Hudson River Estuary Climate Change Lesson Project

Grades 5-8

Teacher's Packet

New York State Water Resources Institute

Cornell University

Introduction

These middle school lesson plans are designed to help young students understand climate and weather basics and explore climate change related issues close to home in the Hudson River Valley. Most of the lessons have been adapted for use from existing peer reviewed plans. The original source material is credited at the beginning of each lesson. The material presented is not designed as a curriculum unit, so each lesson may be used independently.

Special thanks to Steve Stanne, the Hudson River Estuary Program's Estuary Education Coordinator, for his careful help in selecting and editing the lessons. Thanks also to Meghan Marrero, Ed.D. and Mr. Seth Van Gaasbeek, teachers in our region who spent many hours editing and reviewing the plans and correlating them to learning standards.

New York Sea Grant has produced these educational materials in partnership with the New York State Water Resources Institute at Cornell University and the New York State Department of Environmental Conservation Hudson River Estuary Program with support through the New York State Environmental Protection Fund.

Nordica Holochuck
nch8@cornell.edu
New York Sea Grant

November 2014

Contents

Lesson 1

Investigating the Differences Between Climate and Weather

Cornell University

Investigating the Differences between Climate and Weather

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

- S1.2c Differentiate among observations, inferences, predictions, and explanations.
- S2.1d Use appropriate tools and conventional techniques to solve problems about the natural world, including: measuring, observing, describing, classifying, sequencing.
- S2.3b Conduct a scientific investigation.
- S2.3c Collect quantitative and qualitative data.
- S3.1a Organize results, using appropriate graphs, charts, and data tables.
- S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.
- S3.2h Use and interpret graphs and data tables.

Standard 6: Interconnectedness

- 5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Physical Setting

- 2.2i Weather describes the conditions of the atmosphere at a given location for a short period of time.
- 2.2j Climate is the characteristic weather that prevails from season to season and year to year.
- 2.2q Hazardous weather conditions include thunderstorms, tornadoes, hurricanes, ice storms, and blizzards. Humans can prepare for and respond to these conditions if given sufficient warning.
- 2.2r Substances enter the atmosphere naturally and from human activity. Some of these are carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.

Next Generation Science Standards

Science and Engineering Practices:

2. Developing and using models
4. Analyzing and interpreting data
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Grade 6

- ESS2-5. Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

Grade 7

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

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.7

Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Common Core State Standards - Mathematics
Standards for Mathematical Practice

CCSS.Math.Practice.MP2

Reason abstractly and quantitatively.

CCSS.Math.Practice.MP4

Model with mathematics.

Grade 6

CCSS.Math.Content.6.NS.C.8

Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Investigating the Differences Between Climate and Weather

Adapted from the Climate Discovery Teacher's Guide, National Center for Atmospheric Research: http://eo.ucar.edu/educators/ClimateDiscovery/LIA_lesson1_9.28.05.pdf

Introduction

Interpreting local weather data and understanding the relationship between weather and climate are important first steps to understanding larger-scale global climate changes. In this activity, students will collect weather data over several days or weeks, graph temperature data, and compare the temperature data collected with averaged climate data where they live.

Background Information

When atmospheric scientists describe the "weather" at a particular time and place or the "climate" of a particular region, they describe the same characteristics: air temperature, type and amount of cloudiness, type and amount of precipitation, air pressure, and wind speed and direction. Why are the same characteristics used to describe both weather and climate? And why do we eagerly listen to the local weather forecaster but pay far less attention to predictions from the state climatologist?

Weather is the set of current atmospheric conditions, including temperature, rainfall, wind, and humidity at any given place. Weather is what is happening right now or likely to happen tomorrow or in the very near future.

Climate is sometimes referred to as "average" weather for a given area. The National Weather Service uses values such as temperature highs and lows and precipitation measures for the past thirty years to compile "average" weather for any given area. However, some atmospheric scientists consider "average" weather to be an inadequate definition. To more accurately portray the climatic character of an area, variations, patterns, and extremes must also be included. Thus, climate is the sum of all statistical weather information that helps describe a place or region.

In the winter, we expect it to often be rainy in Portland, Oregon, sunny and mild in Phoenix, Arizona, and very cold and snowy in Buffalo, New York. But it would not be particularly startling to hear of an occasional January day with mild temperatures in Buffalo, rain in Phoenix, or snow in Portland. Meteorologists often point out that "Climate is what you expect and weather is what you get." Or, as one middle school student put it, "Climate helps you decide what clothes to buy, weather helps you decide what clothes to wear." Scientists rely on large amounts of data over long timeframes to establish if the current weather patterns are usual. As weather measurements have been made for only 100-200 years, scientists look to records preserved in ice cores, tree rings, and sediment layers to identify how climate has varied in the past. Worldwide averages are used to describe global climate. Global climate is not easy to change. Regional averages may vary a bit, without causing a change in global climate. For instance, if the climate of Tunisia becomes warmer, and the climate of Mexico becomes cooler, the global average may not change. However, if regions warm more and are not balanced by other areas that cool, then global climate warms, as is the case over the past century. To investigate how climate may be changing due to human influences, scientists use weather data from as far back as the historical record goes (100-200 years). Detailed daily weather data are collected at surface weather stations throughout the world.

Understanding and interpreting local weather data and understanding the relationship between weather and climate are important first steps to understanding larger-scale global climate changes.

Objectives

Students will be able to

- Collect and analyze local weather data and compare their findings to climate data.
- Compare and contrast weather and climate.
- Explain that daily weather measurements are highly variable compared to long-term climate data.
- Give examples of climate changes being observed in the Hudson Valley.

Materials Required

- Thermometers
- Student data sheets
- Graph paper

Advanced Preparation

- Print and copy the Weather Data Student Page from Investigating the Difference Between Climate and Weather: http://eo.ucar.edu/educators/ClimateDiscovery/LIA.htm
- Print and copy the Climate Change in the Hudson Valley Fact Sheet: http://www.dec.ny.gov/docs/remediation_hudson_pdf/hreccfs.pdf (end of this section)
- Find climate data for your city, or use the sample data from Newburgh, NY below. Climate data may be obtained from regional climatologists or local news stations. Alternatively, go to www.weather.com or www.wunderground.com and search for your city name to get local weather and monthly averages. Show the graph of monthly averages to the class when introducing Part 2 of this lesson.
- Choose Daily Averages and select the month in which you are doing the activity. Use the mean temperature values when plotting climate data in the Explain part of the lesson.

Engage

Discuss with students:

- When you think about weather, what do you think about?
- If we wanted to compare weather from day to day scientifically, how could we do that?
- Do you think our weather is consistent from day to day, or very variable?
- In which months do you think the weather is most consistent? Most variable?

Explore

1. Explain to students that they will be collecting daily weather data, including temperature, cloud cover, and wind. Ask:
   a. What factors might affect temperature? b. How?
2. Review with students how to use the thermometer.
3. Explain that each day a different pair of students will take the temperature measurement, and that because different people will be collecting data, it is important to use consistent procedures. As a group, determine the procedure that students will follow each day to take measurements.

