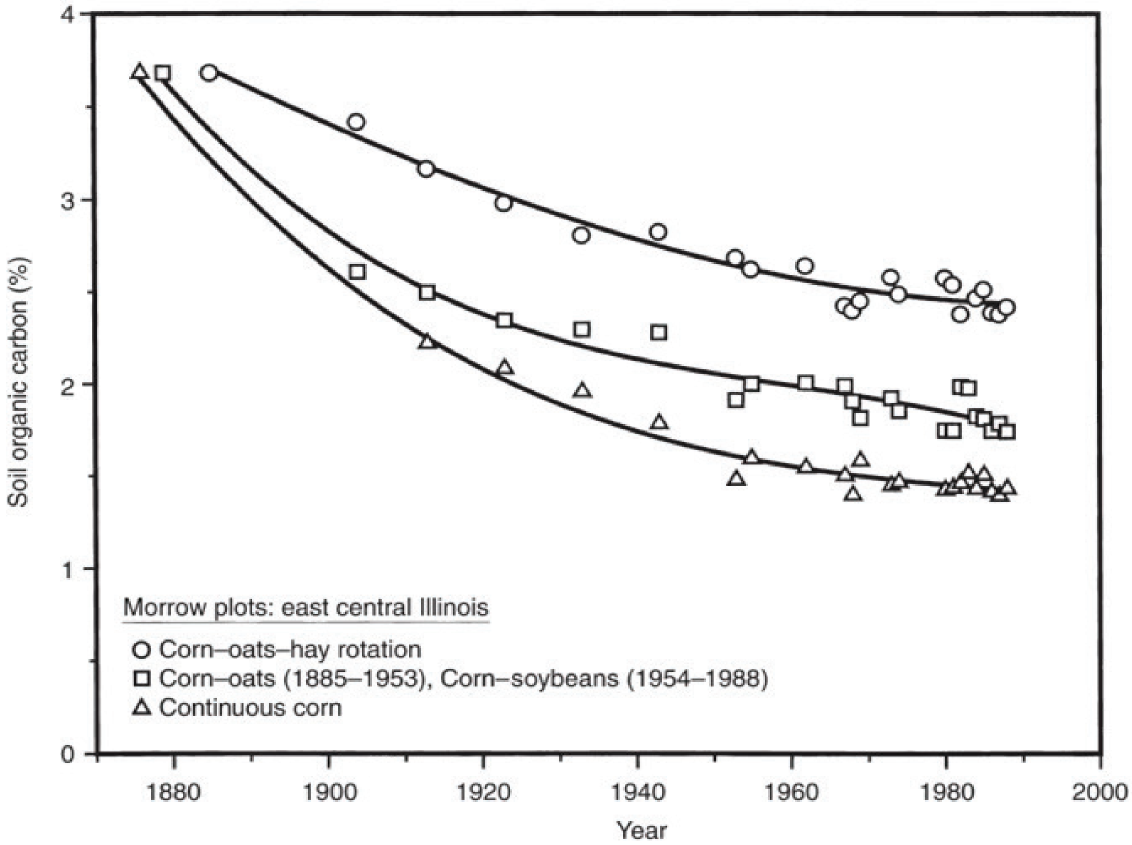


Credit: Modified from Chahal, I., Vyn, R.J., Mayers, D. et al. Cumulative impact of cover crops on soil carbon sequestration and profitability in a temperate humid climate. Sci Rep 10, 13381 (2020). https://doi.org/10.1038/s41598-020-70224-6

2. Three plots of land were studied to see the effects of crop rotation on the carbon content of the soil. Examine the graph of the “Morrow Plots: East Central Illinois” below.

a. Compare the overall trend of the soil carbon for the three plots.

b. Which setup would you use on your own farm: continuous corn, rotating corn and oats, or rotating corn, oats, and hay? Why?



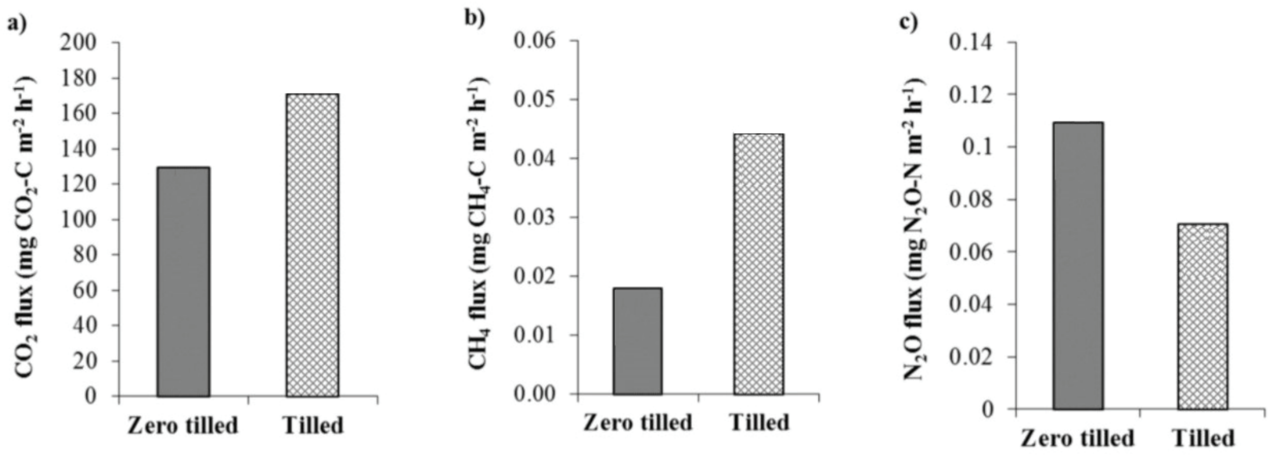
Credit: Modified from https://www.researchgate.net/publication/267704070_Agricultural_Contributions_to_Greenhouse_Gases_3_Agricultural_Contributions_to_Greenhouse_Gas_Emissions

3. Bacteria and fungi (microorganisms) that live in the soil break down organic matter within the soil. In doing so, these organisms give off gases, such as carbon dioxide, methane, and nitrous oxide, all of which are considered greenhouse gases. The release of gases from the soil to the atmosphere is called flux. Examine the graphs that report the flux between zero tilled and tilled farmland.

a. Would you expect tilled soils to contain more or less organic carbon than non-tilled soils? Use evidence from the graphs to support your answer.

b. What effect does tilling have on how much of each of these gases are given off by microorganisms in the soil?

GREENHOUSE GAS RELEASE UNDER TILLING AND NO-TILL CONDITIONS



Credit: https://www.nature.com/articles/srep04586

Consider

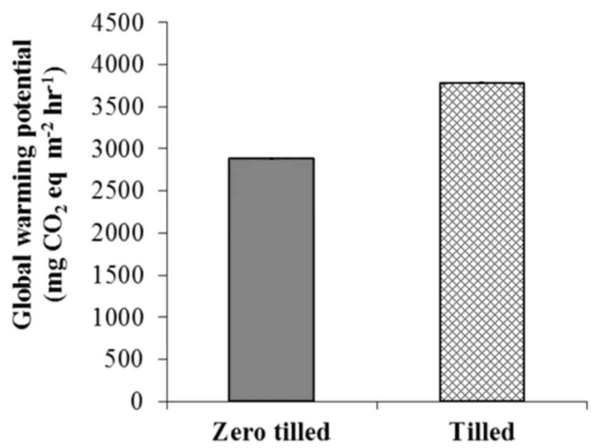
1. Which sustainable farming practice do you think will have the greatest impact on reduction of greenhouse gases in the atmosphere (and increase storage of carbon in the soil)? Why do you think this?