(Observations should include the time of day and location. Care should be taken to ensure that body or building heat doesn't influence temperature measurements. Other considerations might include distance off the ground, number of measurements, length of time outside before measuring, etc.)

4. Post these methods in a prominent classroom location.
5. Model how to use the Weather Data Student Page. Explain that each day, a team will use the student page to record their findings. Be sure students understand how they will qualitatively assess the cloud cover and wind.
6. Create a classroom data table in which student pairs will record the daily temperatures.

Explain

- After one month, direct students to create a line graph of the daily temperatures from the classroom data table.
- Ask students to make at least two observations based on their graph, and identify any patterns they see in the data. Discuss these observations as a class.
- Ask the students if they think that their data is "typical" or representative of the weather for the period of time they have been monitoring. The goal is for students to begin to understand that daily variations in weather are normal.
- Explain that the term weather describes short-term changes in a local area, whereas climate refers to long term patterns and wider regions. Ask students whether they collected weather or climate data.
- Show students the graph of average daily temperature over a year for Newburgh, NY, or for your city. (See Advanced Preparation section above for help finding a graph.)
- www.weather.com/weather/wxclimatology/monthly/graph/USNY1003

- Ask students what general patterns they see about climate from the graph. Ask how this graph might help someone who is visiting the region to plan what sort of clothes to bring with them. For instance, if they are visiting in July, what should they bring? Would it help them to plan for tomorrow specifically?
- Next, show students the average temperature data for the same time period that they observed. To access the data for Newburgh, NY, go to:
  www.weather.com/~~weather/wxclimatology/daily/USNY1003~~
  To use the data from your city, follow the instructions in Advanced Preparation.
  Ask students to focus on the mean temperatures for the time period.
- Compare the data from the climate graph to student weather data for the same time of year. To do this, students should plot climate temperature data points on their graphs with a different color and connect points with a line.
- Discuss the differences between weather and climate:
  - Which is more variable: the daily temperature values or the average temperature values? Why?
  - Is the temperature data that the class collected warmer, cooler, or about the same as the average?
  - If you were asked to predict the temperature for tomorrow, which data would you find the most useful: the previous day's temperature, or the average temperature for that day?

Elaborate

- Bridge the discussion of weather and climate into a discussion of climate change. Explain to students that scientists have been closely studying temperature and other data, and that over the past 150 years or so, our global climate has been warming. Note that scientists are collecting data from all over the world.
- Discuss:
  - If a scientist reported that your state was warmer last month than the same month a year ago, would you consider this to be evidence for climate change? Why or why not?
  - Distribute copies of the Climate Change in the Hudson Valley Fact Sheet:
    www.dec.ny.gov/docs/remediation_hudson_pdf/hreccfs.pdf *(The NYSDEC is updating this sheet to include even more information, so please check for the latest version.)*

  Read the first page as a class. Then discuss:
  - How is New York State's climate changing?
  - How are these changes affecting living things?
  - What are scientists predicting for the future?

Evaluate

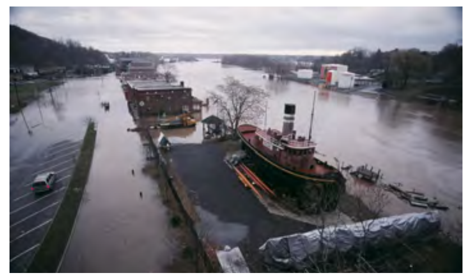
In a paragraph or Venn diagram, have students compare and contrast weather and climate.

New York State DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Hudson River Estuary Program

Climate Change in the Hudson Valley

The climate of the Hudson Valley is changing. Climate scientists have documented actual and expected changes in our regional climate and how these changes will affect natural and human communities in our region.



Climate change is increasing the risk of flooding in shoreline communities (C. Bowser)

Why is the climate changing?

As the sun warms the Earth, the Earth radiates heat. Certain gases, called greenhouse gases (GHGs), trap some of this heat in the lower atmosphere. Some human activities, like burning fossil fuels, release GHGs into the atmosphere and intensify the greenhouse effect, warming the earth. This warming, called global warming, is affecting long-term weather patterns, or climates, around the world and in the Hudson Valley.

How much has the climate changed in our region?

- New York State's average temperature has gone up nearly 2ºF in 30 years.
- Winter average temperatures have warmed even faster, 5ºF in 30 years.
- Bloom dates of many plant species are 4-8 days earlier on average than they were in the early 1970s.
- Average rainfall is increasing, and days with snow cover are decreasing.
- Sea level in New York Harbor is 15 inches higher today than it was in 1850.

What kinds of changes can we expect in the future in the Hudson Valley?

- Shorter, warmer winters and longer, hotter summers will affect local farmers and winter recreation, and may increase diseases carried by insect populations as they shift northward.
- Rising sea levels and strong storms will cause localized floods and threaten shoreline infrastructure and development.
- Rising summer air temperatures will increase pollution-related asthma and heat exhaustion, especially in urban areas.
- Invasive species and nuisance plants will thrive under elevated atmospheric CO_2 levels.

New York State
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

How can we respond to climate change?


Wetlands help absorb floodwaters (C.Bowser)

The severity of climate change we see will depend on energy choices we make today and over the next decade. The Hudson River Estuary Program is working with NYSDEC's Climate Change Office and regional partners to help communities understand the sources and projected impacts of climate change and to coordinate regional responses.

How can local governments reduce greenhouse gas emissions?

- Organize a global warming task force and complete a greenhouse gas emissions inventory. For more information: ICLEI Local Governments for Sustainability (http://www.iclei-usa.org/programs/climate) and The Climate Registry (www.theclimateregistry.org/)
- Reduce greenhouse gas emissions and save money by improving the energy efficiency of municipal buildings and operations
- Install solar, wind or other renewable energy technologies in power facilities
- Add hybrid and more fuel-efficient vehicles to government fleet
- Reduce solid waste through recycling programs

How can local governments adapt to a changing climate?

- Identify potential impacts (e.g., increased risk of flooding)
- Develop emergency management teams and improve emergency communication
- Keep development out of flood-prone areas
- Manage stormwater to reduce flooding and find alternatives to paved surfaces
- Conserve wetlands and forests that absorb floodwaters and recharge groundwater

What can I do to help?

- Reduce greenhouse gas emissions and save money by improving energy efficiency
- Walk, bike or carpool to work or on errands
- Buy Energy Star appliances
- Support green power. Check your utility's website for more information
- Get involved in your local government! Organize a community presentation or event on climate change

How can I learn more about climate change in the Hudson Valley?

Visit the Hudson River Estuary Program web site at: http://www.dec.ny.gov/lands/39786.html

Or contact:
Kristin Marcell, Special Projects Coordinator
NYS DEC Hudson River Estuary Program, 21 South Putt Corners Rd., New Paltz, NY 12561
kamarcel@gw.dec.state.ny.us
845-256-3017

www.dec.ny.gov

Lesson 2

Observing Changes at Mohonk Preserve

Observing Changes at Mohonk Preserve

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

- S1.2c Differentiate among observations, inferences, predictions, and explanations.
- S2.1d Use appropriate tools and conventional techniques to solve problems about the natural world, including: measuring, observing, describing, classifying, sequencing.
- S3.1a Organize results, using appropriate graphs, charts, and data tables.
- S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.
- S3.2h Use and interpret graphs and data tables.

Standard 6: Interconnectedness

- 5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Physical Setting

- 2.2i Weather describes the conditions of the atmosphere at a given location for a short period of time.
- 2.2j Climate is the characteristic weather that prevails from season to season and year to year.
- 2.2q Hazardous weather conditions include thunderstorms, tornadoes, hurricanes, ice storms, and blizzards. Humans can prepare for and respond to these conditions if given sufficient warning.
- 2.2r Substances enter the atmosphere naturally and from human activity. Some of these are carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.

Next Generation Science Standards

Science and Engineering Practices:

4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Grade 6

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

Grade 7

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

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.7

Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Common Core State Standards - Mathematics

Standards for Mathematical Practice

CCSS.Math.Practice.MP2

Reason abstractly and quantitatively.

CCSS.Math.Practice.MP4

Model with mathematics.

Grade 6

CCSS.Math.Content.6.NS.C.8

Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Observing Changes at Mohonk Preserve

New York Sea Grant developed this lesson plan using information from the Mohonk Preserve website www.mohonkpreserve.org

Introduction

Students will plot recent data and long-term averages of temperature and precipitation to discover the importance of long-term data sets. Using a presentation developed by scientists at Mohonk Preserve, they will learn more about the data sets and relate the weather data with phenological data. Phenology is the study of how living things respond to cyclical phenomena, in particular, how plants and animals respond to seasonal changes.

Background Information *(from the Mohonk Preserve website)*

A preliminary analysis of the Preserve's weather data shows that the average temperature has risen about two degrees over the past 113 years.

Composed of more than 40,000 days of weather observations, these records are part of the collection of the Preserve's Mohonk Lake Cooperative Weather Station, established in 1896 by the U.S. Weather Bureau (now the National Weather Service).

Weather readings at Mohonk began in the mid-1880s, taken by the Smiley family, founders of the neighboring Mohonk Mountain House, and are now continued by Preserve research staff. Beginning in the late 1970s, data collection expanded to include regular monitoring of the pH of precipitation, lakes, and streams.

Why are these data important?

To identify the extent of global climate change, researchers need access to reliable data covering the longest period possible. The Preserve's weather data is dependable because the station has been in the same, comparatively stable location for over a century and the same protocol has been followed by the relatively few people involved in collecting the data.

Objectives

Students will be able to

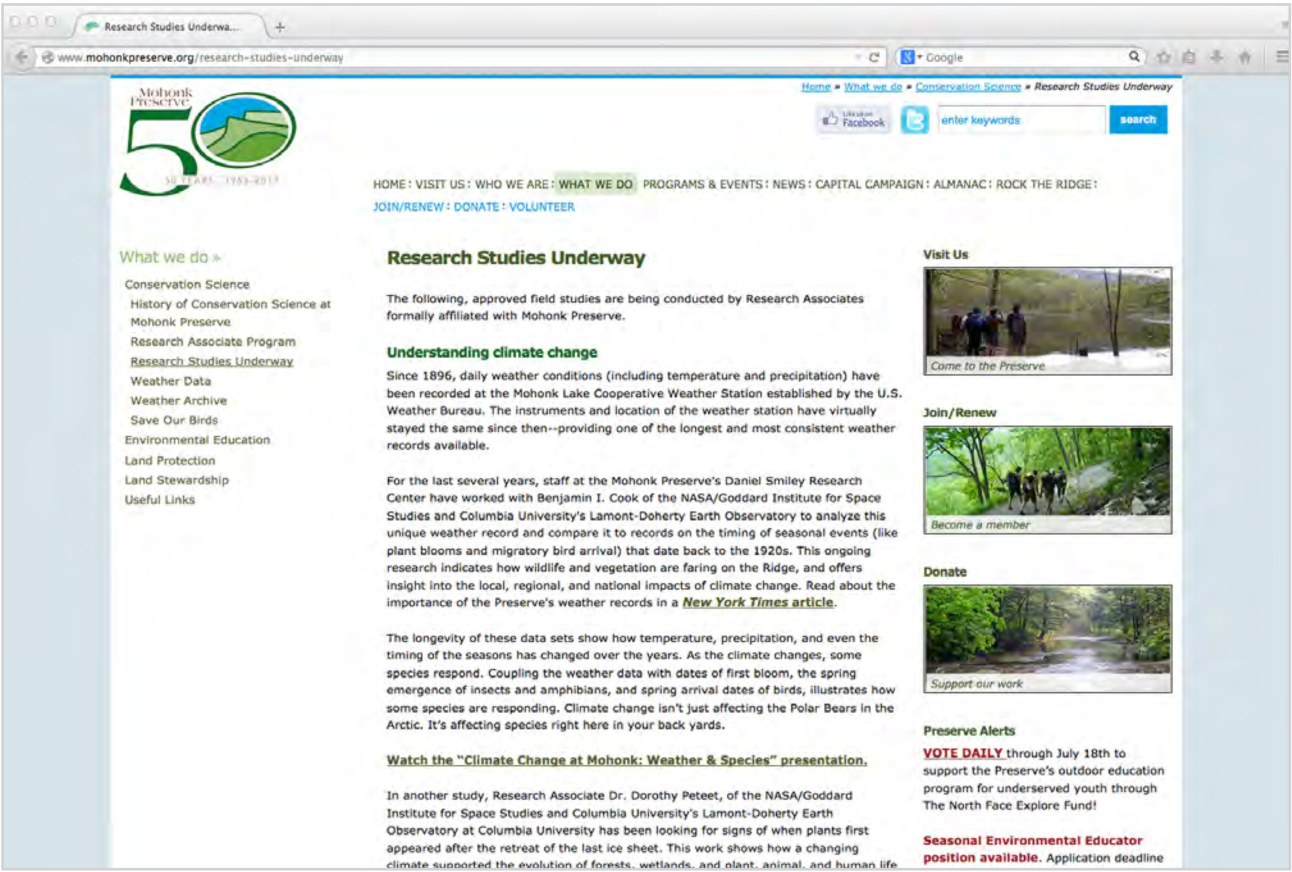
- Discuss the importance of long-term data sets.
- Analyze temperature and precipitation data.
- Compare recent data to long-term averages.
- Relate observed changes in weather and climate patterns to phenological changes.

Materials Required

- Presentation: "Climate Change at Mohonk: Weather & Species 1896-2012" (see advanced preparation). This lesson plan recommends starting and stopping points if you do not wish to show students the entire presentation at once.
- Computers or tablets with Internet access for pairs of students.
- Graph paper.

Advanced Preparation

- Download the presentation above from www.mohonkpreserve.org/research-studies-underway
- If possible, bookmark the site: www.mohonkpreserve.org/weatherarchive, from which students will get data in the Explore section.
- Photocopy the student worksheet.



The website is shown above.