2. Each greenhouse gas has a similar effect on the environment in that they cause warming but differ in exactly how much warming they can cause.

   a. Nitrous oxide is capable of warming the environment much faster than either carbon dioxide or methane. Revisit the graphs in step 3 of the procedure and use them to make a recommendation as to whether farmers should till their land or not.

   b. The following graph takes into account how much each greenhouse gas is released due to tilling, as well as how much each gas warms the atmosphere. Using this information, what recommendation would you make to farmers about tilling the land? Explain your thinking.

OVERALL GLOBAL WARMING POTENTIAL UNDER TILLING AND NO-TILL CONDITIONS



Credit: https://www.nature.com/articles/srep04586

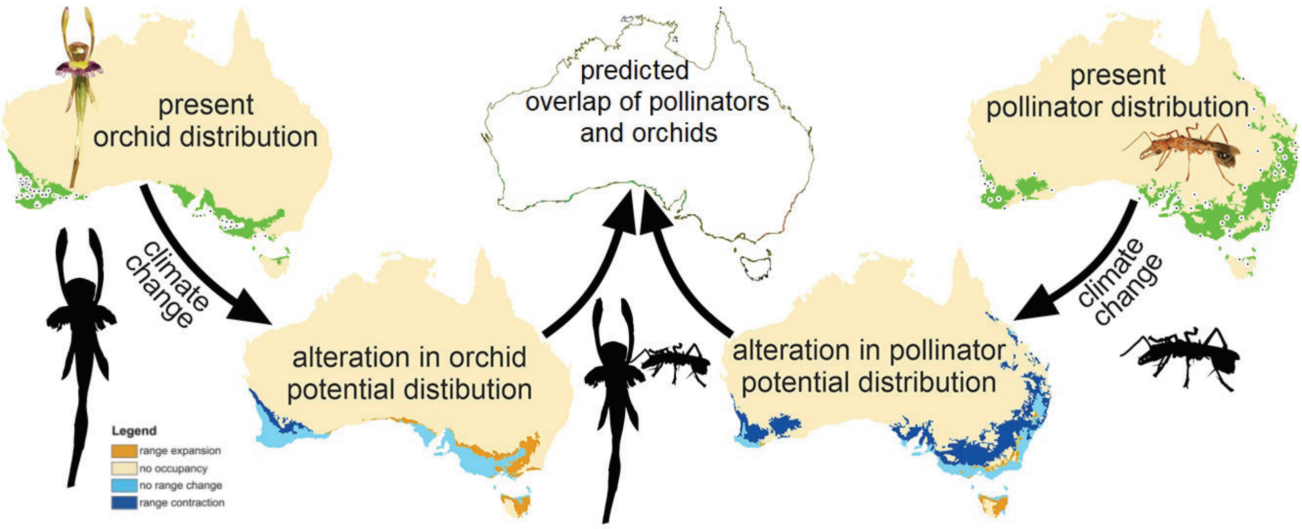
3. Would you describe sustainable farming practices as a mitigation strategy or an adaptation strategy in terms of climate change? Why do you think that?

Extension

1. **Applying Concepts:** Many plants, including crops, depend on pollinators, and pollinators depend on plants. The pollinators take food from flowers, while helping the plant to reproduce. However, all living organisms depend on their environment to survive. Due to climate change, many species' habitats will be affected enough to change the range in which they can live. The following diagram shows changes in the distribution of orchid plants and their pollinators along the southern coast of Australia.

   a. Describe the expected changes to each species' distribution given changes in climate.

   b. Indicate on the map labeled "predicted overlap of pollinators and orchids" where the species used to overlap versus where they are expected to in the future.



Credit: https://www.sciencedirect.com/science/article/pii/S004896972103922X#f0015

   c. Describe how the range in their overlap is expected to change given a change in climate.

   d. How will the change in climate affect the survival of each species?

   e. If we looked at a crop rather than a flower species, how would this affect food production?

ESD KIT: IMPACTS OF CLIMATE CHANGE

Sustainable Development Goal 13: Climate Action

ESD KIT PROJECT: DESIGN A RESILIENT CITY

Climate change has been linked to increased greenhouse gas emissions (especially carbon dioxide) due to the rate at which fossil fuels have been used over the past 150 years. The increase in average global temperature leads to further changes, such as sea level rise and changes in weather patterns. Each of these effects can impact both ecosystems and cities. In this project, you will design a city that is resilient to the effects of climate change. Resiliency here is defined as implementing adaptation or mitigation strategies. Mitigation strategies will help reduce your city's impact on fossil fuel emissions, and therefore future climate change. Adaptation strategies will help alleviate the current effects caused by climate change.

Getting Started

Start by looking at your city or a city nearby where you live.

1. What is your community's climate? What are features of the environment or weather patterns that you have seen in your area that would support your answer?
2. Consider your city, or a city nearby you that has similar environment, weather and climate patterns to where you live. Are there any trends in architecture that are common in this city that you think might be related to its climate?
3. How close is this city to a major body of water? What are some benefits of being near water?
4. What are some effects of climate change that directly impact this city?

5. Look at a map of the city to study its layout.
   a. Where in the city do most people live?
   b. Where are the businesses located?
   c. What does the city manufacture? What does it need to import?
   d. Where are green spaces located in the city?
6. Think about climate-related adaptation and mitigation strategies.
   a. What adaptation or mitigation strategies does this city already have in place related to climate change?
   b. Can you think of any adaptation or mitigation strategies that are not being used in this city but that may be appropriate? What would you suggest and why?

Revisit Investigation 1: Considering Climate. You analyzed how the climate of an area relates to the weather patterns. Start with this information when it comes to deciding where you would like the city you design to be located. Consider the challenges that would come with building in certain climates.

Design a City

How might you design a city that is more resilient to the effects of climate change than the one you examined? Consider the location you chose for the city, and ask yourself:

1. What specific mitigation and adaptation strategies would reduce the effects of climate change?
2. What strategies would make sure the city reduces its impact on future climate change?

Revisit each of the Investigations in this ESD Kit. How can what you learned guide you in designing your city?

Investigation 2: Greenhouse Gases and Climate

- How does the city you are designing exchange carbon dioxide with the atmosphere?
  - What in your city gives off carbon dioxide?
  - How could the amount of carbon dioxide given off by a city be monitored?

Investigation 3A: Measuring Carbon Dioxide and Acidity

- How does the city you are designing contribute to the production of acid rain? What strategies could reduce the city's contribution to the production of acid rain?
- Does the city you are designing receive acid rain? If so, what modifications can be made to mitigate the effects of acid rain?

Investigation 3B: Reduction of Greenhouse Gas Emissions

- How can individuals or businesses reduce their carbon emissions?
- What can you add to or build within the city you are designing that would reduce carbon dioxide levels in the atmosphere?
- What are the other greenhouse gases? How could the city you are designing emit them. How could these emissions be reduced?

Investigation 4A: Testing Heat Capacity

- If the city you are designing is located near a large body of water, how is the city's climate affected by that water?
- If the city you are designing is not near a body of water, how will this affect trade and transport? How will this in turn affect the amount of carbon emissions?

Investigation 4B: Coastal Storms

- How could the city you are designing be affected by coastal storms?
- What structures could be built to mitigate the effects of coastal storms?

Investigation 5A: Ice Melting, Thermal Expansion, and Sea Level Rise

- How could the city you are designing be affected by the current sea level?
- Given future predicted sea levels, how could the city you are designing be affected by sea level rise?

Investigation 5B:

- What structures could be built to mitigate the effects of coastal flooding?

Investigation 6A: Albedo

- Considering the climate your city will be in, how can buildings be constructed to minimize heat or air conditioning use? What building materials could be used?
- Consider the albedo of the building materials. How do they contribute to the Urban Heat Island Profile of the city?