Engage

- Discuss with students:
- How do we know what weather and climate were like 100 years ago?

Explain that there is a place in the Hudson Valley where the same measurements have been taken daily for well over 100 years. Show students the first 4 minutes and 35 seconds (or a little more) of the presentation (see Materials Required).

The presentation will give students some background on the area in which the data have been collected.

Explore

Explain to students that they are going to analyze some of the data that have been collected at Mohonk. The data used to be kept in log books but more recently is available digitally.

Divide students into pairs or groups of three. Each group should be assigned a different month. The groups will be using the weather archive (www.mohonkpreserve.org/weather-archive) to look at changes in their month over the amount of time captured on the page (<10 years). They will compare the observed data to the long-term averages and note any special data mentioned in the data sheet.

Bring up an example, e.g., January 2014 and model with students how to identify the month's actual data and to transfer the data from the data sheets to their student worksheets. You may want to show them how to do this with a document camera or on your SmartBoard.

Also model to students how to create their graph. Their years should go on the x-axis (independent variable) and temperature and precipitation on the y-axis (dependent variable). They will probably need a reminder about how to create an appropriate scale. Also note that they will graph the average readings as a straight line across the graph, which may cause some confusion.

If students are advanced, have them graph all three variables on the same graph. Most middle schoolers will probably need to graph temperature, rainfall, and snowfall on separate graphs.

Explain

Once all student groups have graphed their data, line up the data in the order of months across a long wall in your classroom. If your students did three different graphs, be sure that they align the rows so that precipitation graphs are lined up next to one another and so on.

While the graphs will not perfectly align because students have selected their own scales, students should be able to see the trend in how the data compare with the long-term averages, no matter the month. Discuss these findings as a class.

Also ask students to share any "interesting notes" they recorded.

Begin the recording again at 6:31. Stop the recording several times to discuss the findings and compare them to students' findings using discussion questions such as the ones below:

Discuss

- Why do your graphs look different from the ones in the presentation?
- What can you learn from some of the different sets of data, e.g., top 10 warmest years?

At 7:53, the narrator begins explaining the idea of lake ice cover. She notes that ice duration, the number of days that Mohonk Lake is completely frozen over, is now 27 days shorter than it was in the 1930s. Stop the presentation at 8:55.

Discuss how lake ice can affect living things, and also why lake ice is important. How does this data set relate to the temperature data?

Continue the presentation. The narrator begins to discuss precipitation data. Ask students to relate their data to the data she presents. Stop at 10:18.

Elaborate

Have students discuss the following with a partner:

- How do you think living things are affected by the changes in temperature that have been observed?
- Consider:
  - Plants
  - Birds
  - Frogs and other ampibians
  - Insects

Direct pairs of students to then share their ideas with the class.

- Begin the presentation again at 11:05, when the narrator begins discussing phenological data. Stop at 14:12.

The narrator discusses many examples of early emergence or arrival of plant, amphibian, insect, and bird species.

Discuss with students

- What do you take away from this clip? Why is this information important?
- Do you think this is evidence that the plants and animals are adapting to changes in climate? Why or why not?
- How do you think living things are affected in summer and fall?

Have students write a prediction about how they think bird species are responding to climate changes during the fall season.

Begin the presentation again at 17:43, when the narrator begins discussing the growing season, and play to the end (~23 minutes). She then discusses changes in peak fall foliage and changes in migration of species. Have students take notes that relate to their hypotheses. Pause the video occasionally to facilitate student note taking.

Discuss

- Were your hypotheses supported? What evidence to you have?

Evaluate

Wrap up the lesson with a discussion of why long-term data sets are so important. Ask students to think about what we would know if we only had the data sets they graphed versus what we know based on the long-term data. Why is this important? How can this knowledge be used?

Observing Changes at Mohonk Preserve **Student Worksheet**

Explore

You will be analyzing the temperature and precipitation data for one month over the course of several years. Mohonk scientists have done this for over 100 years! Repeat the following directions for your assigned month for each year.

Directions

1. Go to www.mohonkpreserve.org/weather-archive
2. Choose the most recent year for which there are data for your month.
3. See the column that says "Actual This Year," which is the middle column.
   Record the temperature, precipitation (rain) and snow, in the data table below.
4. Also record any interesting notes in the last column.

Month Assigned:________________________________

Year	*Temperature (°F)*	*Precipitation (rain) (inches)*	*Precipitation (snow) (inches)*	*Interesting notes*

Next, record the average since 1896 (1st column):

Long Term Average (Years)	***Temperature (°F)***	***Precipitation (rain) (inches)***	***Precipitation (snow) (inches)***

5. The next step is to create your graphs.
   a. First, graph your temperatures.
      i. Evenly space out the years observed on your x-axis, and
      ii. Determine the best scale for your y-axis based on the range of temperatures you recorded
      iii. Plot your observed temperatures on your y-axis. Then, graph your long term average as a straight line across your graph.
   b. Next, graph your rainfall data. Follow the same procedure.
   c. Finally, graph your snowfall data.

6. Use your data tables and graphs to answer the questions below:
   a. How do the temperature readings you recorded compare to the long-term averages?

   b. How do the precipitation readings you recorded (rain and snow) compare to the long-term averages?

   c. In your own words, explain what these observations mean.

   d. How do your "interesting notes" support your explanation?

Elaborate

Scientific Question: How are bird species responding to changes in the fall season at Mohonk Preserve?

Hypothesis:

Lesson 3

Climate Change in My City

New York State Water Resources Institute
Cornell University
Hudson River Estuary
Sea Grant New York

Climate Change in My City

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

- S1.3 Represent, present, and defend their proposed explanations of everyday observations so that they can be understood and assessed by others.
- S1.4 Seek to clarify, to assess critically, and to reconcile with their own thinking the ideas presented by others, including peers, teachers, authors, and scientists.
- S2.3c Collect quantitative and qualitative data.
- S3.1a Organize results, using appropriate graphs, charts, and data tables.
- S3.2c Evaluate the original hypothesis in light of the data.
- S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.
- S3.2h Use and interpret graphs and data tables.

Standard 6: Interconnectedness

- 5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Living Environment

- 7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Standard 4: The Physical Setting

- 2.2i Weather describes the conditions of the atmosphere at a given location for a short period of time.
- 2.2j Climate is the characteristic weather that prevails from season to season and year to year.
- 2.2q Hazardous weather conditions include thunderstorms, tornadoes, hurricanes, ice storms, and blizzards. Humans can prepare for and respond to these conditions if given sufficient warning.
- 2.2r Substances enter the atmosphere naturally and from human activity. Some of these are carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.

Next Generation Science Standards

Science and Engineering Practices:

2. Developing and using models
4. Analyzing and interpreting data
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Grade 6

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

Grade 7

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

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

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

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

CCSS.ELA-Literacy.WHST.6-8.1a
Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

CCSS.ELA-Literacy.WHST.6-8.1b
Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

CCSS.ELA-Literacy.WHST.6-8.2b
Develop the topic with relevant, well-chosen facts, definitions, concrete details, quotations, or other information and examples.

CCSS.ELA-Literacy.WHST.6-8.2d
Use precise language and domain-specific vocabulary to inform about or explain the topic.

CCSS.ELA-Literacy.WHST.6-8.8
Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Common Core State Standards - Mathematics
Standards for Mathematical Practice

CCSS.Math.Practice.MP2
Reason abstractly and quantitatively.

CCSS.Math.Practice.MP4 Model with mathematics.

Grade 6

CCSS.Math.Content.6.NS.C.8
Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Climate Change in My City

Adapted from the World Wildlife Foundation Lesson on the WWF blogs
http://www.wwfblogs.org/climate/sites/default/files/WWFBinaryitem5966.pdf

Introduction

In this lesson, students will analyze short and long-term data and look for patterns and trends.

Background Information

Weather concerns the present and near-term future state of the atmosphere, whereas climate accounts for all past weather events as well as the future (in the form of climate model projections).

Scientists evaluate global warming by looking at trends in the global temperature, which is the average of the highs and lows measured at thousands of locations around the Earth. Observations collected over the last century suggest the average land-surface temperature has risen 0.45-0.6°C (0.8-1.0°F). The surface of the ocean has also warmed at a similar rate. Studies that combine land and sea measurements have generally estimated that global temperatures have warmed 0.3-0.6°C (0.5-1.0°F) in the last century.

Regional and local temperature trends will be different from the global average—over the last century some areas have warmed while others have cooled.

Objectives

Students will be able to

- Analyze temperature and precipitation data.
- Compare recent temperature and precipitation data with long-term averages.
- Describe how local temperatures have changed in the last ~75 years.
- Explain the importance of comparing short-term data with long-term averages.

Materials Required

- Smartboard or computer and projector
- Laptops or tablets for pairs of students to work on (alternatively, you can do the activities as a whole class)

Advanced Preparation

- Photocopy student worksheets
- If possible, bookmark the following website on computers or tablets on which students will be working:
  - http://www.ncdc.noaa.gov/sotc/national

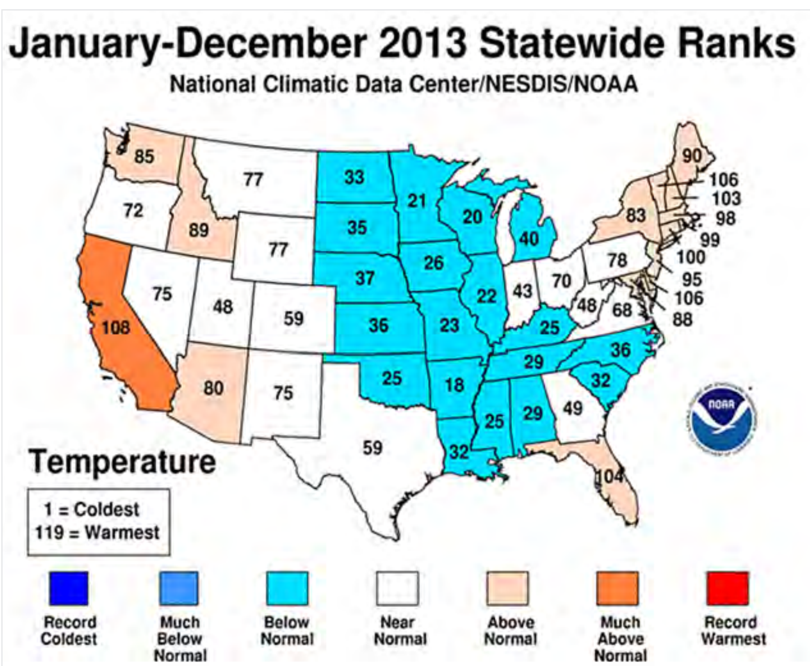
Engage

As a "Do Now," ask students to think about the weather in their area over the last year. Ask them what stands out in their minds, e.g., warm winter, rainy spring, heavy snowfall, more snow days than usual, etc.
Then ask them to make a judgment, based on their own observations, as to whether the previous season was warmer or colder than normal, and whether it was drier or wetter than normal. Ask them to consider what factors influence their responses, e.g., how much time they spend outside, how much their lifestyles depend on the weather, etc.

Have each student make a prediction about whether the previous year's temperature and precipitation were normal, above, or below normal (see student worksheet), for both New York and the nation. Tell them that they will be analyzing data to test their hypotheses.

Explore

- Show students the page: NOAA National Climatic Data Center: www.ncdc.noaa.gov/sotc/national
- Discuss the national overview for the previous year, which indicates noteworthy climate events on an annual basis.
- Next, scroll to select Temp, Precip, and Drought from the menu. Open that page, scroll down and select National Temperature and Precipitation Maps. Under Products, select Statewide Average Temperature Ranks. Discuss the color scale so that students understand how to read it. A year's data are compared to either the 20th century average or 119 year average. For the purposes of this lesson, you can refer to it as a 100 year average. Be sure students understand what is meant by this term.
- Also discuss the ranking system. The ranks indicate years from coldest to warmest, with low numbers indicating much colder than normal years, and highest numbers indicating much warmer than normal years. For instance, in the image below from 2013, Minnesota experienced its 21st coldest year on record, whereas California experienced its 12th warmest year on record.



- Have students work in pairs to further analyze the maps as directed on the student worksheets.

Explain

- As a class, discuss students' findings and whether their predictions were supported by the data or not. Ask:
  - Why might your predictions be different from what the data show?
  - Why is analyzing data important?
  - Why is looking at precipitation, in addition to temperature, important?
- Bring up the temperature and precipitation maps that students analyzed and discuss any patterns you can observe in the maps.
- Why are the rankings important? Why do scientists look at long-term averages?

Elaborate

- Explain to students that the NASA Goddard Institute for Space Studies, located in Manhattan, maintains a database of temperatures in many cities throughout the United States. Bring up the stations website http://data.giss.nasa.gov/csci/stations/ and click on New York. Then click on your city, or one close to you.
- Discuss:
  - What are some observations you can make based on this graph?
  - What is the overall trend—are temperatures increasing or decreasing?
  - Why does it go up and down? Why are there blank spaces in the graph?
- Next show students the following page: http://data.giss.nasa.gov/csci/bargraphs/, which shows continental United States and global temperatures as compared to the mean for the past ~180 years.
- Use questioning to be sure students understand that this image is very similar to the maps they analyzed earlier.
  - What does it mean when bars are above zero? Below?
  - What are some observations you can make based on this graph?
  - What is the overall trend—are temperatures increasing or decreasing?
  - Why are these data important?
  - How do our local data (on the previous graph) compare to these data?
  - How do last year's data (on the maps they analyzed) compare to these long term data?
  - Why might they be different? (Remind students that they are comparing different types of data, but they can look at the overall trends).

Evaluate

Using weather.com or another weather site, show students the past month's high and low temperatures for your city. (Put in your zip code, then click on "Monthly." You can also click to the previous month.)

Discuss, or ask students to respond in writing to, the following questions:

- How do these data compare to the data we have been looking at in this lesson? Are they above average, below average, or near normal?
- Why are both short-term and long-term data important?