Investigation 6B: Albedo Enhancement

- How could you design a city to have a high albedo? What alternative materials might be used to construct the buildings in your city?

Investigation 7A: Effects of Climate Change on Terrestrial Ecosystems

- How close will farms be to the city you are designing? Consider the impacts of trade and transport, and the impacts on the soil close to the city.

Investigation 7B: Sustainable Farming Practices

- Consider how cities impact soil quality. How could you design your city to reduce its impact on the soil?

Make a Map of Your City Design

1. "Downtown" with businesses
2. Housing
3. At least five specific Adaptations or Mitigation Strategies to address possible effects of climate change

Other Considerations

Additional Impacts due to Climate Change

The Investigations you completed within this ESD Kit covered many impacts of climate change; however, there are others that you might consider depending on the location of the city you design. Your city may be affected by an increase in the number and severity of droughts, wildfires, severe inland storms and flooding. A good resource that summarizes these effects can be found here: https://ec.europa.eu/clima/climate-change/consequences-climate-change_en. Many cities have adaptation strategies for these effects that you may want to include in your design.

Power Supply (source, transmission lines)

Buildings within cities are reliant on a source of energy. The energy required for most human-made products is most often electricity. A majority of electricity is generated by the burning of fossil fuels, although there are many alternative sources (e.g., wind and solar) that do not use fossil fuels and so do not release carbon dioxide and other greenhouse gases. When designing your town, consider what fuel sources could be readily available given where in the world the city is located. Will the power supply be locally generated, or does it need to be transmitted into the city? How will the main source of energy contribute to carbon dioxide emissions, or will the city focus on the use of clean, renewable energy sources?

Transportation Needs

Most modes of transportation use fossil fuels as an energy source and so contribute to greenhouse gas emissions, especially carbon dioxide. Emissions can be decreased when fewer individuals use cars and public transportation is readily available. The size and walkability of the city also contributes to how often cars and other transportation is required. Taking these factors into consideration when designing your city can result in lower emissions.

Sensing and Control

Being able to automatically sense changes and control responses to them can save energy and can reduce the amount of greenhouse gases released by burning fossil fuels. For example, heating and cooling buildings uses a great deal of energy. Having a system that automatically senses temperature and turns on air conditioning and heat only when necessary can save a lot of energy.

Sensing can also be used to monitor greenhouse gas emissions, atmospheric temperature, water acidity, and other factors related to climate change. Monitoring these factors can help a city focus on early warning indicators and react to changes before they become unmanageable. Consider what you may want to monitor in your city, and how, to implement adaptation strategies before large changes occur.

Present Your Solutions

You can describe and show your city plan in various ways:

- written report
- a slide show
- an animated *Scratch*® presentation
- an oral presentation with visuals or a model, which may also be video recorded

ESD KIT: IMPACTS OF CLIMATE CHANGE

Sustainable Development Goal 13: Climate Action

APPENDIX 1: USING *SCRATCH*® WITH THE ESD KIT INVESTIGATIONS: TIPS AND TECHNIQUES

An important aspect of your work with ESD KitS is reporting and presenting the results of the Investigations and ESD Kit Project. This can be done in a variety of ways: written reports, slide shows, videos, and oral presentations. *Scratch*® is a highly recommended platform to report and present findings or designs for projects. *Scratch*® is a programmable learning environment that enables you to design and build your own interactive stories, games, and animations — and to share your creations with others in the online community. *Scratch*® is also a good vehicle for creative and interesting ways to visualize data. In the process, you will also learn how to code.

If you are not already familiar with the basics of *Scratch*®, first look at *Getting Started with Scratch*®, which tells you how to set up an account on the *Scratch*® website and where to find introductory tutorials and guides. If you are familiar with *Scratch*®, skip ahead to *Tips and Techniques for Scratch*® for how to work with *Scratch*® to share what you learn while working through the ESD Kit Investigations.

Notes for the Facilitator: You should be familiar with the basics of *Scratch*® so as to be able to assist learners with their activities and projects. You can achieve this by following *Getting Started with Scratch*®, working on the same tutorials that learners will use.

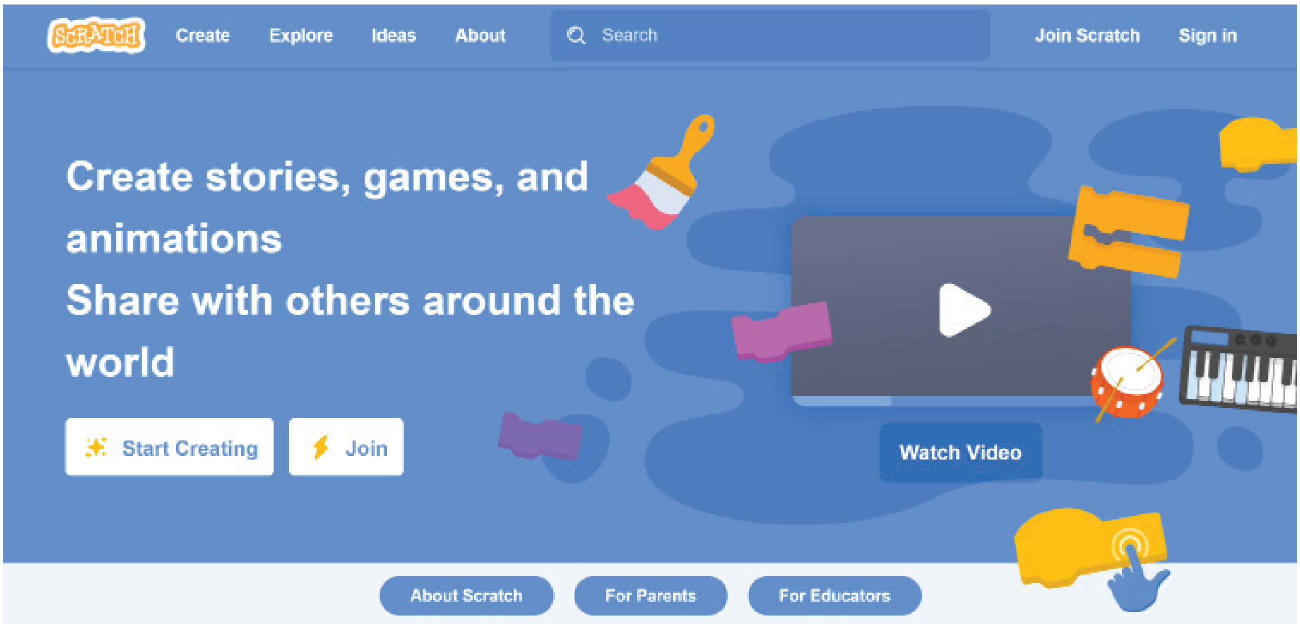
Scratch® *Tips and Techniques* goes into detail about topics that are directly relevant to ESD Kit activities, especially how to incorporate data into *Scratch*® projects and create interesting and novel visualizations of that data. There are links to sample *Scratch*® projects that both facilitators and learners can look at, learn from, and remix.

Some of the Investigations include suggestions for optional *Scratch*® activities. In your preparation to facilitate Investigations, review the *Scratch*® activity and look at any sample *Scratch*® projects that are linked to it.