Student Worksheet Climate Change in My City

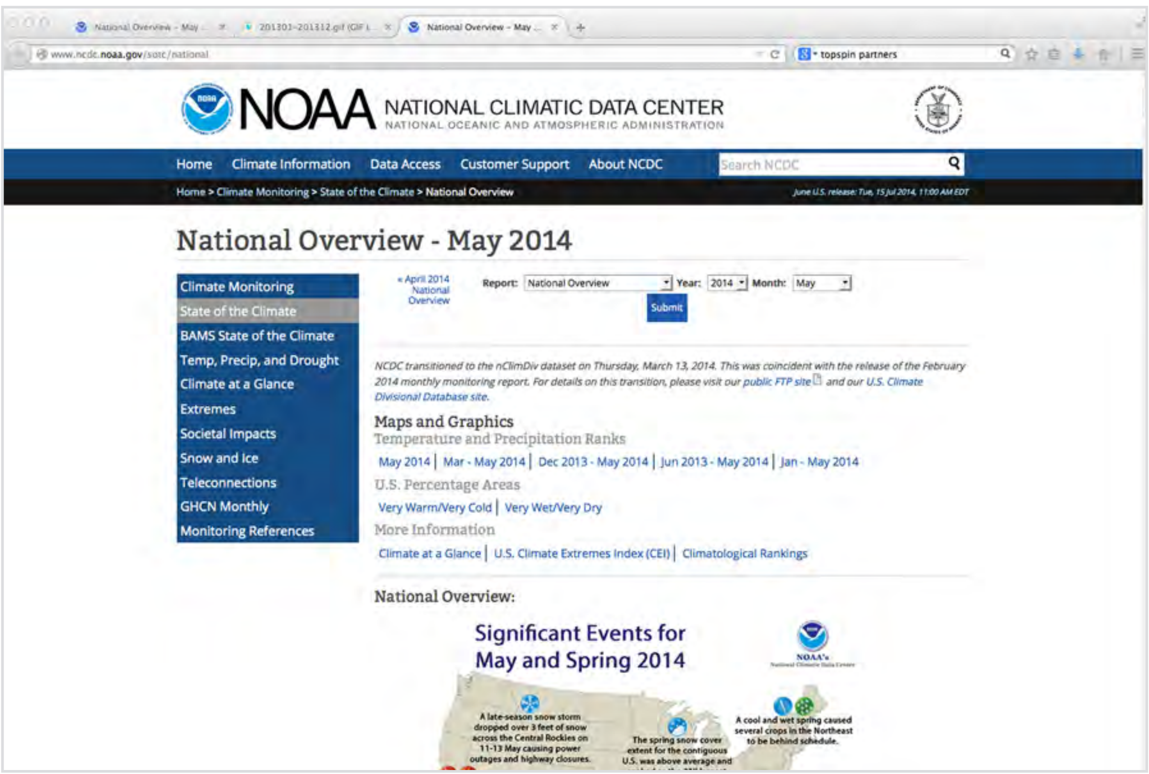
Engage

Think about the last calendar year. Think about what you remember about the weather, both near home and in the news from other locations. Then, make a prediction about how the temperature and precipitation of last year compares with long-term averages. Circle your prediction:

- In New York State, temperature was warmer than/the same as/cooler than normal last year.
- In New York State, precipitation was more than/the same as/less than normal last year
- In the continental United States, temperature was warmer than/the same as/cooler than normal last year.

Explore

1. Go to: http://www.ncdc.noaa.gov/sotc/national



2. Scroll to select Temp, Precip, and Drought from the menu. Open that page, scroll down and select National Temperature and Precipitation Maps. Under Products, select Statewide Average Temperature Ranks.
3. What year's data are you analyzing? ______________________________
4. To view and analyze the January-December Average Ranks for Temperature Map, select December as the month and 12 months in the Time span drop down menu.
   a. Was the yearly average for New York warmer or colder than normal, or near normal?

   b. How does this finding compare with your prediction?

c. In the data table below, write the number of states that fall into the following temperature categories for the year you are analyzing:

Temperature Category	*Number of States*
Record Temperature	
Much Above Normal	
Above Normal	
Near Normal	
Below Normal	
Much Below Normal	
Record Coldest	

d. For the year you analyzed, was the continental United States warmer or colder than the 100 year average? Use data from the table to support your answer.

e. How does this finding compare with your prediction?

5. Next, analyze the January-December Statewide Ranks for Precipitation Map.
   a. Was the yearly average for New York drier or wetter than normal, or near normal?
   b. How does this finding compare with your prediction?

c. In the data table below, write the number of states that fall into the following precipitation categories for the year you are analyzing:

Precipitation Category	*Number of States*
Record Wettest	
Much Above Normal	
Above Normal	
Near Normal	
Below Normal	
Much Below Normal	
Record Driest	

d. For the year you analyzed, was the continental United States drier or wetter than the 100 year average? Use data from the table to support your answer.

e. How does this finding compare with your prediction?

Lesson 4

Paleoclimate of the Hudson Valley

Paleoclimate of the Hudson Valley

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

- S2.3b Conduct a scientific investigation.
- S2.3c Collect quantitative and qualitative data.
- S3.1a Organize results, using appropriate graphs, charts, and data tables.
- S3.2c Evaluate the original hypothesis in light of the data.
- S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.
- S3.2h Use and interpret graphs and data tables.

Standard 6: Interconnectedness

- 5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Living Environment

- 1.1f Many plants have roots, stems, leaves, and reproductive structures. These organized groups of tissues are responsible for a plant's life activities.
- 3.2c Many thousands of layers of sedimentary rock provide evidence for the long history of Earth and for the long history of changing life forms whose remains are found in the rocks. Recently deposited rock layers are more likely to contain fossils resembling existing species.
- 7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Standard 4: The Physical Setting

- 2.1h The process of weathering breaks down rocks to form sediment. Soil consists of sediment, organic material, water, and air.
- 2.2j Climate is the characteristic weather that prevails from season to season and year to year.
- 2.2q Hazardous weather conditions include thunderstorms, tornadoes, hurricanes, ice storms, and blizzards. Humans can prepare for and respond to these conditions if given sufficient warning.
- 2.2r Substances enter the atmosphere naturally and from human activity. Some of these are carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.

Next Generation Science Standards

Science and Engineering Practices

2. Developing and using models
4. Analyzing and interpreting data
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Grade 6

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

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.1
Cite specific textual evidence to support analysis of science and technical texts.
CCSS.ELA-Literacy.RST.6-8.2
Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
CCSS.ELA-Literacy.RST.6-8.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.
CCSS.ELA-Literacy.RST.6-8.8
Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Common Core State Standards - Mathematics
Standards for Mathematical Practice

CCSS.Math.Practice.MP2
Reason abstractly and quantitatively.
CCSS.Math.Practice.MP4
Model with mathematics.