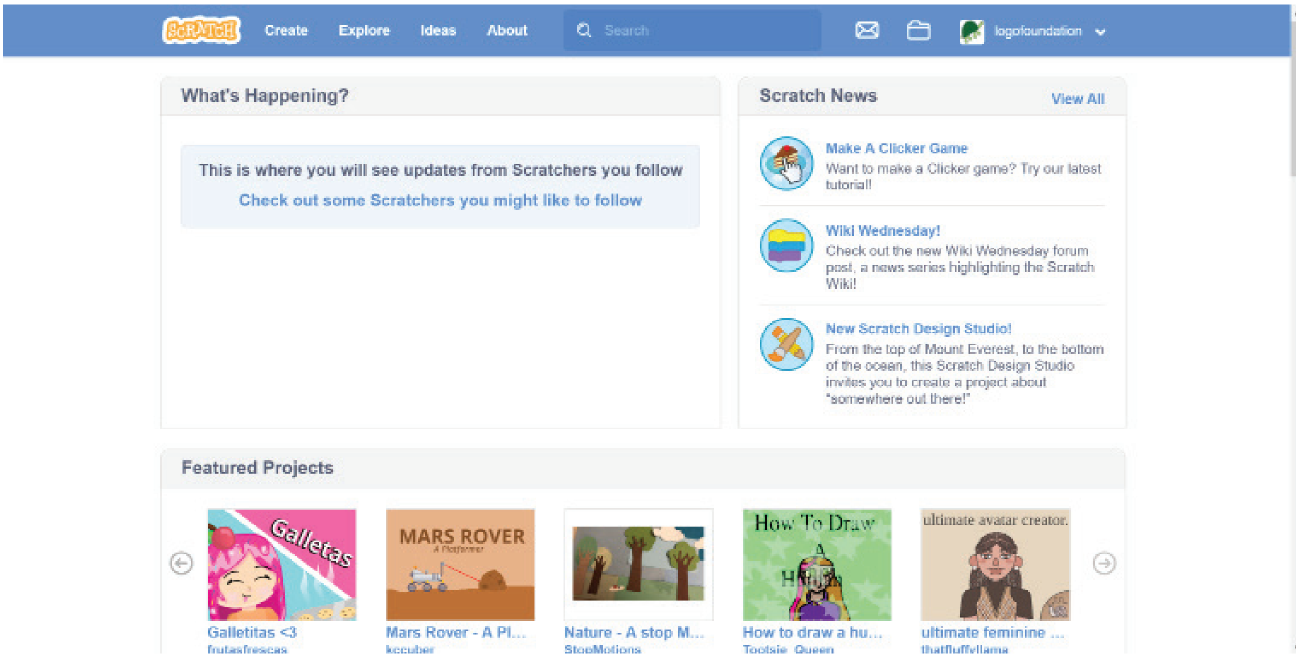
Getting Started with *Scratch*®

Scratch® works in your Web browser. There is no need to download and install an application. Your projects are saved automatically in the cloud. You can sign into your account from any computer and have access to everything you have created.

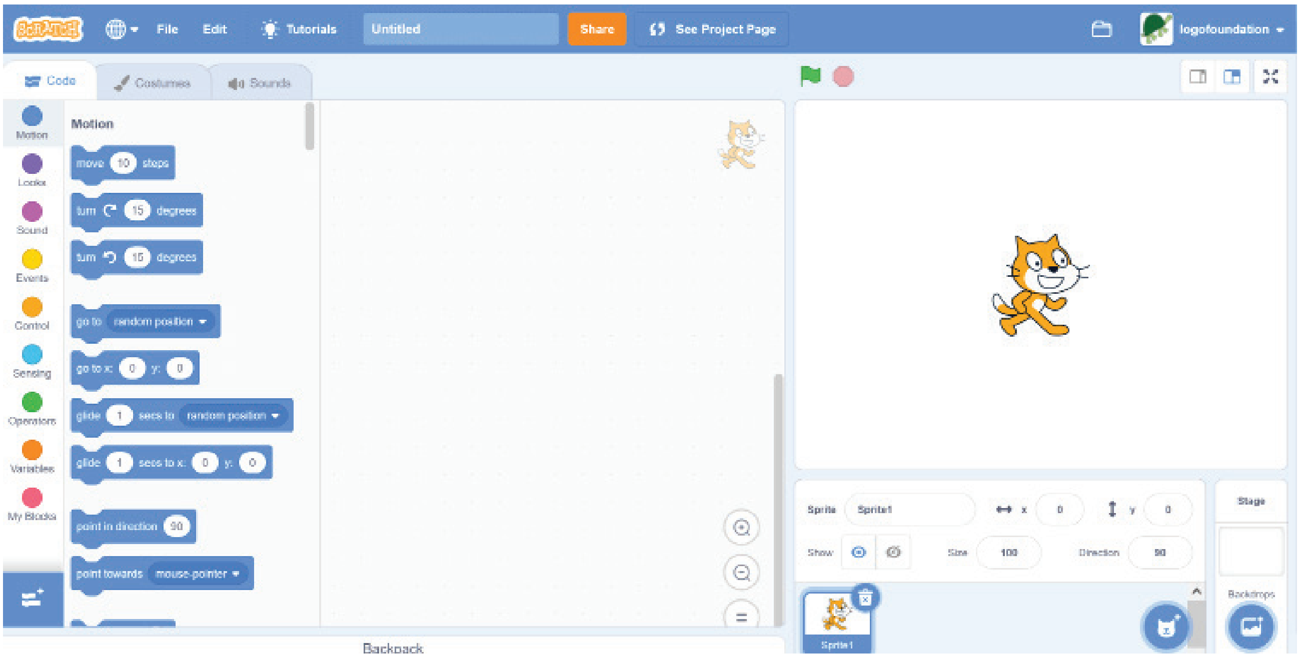
To get started, go to the *Scratch*® website: https://scratch.mit.edu/ This is what you'll see:



You should first create your own account on *Scratch*® so that you can save your work and share and communicate with other Scratchers. Click the **Join** button at the lower left or **Join Scratch** at the upper right. Follow the steps to set up your account. Once you are signed in, the *Scratch*® homepage will look something like this:

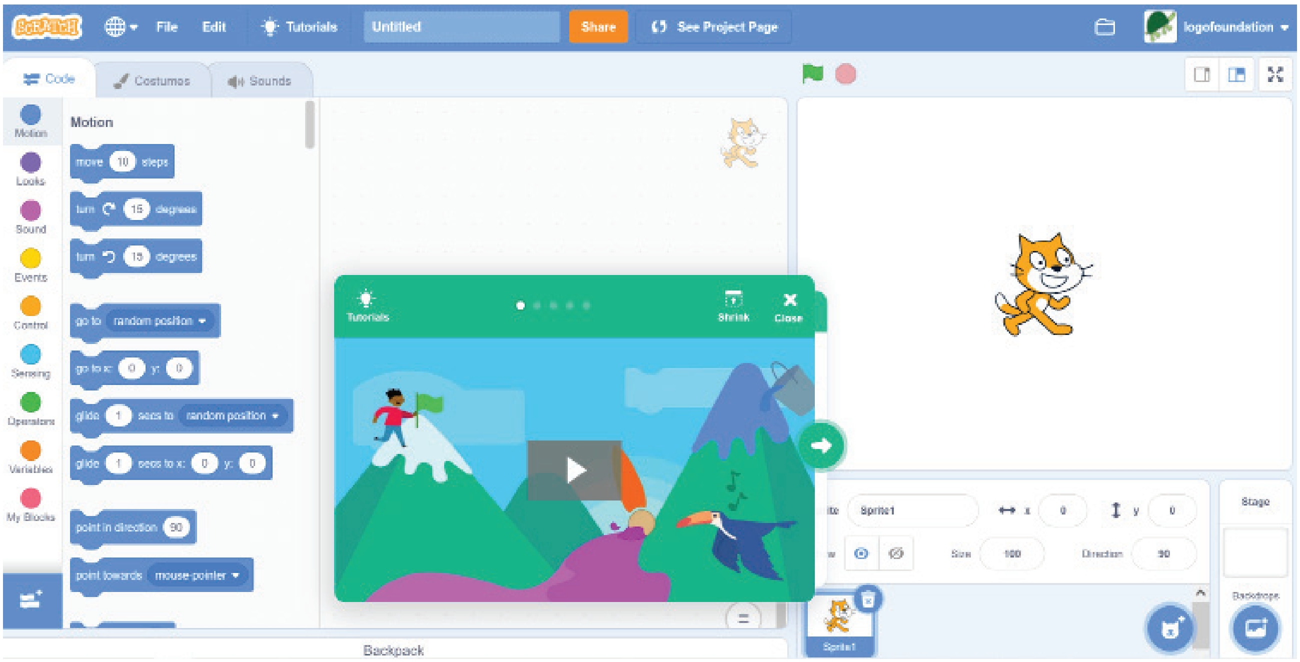


Your username appears at the upper right. You can browse the **Featured Projects** and other projects that appear as you scroll down the page. To get started yourself, click on **Create** at the upper left. This will take you to the *Scratch*® Editor. Your screen will look like this:



You can watch a brief video that shows some of the many things you can do with *Scratch*®. You can also jump right in by clicking on **Create** at the upper left or **Start Creating** at the lower left. This will bring you into the *Scratch*® Editor with an introductory tutorial running.

Click on **Tutorials** at the top of the page to go to a page with links to more than two dozen tutorials that will get you started with *Scratch*®. Each one appears in a window over the Editor.



You can stop and start, and back up as you need to. As you follow the tutorial, you will create your version of the project in the *Scratch*® Editor. Initially it will be called Untitled. You can click on the name and change it. It will automatically be saved in your *Scratch*® account.

More Resources

In addition to the resources on the *Scratch*® website, the *Scratch*® Wiki https://en.scratch-wiki.info/ has a great deal of information about *Scratch*®.

The *Scratch*®ED website at https://scratched.gse.harvard.edu is an archive of documents and projects created by *Scratch*® Educators.

For very young children there is *Scratch*® *Jr*, which you will find at http://www.scratchjr.org/. You may download and install it on your iPad or Android tablet. There is also a version for Chromebooks.

Scratch® Tips and Techniques

Putting on a Show

You can think of your *Scratch*® program as a theater. Your screen is the stage, and the backdrops are the scenery. The actors in your show are called sprites. They can wear a variety of costumes, move around, talk, sing, and interact with each other. Your show can have several scenes. To change from one scene to another, you can write the program to change the backdrop, hide characters that won't appear in the next scene, and get new characters to appear.

Working with Images

There are dozens of backdrops for the stage and costumes for the sprites that are built into *Scratch*®. You can choose which ones you want to use. You can also import images into *Scratch*®. These can be your own photos or images produced using other applications or downloaded from the internet. There is also a Paint Editor that you can use to draw backdrops and costumes or to alter existing images.

Visit this page for more information about using images in *Scratch*®: **https://digitalmaestro.org/articles/prepare-images-for-use-in-scratch-code-projects**

Displaying Text

One way to include text in your project is to use the paint program to create or modify a backdrop for the stage, or a costume for a sprite. Click on the letter T and then click where you want to begin your text. This creates a text box where you can type your text. You can also paste text that you have copied from another application. Once you have written some text, you can select the text box with the pointer icon to resize, move, or rotate it. If your text is on a sprite costume, you can make it move around by programming the sprite to move. Text on backgrounds or costumes will remain on the screen until the scene or costume changes.

Another way to use text is to use the **say** or **think** blocks. These can be found in the "Looks" tab to the left of the *Scratch*® program. These will display comic book style balloons with text in them next to your sprite. You can also choose how long these balloons appear, and you can program as many as you want to use in a scene.

Sounds

Using the Text to Speech extension, a sprite can say what you type into the **speak** block.

Scratch® can also play recorded sounds. These can be music, sound effects, and spoken words. You can record music or your own voice in *Scratch*® and then play it as part of your project. To do this, click on the Sounds tab, then on Choose a Sound, then on the microphone icon.

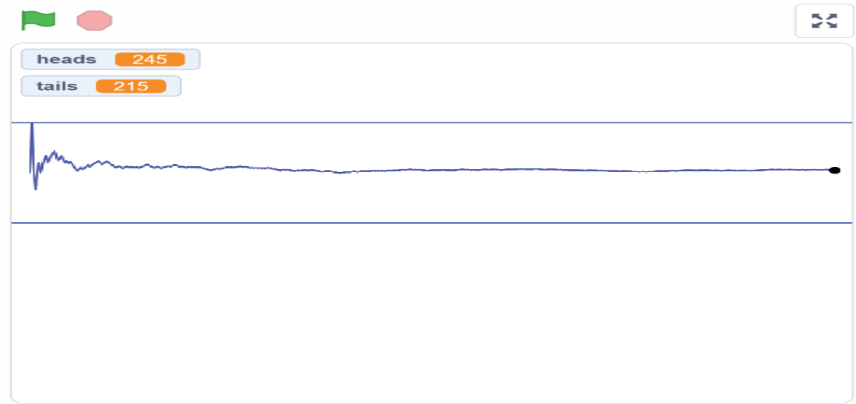
In addition to recorded music, there is a music extension that you can use to create melodies note by note, to be played by a variety of online instruments.

Working with Data

When trying to understand the significance of some data, it is helpful to have a visual representation rather than just a list of numbers. We often see line and bar graphs, pie charts, and other diagrams used for this purpose. For example, look at *Investigation 4: Understanding Our National Energy Mix* and *Investigation 7B: Logging Temperature Automatically Using a micro:bit* where data is used to create graphs. *Scratch*® can be used to draw graphs, but it also adds the ability to create a wider range of visual representations of data that can also be dynamic and interactive.

For example, look at the *Scratch*® project Coin Toss: **https://scratch.mit.edu/projects/486312136/**

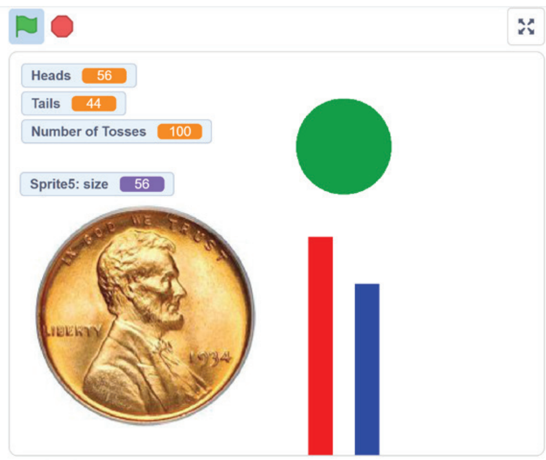
It uses the **pick random** block to simulate tossing a coin 460 times. It creates a graph showing the percentage of heads as the tossing progresses. The graph looks different each time the program is run, but the following image is typical. In *Scratch®*, you can watch this emerge as the graph is drawn in real time.



Another coin tossing project is Coin Toss Visualization: https://scratch.mit.edu/projects/2207857/

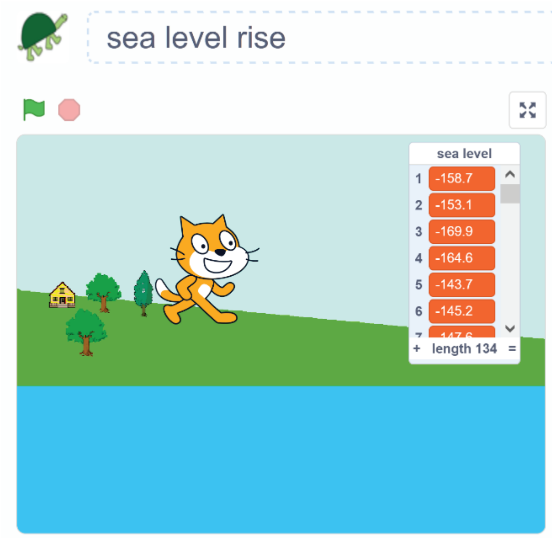
The coin is flipped 100 times and the visual representations of the proportions of heads and tails emerge dynamically. In addition to a bar chart, the size of the green circle increases and decreases based on the percentage of heads up to that point.