Paleoclimate of the Hudson Valley: Historic Plant Communities

***Adapted From:** http://www.caryinstitute.org/educators/teaching-materials/changing-hudson-project/pollution/day-2-paleoclimate-hudson-valley*

Introduction

This hands-on activity from the Cary Institute of Ecosystem Studies is appropriate for middle school students and can help them learn about the history of climate change in our region. The Hudson Estuary Paleoclimate is modeled by replicating fossilized pollen in marsh sediment.

Students use model "soil samples" to discover clues to the Hudson Valley's climate history over the last 16,000 years.

Objectives

Students will be able to

- Explain how scientists use sediment cores to study past climate
- Analyze model soil samples
- Determine the climate in which model soil samples were created
- Describe climate patterns over time in the Hudson Valley.

Advanced Preparation

1. Make copies for each student of the student worksheet and Hudson Valley Paleoclimate reading.

2. Create a sample "sediment core" with visibly different layers of soil. You can build this in a graduated cylinder, tennis ball container, soda bottle, etc. Either create layers as described in the chart below, or just use different types of soil to stimulate students' thinking.

3. Before class, prepare eight bags of soils with the mixtures of confetti described below. The ratios are approximate; feel free to use whatever colors of confetti you have on hand, pieces of paper (hole-punch construction paper or laminated colored paper) or other materials to represent the pollen. You can use visibly different soil types for each 'layer' with pollen, but this is not necessary.

   You can also just tell the students that the soil layers might look alike now, but they look different when scientists collect them. Once you have prepared the ziplock bags with the soil and confetti, disperse the bags to your groups of students. If you can't make eight groups, it would be advisable to give one group two layers (probably the simpler layers, ie. 2, 3, or 4). Once students have identified the 'pollen' based on the charts they have, they will be able to reconstruct the paleoclimate of the Hudson Valley. You can keep the ziplock bags for future use.

Color and Shape	Plant Species	Climate Characteristics
Pink Hearts	Oak	Found in warm, temperate sites with dry, warm summers
Red Hearts	Spruce	Found in cold, sub-alpine sites
Silver Circles	Fir	Prefers cold, somewhat moist soils.
Clean Stars	White Pine	Temperate, cool climate
Silver Stars	Chestnut	Prefers moist and cooler termperatures
Blue Stars	Hickory	Warm and dry, well-drained soils
Black Stars	Paper Birch	Enjoys cold, sub-alpine conditions
Gold Hearts	Hemlock	Requires moist soil, temperate conditions
Turquoise Circles	Ragweed	Native, indicator of disturbance
Red Stars	Common Reed	Invasive grass, hybrid of native and alien
Purple Stars	Sedge	Wetlands or tundra indicator
Gold Circle	Dwarf Birch	Grows in cold climates, often at high altitudes
Dark Pink Circle	Sorrel	Disturbance indicator
Blue Circles	Creeping Evergreen Shrub	Very cold climate, rocky soils, often found at high altitudes

Materials Required (for each group of about three students):

- 8 bags of soil with 14 types of confetti (or other materials) organized in the manner described below. Be sure to label each bag with Layer 1-8.
- student worksheet and reading(s)
- tweezers
- paper plates
- Student worksheets http://www.caryinstitute.org/sites/default/files/public/downloads/less on-plans/paleoclimate_worksheet.pdf
- Copies of the reading on the Paleoclimate of the Hudson River Valley: http://www.caryinstitute.org/sites/default/files/public/downloads/less on-plans/paleoclimate_reading.pdf

Optional Materials (for each group of about three students)

- flower
- hand lenses or microscope and slides

Layer	Soil Type	Time Period	Species Found in Soil Core	Confetti Set-up
1	Sandy	100-400 years ago	Ragweed, common reed, few oak (due to deforestation), sorrel	10 turquoise circles 10 dark pink circles 10 red stars 5 pink hearts
2		400-3,000 years ago	Oak and chestnut	10 pink hearts 10 silver stars
3	Well-drained loam or clay	3,000-5,000 years ago	Oak and hickory	10 pink hearts 10 blue stars
4	Shallow loam or silt, loam over bedrock	5,000-7,500 years ago	Oak and hemlock	10 pink hearts 10 gold hearts
5	or peat	7,500-11,000 years ago	White pine and oak	10 clear stars 10 pink hearts
6	or peat	11,500-12,700 years ago	Spruce, fir, paper birch	10 red hearts 10 silver circles 10 black stars
7	Sandy soils	12,700-15,000 years ago	Spruce, some fir, oak, white pine	10 red hearts 10 clear stars 5 silver circles 10 pink hearts
8	Rocky soils with some peat	15,000-16,000 years ago	Creeping evergreen shrub dwarf birch, sedge	10 blue circles 10 gold circles 10 purple stars

Engage

Show students the sediment core you created. Ask them to make some observations of the core.

- How are the layers similar? Different?
- Why do you think this is the case?

Note that the core is a model of cores the scientists can take of real soil.

Show students some photographs of real sediment cores, e.g.:
http://www.windows2universe.org/earth/climate/images/sediment_core_sm.jpg

- Why do you think scientists take sediment cores like these?
- Have you ever seen rock layers? What did you observe?
- Where are the oldest layers? The newest?

Explain to students that when we collect a sediment core, we are getting a slice of the soil's layers. There are many differences between layers, including the tiny, fossilized pollen grains found within them.

Ask

- What is pollen? A powdery substance produced by the male part of a flower that can fertilize the ovules (eggs) in the female part of the flower.
- How is pollen transported? By wind, insects, birds, etc.
- Is all pollen the same? Why or why not? No, pollen for different types of plants has different characteristics.
- How might pollen give scientists a clue about climate? Different plants grow in different climates, so seeing certain types of pollen could indicate what the climate conditions under which the plants grew. [If possible, have students observe pollen from flowers with hand lenses or under a microscope.]

Discuss

- How can scientists tell what kind of pollen is in a sediment core? Take the pollen from the core and observe it under a microscope, then compare it to a key or other known sample.

Explore

1. Note that by analyzing fossilized pollen grains in sediment cores, scientists are able to learn about ancient climates, paleoclimates. Explain to students that they will become 'scientists' to discover the paleoclimate of the Hudson Valley. Tell students to imagine that scientists have collected a sediment core from Hudson Estuary marsh sediment.

2. Explain that each group will get a sample of "soil" that represents one section of the soil. The layers are numbered, with the newest layers as Layer 1. They will analyze the "pollen" inside and compare the pollen they find to the reference chart. The goal is to predict the type of climate that might have existed during the period represented by their soil sample.

3. Show students how to use the student worksheet. If necessary, review with students how to calculate percentages so that they may determine the percentage of each type of pollen in their soil sample. Note that they should do this step after analyzing all of their soil.

4. Distribute the materials to each group of students: one layer (bag with 'pollen'), tweezers, and a paper plate. Students should sift through their sediment layers and separate out each of the different pollen types. Allow enough time to discover what layer they have and what type of climate may have existed during this period, using the information on their student worksheet.

5. As students work, create a class chart on the board (see student worksheet), in which groups can record their findings.

6. Students should then read Paleoclimate of the Hudson Valley and try to determine the time period from which their soil sample originated.