In addition to visualization, there is sonification. The pitch of a note played on a virtual piano reflects the percentage of heads.

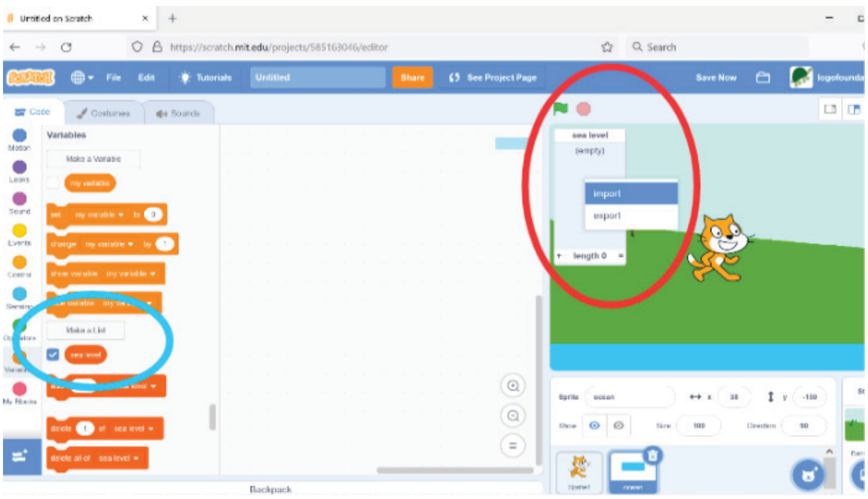


In the coin tossing projects, the program generates the data for the visualizations. You can also bring outside data into a *Scratch®* project.

The sea level rise project at https://scratch.mit.edu/projects/585163046/ uses global mean sea level data for the years 1880 to 2014 from the Climate.gov website. To bring this data into *Scratch*®, we first download it from Climate.gov as a .csv file (Microsoft Excel). We then create a list named "sea level" and imported the data into it. Here is how to do that:



Go to the variable section of the code tab and click on Make a List. Give the list a name. The list appears on the stage. (You can make it invisible by unchecking the blue box next to the name.) Now right-click on the list and you will see the option to import or export data. Click input and then select the .csv file you want to import. You can only import one column of a .csv file into the list. If there are more columns in the file, *Scratch*® will ask you which one you want to import. The sea level data file from Climate.gov has three columns. The second column has the data we need on sea level.



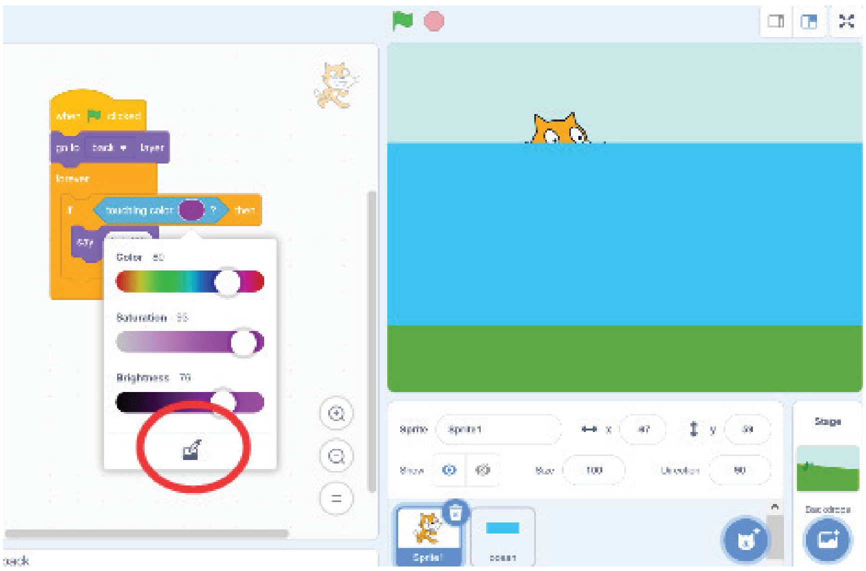
Once the data is imported, you may have to do some touching up. Often a .csv file will have a label in the first row of each column. This label will be imported into the *Scratch*® list along with the data below it. To remove this label and leave only data in the list, click on that first item. An X will appear in it. Click the X to remove the item.

Now the list of sea level data is ready to use. Create a variable named "pointer." This is used to step through the list of data one item at a time. The Y coordinate of the ocean sprite is set to each value of the sea level data in turn until the end of the list is reached.

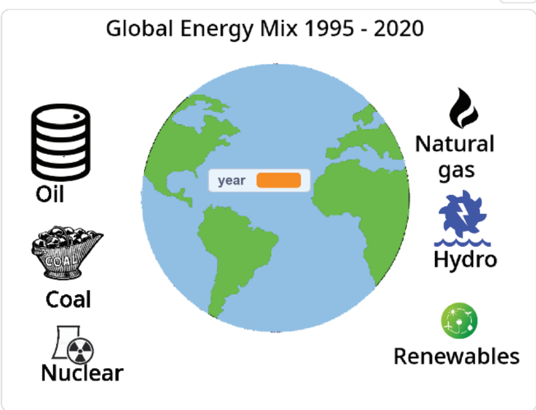
To see more about how the program works, go to the code tab of the ocean sprite, and look at the comments attached to the code for an explanation.

The cat is also programmed to cry out for help as the sea level rises and touches her. The code looks to see if the cat is touching the color blue (the sea) and causes the cat to say "Help!!!" when that happens. Look at the code tab of the cat sprite to see that program.

To get the correct color into the **touching color** block, click on the color oval in the block and then on the color picker icon below the sliders. Then click on the color that you want to pick up. In this case, that's the blue of the ocean sprite.

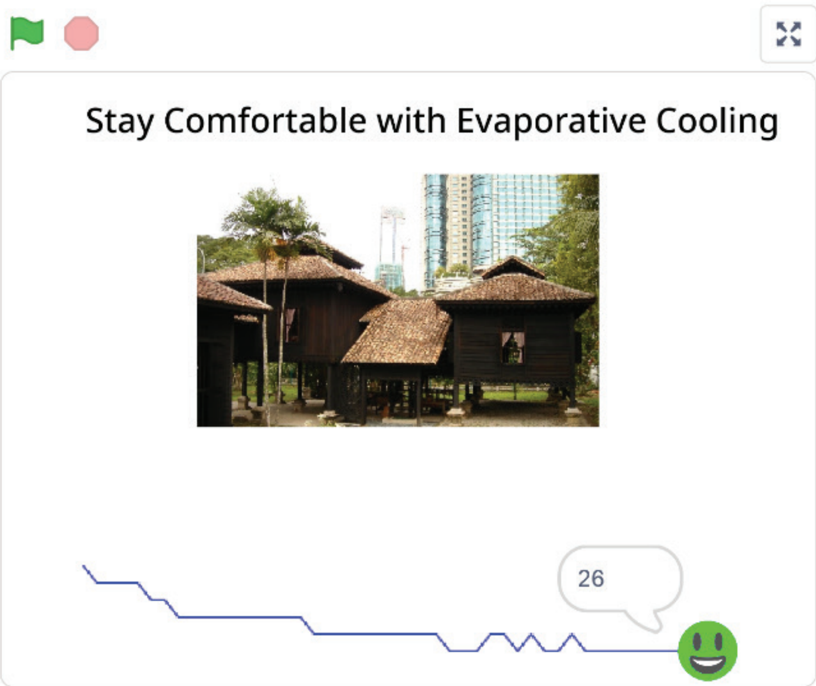


Investigation 4: Understanding Our National Energy Mix looks at the distribution of different energy sources over time. The data are represented by line graphs. The *Scratch®* project *Global Energy Mix* https://scratch.mit.edu/projects/573662932/ visualized that same data by increasing and decreasing the sizes of icons representing each energy source. You can remix it to use your own icons. You could extend the time frame so as to include projections of the energy mix in the future.



In *Investigation 7B*: ***Logging Temperature Automatically Using a micro:bit***, temperature data will be logged using a micro:bit. The data, when downloaded from the micro:bit as a .csv file can be used to make a graph or *Scratch®* program. Using Excel, we can create a line graph in the .csv file, showing the change in temperature under a damp clay flowerpot over a period of 47 minutes.

The *Scratch®* project *Evaporative Cooling* (https://scratch.mit.edu/projects/574196032/) uses that data to draw a line graph in a somewhat different way.

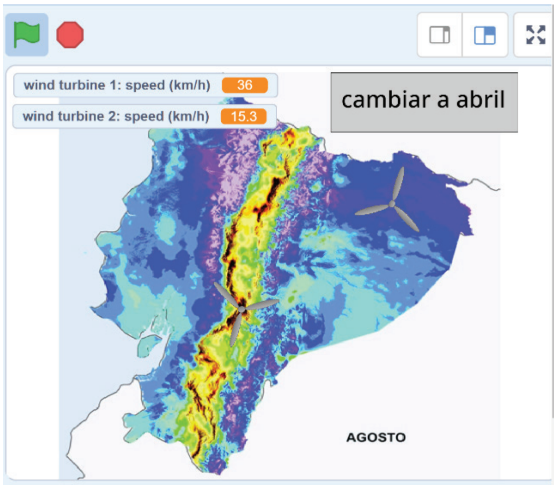


Making Your *Scratch*® Project Interactive

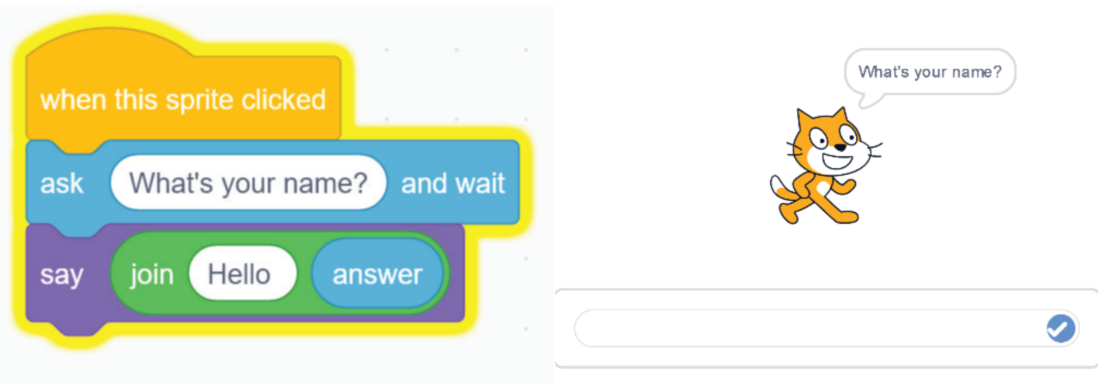
Anyone who uses an interactive *Scratch*® program can affect the course of action, what appears, and the sounds, voices, and music that are heard. Here are some examples:

Exploration 3B1: Locating Wind Energy shows how the potential for wind power in Ecuador varies from one location to another. In the *Scratch*® project Ecuador Wind Power (**https://scratch.mit.edu/projects/579828042**), the colors on the map indicate average monthly wind speeds. There are two sprites in the shape of wind turbines that can be dragged around the map. They are programmed to detect the color they are touching and set the wind speed accordingly. These values appear at the top of the screen. To actively visualize the data, the wind speed variables determine how rapidly each wind turbine spins.

Sprites can be programmed to detect color or other sprites. They can respond to a mouse click. They can be dragged with the mouse or by using specific keyboard keys. Other keypresses could be programmed to trigger other actions.



The **ask** and **answer** blocks allow you to prompt the user for a response and take action based on what they type into the dialog box that appears.



Here, the cat asks, "What's your name?" When you type in your name and click the check box, the cat replies with "Hello" followed by your name.

You can use this feature to determine the flow of your program. For example, you could create a project where you ask whether the user wants to learn more about Coal or Gas. The response could trigger a switch to an appropriate backdrop and start a flow of information and actions on the chosen topic.

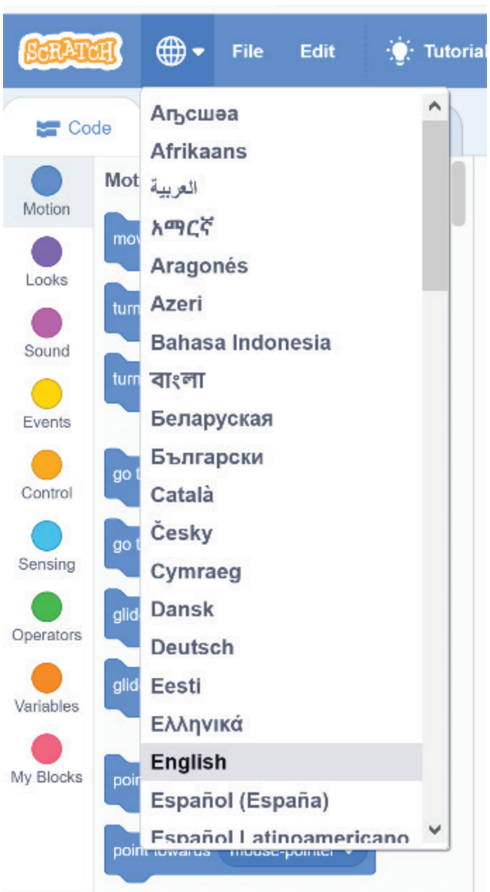
Look at the Sensing section of the Blocks Palette for some additional ways to make your *Scratch*® project interactive.

Changing Language

Scratch® supports many languages. Click on the globe icon in the upper left corner and you will see a list of the available languages. When you select one, the text on the code blocks, the menu items, and other text elements of the *Scratch*® user interface change to that language.

This makes it possible for Scratchers worldwide to work in their own language. It is also useful when looking at a project that someone has created with *Scratch*® set to a language other than your own. You can switch to your language and the code blocks will change so that you can better understand the project.

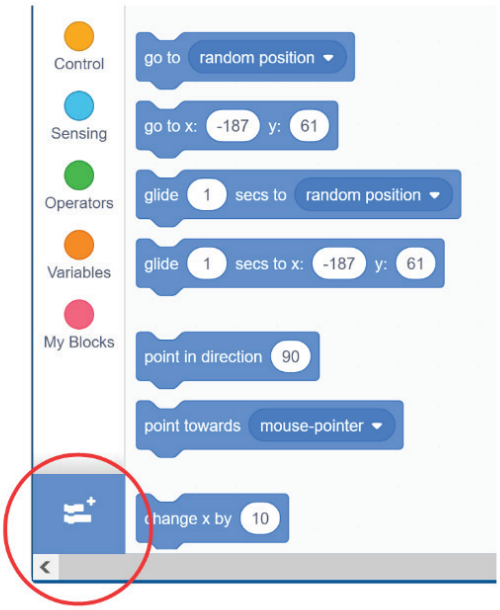
This feature does not change the text that the user has written on backdrops or sprite costumes, or text written into the **ask**, **say**, or **think** blocks. There is a separate translation extension to change these features.



Scratch® Extensions

A *Scratch*® Extension is a collection of code blocks for a specific purpose. The Pen extension enables Sprites to draw lines as they move. This is used to draw line graphs in the Evaporative Cooling and Coin Toss projects shown above. The Coin Toss Visualization project uses the Pen extension along with the music extension.

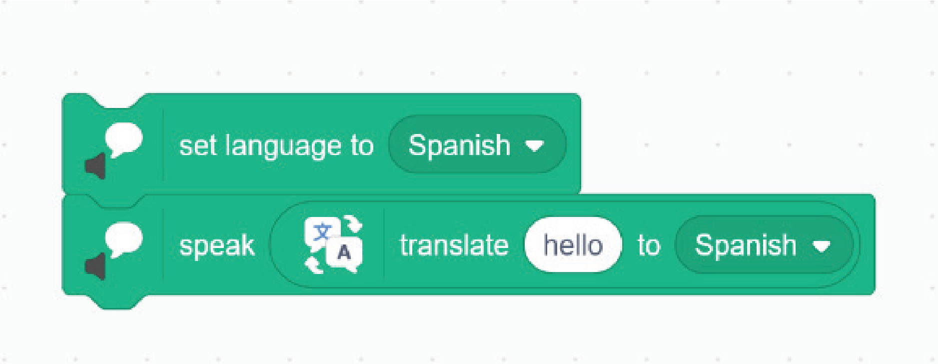
To use an extension, click the icon at the lower left of the *Scratch*® Screen. This brings you to a page where you can select the extension you want to load.



There is an extension for micro:bit which allows *Scratch*® to respond to various movements of the micro:bit as well as the pressing of the buttons on the board.

With Video Sensing, *Scratch*® responds to movements picked up by the computer's camera.

Text to Speech produces audible speech of the written words you type into the speak block. Translate take the text you type into the translate block and reports it translated into the language you specify. It's interesting to use these two extensions together. With the code at the right, you will hear *Scratch*® say "Hola."



Sharing and Remixing *Scratch*® Projects

There are millions of projects shared on the *Scratch*® website. Examining these projects is an effective way to learn more about *Scratch*® programming and project building, as well as about the content conveyed in the projects.

When you first create a *Scratch*® project, it is private so that only you can see it. You can share it so that everyone else who visits the *Scratch*® website can also view it. In either case, only you can make changes to it. But *Scratch*® also allows you to remix someone else's project, making a copy of it for yourself. Here is how that works:

Sign into your *Scratch*® account and go to a project you are interested in. You will see a green "Remix" button at the top of the Projects Page. When you click this, a copy of the project will be saved in your account. It will have the same name as the original project with the word "remix" added at the end. There will be a message at the top of the Projects Page crediting the author of the original.

You are now free to alter it, add to it, use parts of it in another project of yours. You can share your resulting project. For more information about remixing, look at: **https://en.scratch-wiki.info/wiki/Remix**

Additional *Scratch*® Projects Related to the ESD Kits

Here are some examples of Projects created by *Scratch*® users and shared on the *Scratch*® website that relate to the themes of the ESD KitS. You can search on the *Scratch*® website using terms such as "wind power," "water quality," or "renewable energy" and you will find many more.

You can search for Projects or Studios. A *Scratch*® Studio is a collection of Projects that are related to each other in some way. Any *Scratch*® user can set up a Studio. If you search for "renewable energy" you will see Projects related to that theme. If you click the Studios tab, you will see Studios with collections of Projects on that theme. If you click on one of them, you will see the Projects in that Studio.

Wind Power

https://scratch.mit.edu/projects/15858581/
This is an interactive report on wind power and other sources of energy used to produce electricity.

Wind Power Grids

https://scratch.mit.edu/projects/718595

An overview of US Wind Power electric power grids.

The Story of Energy

https://scratch.mit.edu/projects/1021089

This interactive story of energy includes four games focused on using renewable energy sources and reducing energy consumption.

Solar Panel

https://scratch.mit.edu/projects/11732/

This *Scratch*® project presents the case for increased use of solar panels to generate electricity.

Protect our water quality!

https://scratch.mit.edu/projects/437778501/

This animated tutorial on water quality is followed by a brief quiz.

Water Quality

https://scratch.mit.edu/projects/299820109/

This is an interactive presentation about water quality with a quiz at the end.

ESD KIT: IMPACTS OF CLIMATE CHANGE

13 CLIMATE ACTION

Sustainable Development Goal 13: Climate Action

APPENDIX 2: ABOUT MICRO:BIT

The micro:bit is a microcontroller that connects with a wide range of sensors and output devices and is programmed by connecting it to a laptop, tablet, or smartphone. It is designed for use in education and is widely available in many countries. Visit the micro:bit Foundation website at **https://microbit.org/** for all the information you need to get started. Click the Get Started tab on the homepage for tutorials on how to set up and program the micro:bit. To obtain a micro:bit, click the Buy tab on the homepage to locate a distributor in your country.

For activities that include data logging, you will need a micro:bt V2, which is the current version. To become familiar with how data logging works, go to **https://microbit.org/get-started/user-guide/data-logging/.**

The micro: bit is a good choice for ESD Kit Investigations and projects for several reasons. It is

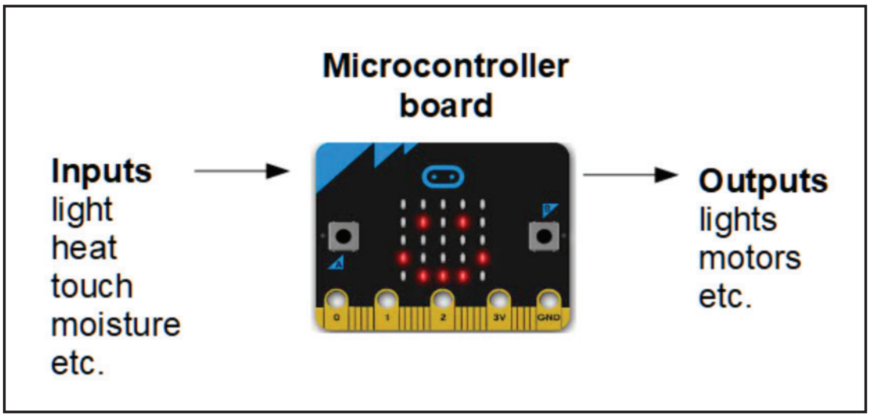
1. designed for education and has extensive support for teachers and students,
2. relatively low cost, and
3. widely available around the world.

Also, micro:bit has sensors built into the board itself, including temperature and light. Additional external sensors may be connected to it. The current version (V2) can be used for data logging.

An alternative to micro:bit is Arduino **https://www.arduino.cc/**, a family of similar microcontrollers. They are also widely available and well-supported.

More About Microcontrollers

A microcontroller is a device that takes inputs from sensors and acts upon them to control various devices. They are found in many appliances including microwave ovens, heating and cooling units, and automobiles.



Credit: Logo Foundation

Here are some examples of how a microcontroller can be used with sensors and output devices:

Light sensor à turn lights on at night, off during the day

Temperature sensor à turn a fan on when it's hot, off when it's cool

Moisture sensor à turn irrigation water on when the ground is dry; off when moist

Microcontrollers can also be used to record sensor data over time. For example, you could record temperature at one-minute intervals over a period of 24 hours and then use the data in a graph or other visual representation.