Explain

- Explain that scientists are interested in studying the history of climate change in order to understand patterns of change over time. Since each type of pollen has a distinct shape, scientists can find out what plant produced the pollen. By discovering what types of plants lived during each time period, scientists can infer what the climate was like during that time, and even how many of each type of plant lived during that period.
- They can also draw conclusions about how long it took for different changes to take place. For instance, how long did it take from the last Ice Age until the appearance of marsh plants? The speed that plant communities migrate into an area can help scientists understand how plants are currently migrating around the world, and what might happen when the temperatures increase in the future. Scientists from Columbia University's Lamont-Doherty Earth Observatory have collected pollen samples throughout the Hudson River area, and are continuing to collect samples to create a more complete picture.
- As a class, create a rough graph of the general temperature changes (put 'temp' on the y-axis as warm, cool, and cold and time on the x-axis). Discuss:
  - What do you observe?
  - What trends do you see?
- This should allow a discussion of the history of climate change in the Valley. Then, show students the two graphs of climate change over the last 14,000 years and the last 400 years. For each graph, be sure students understand the scale and specific data they are viewing Discuss:
  - What observations can you make about the first graph?
  - Why do the lines go up and down constantly?
  - What overall trend do you see?
  - What observations can you make about the second graph?
  - How and why is it different from the first graph?
  - What overall trend do you see?
  - How do these graphs relate to our class graph?
- When discussing the pattern of climate change over the last 16,000 years, it might be helpful to give students background on climate change. There are a number of things that can alter the global temperature: changes in the sun's activity, distance of the sun's orbit from earth, volcanic eruptions, greenhouse gas emissions (including aerosols, which can provide a cooling effect). However, we know from data that the sun (solar radiation) has been relatively constant in the 20th century, and that greenhouse gases are higher now than at anytime during the last 600,000 years.
- Direct students to complete the questions on their worksheet. Review them as a class.

Elaborate

For homework, have students investigate other regions of the world to determine the paleoclimate data. Information can be found at: Climates of the Past (http://bit.ly/11a4PsU).

Another option is to bring students on a guided walk and discuss what a current 'layer' would look like.

Evaluate

Have students write an essay or story about one layer of the model soil. In their story, they should:

- Accurately describe the climate and plant life of the time of the layer
- Refer to information from the chart and graph on the student handouts
- Incorporate additional research (including information about the animals that have lived in the area).
- Illustrate their story appropriately

Rubric for Evaluate

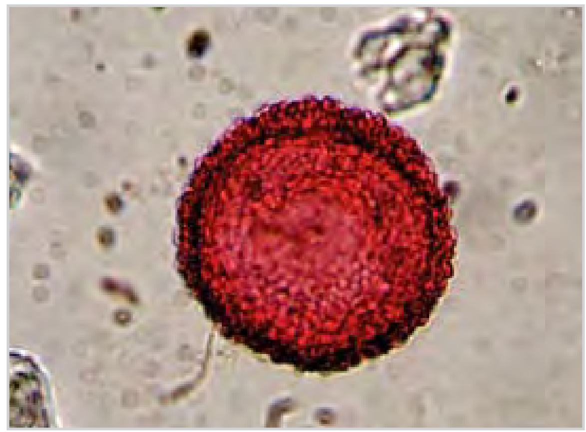
Component/Score	3 (Exemplary)	2 (Satisfactory)	1 (Needs improvement)
Description	Vividly and accurately describes the climate and foliage of the selected soil layer	Describes the climate and foliage of the selected soil layer	Describes either the climate or the foliage of the selected soil layer
Use of data	Accurately and appropriately supports description with multiple pieces of data.	Accurately and appropriately supports description with data.	Refers to data, but data may be inappropriate or inaccurate.
Incorporate Research	Incorporates several appropriate factual details from outside sources.	Incorporates factual details from outside sources.	Details from outside sources are not factual or inappropriate.
Illustration	Illustration closely matches with description and other details and enhances writing.	Illustration matches description and other details	Illustration is not linked with description and other details

Name ____________________ Date _____________________

Student Worksheet Paleoclimate of the Hudson River Valley

This activity is based on actual pollen data collected by pollen researchers since the 1950's and most recently scientists from Lamont-Doherty Earth Observatory in and around the Hudson River. Based on the soil samples that you analyze during class, you will determine the amount and type of 'pollen' in each sample. From this information, you will determine the type of vegetation and age of the samples and will draw conclusions about the climate when the pollen was dispersed from its host plant.

Sedge Pollen



Eastern Hemlock Pollen

Materials

- Pie pan or paper plate
- Tweezers (optional)
- Soil samples with confetti representing pollen grains

Procedure

1. Each group of students will receive a sediment sample, paper plate, and tweezers. Each sample contains 'pollen', with each color representing pollen from a different species of plant.
2. Separate the pollen from the sediment. Look carefully through the entire soil sample; some of the pollen grains are hard to find!
3. Use the pollen key below to determine what species of plants are represented in your sample. Calculate the percentage of the total pollen that comes from each species. Fill in the data table for the soil layer you are working on. Share your observations with the class.
4. Use the information given with each species description to decide what the climate was like when your layer was deposited.

Modified from a Windows to the Universe® (http://windows2universe.org) © 2010, National Earth Science Teachers Association (supported by UCAR) lesson plan, using data from Lamont-Doherty Earth Observatory, for the Changing Hudson Project, Institute of Ecosystem Studies, 2007. Last revision: Cary IES, January 2013.

Pollen Key

Color and Shape	Plant Species	Climate Characteristics
Pink Hearts	Oak	Found in warm, temperate sites with dry, warm summers
Red Hearts	Spruce	Found in cold, sub-alpine sites
Silver Circles	Fir	Prefers cold, somewhat moist soils.
Clear Stars	White Pine	Cool, temperate
Silver Stars	Chestnut	Prefers moist and cooler temperatures
Blue Stars	Hickory	Warm and dry, well-drained soils
Black Stars	Paper Birch	Enjoys cold, sub-alpine conditions
Gold Hearts	Hemlock	Requires moist soil, temperate conditions
Turquoise Circles	Ragweed	Native weedy plant that expands with disturbance
Red Stars	Common Reed	Invasive grass, hybrid of native & alien
Purple Stars	Sedge	Wetland or tundra indicator
Gold Circle	Dwarf Birch	Grows in cold climates, often at high altitudes
Dark Pink Circle	Sorrel	A shrub, used to indicate disturbance
Blue Circles	Creeping Evergreen Shrub	Very cold climate, rocky soils, often found at high altitudes

Data: Write down the type and number of pollen you found:

"Pollen"	# Found	Plant Species	Climate

Class observation data: Write down the percentage of each plant species found in each layer.

Plant Species	Sediment Layer							
	8	7	6	5	4	3	2	1
Oak								
Spruce								
Fir								
White Pine								
Chestnut								
Hickory								
Paper Birch								
Hemlock								
Ragweed								
Common Reed								
Sedge								
Dwarf Birch								
Sorrel								
Creeping Evergreen Shrub								

Questions

1. Based on your observations, what was the climate like during the time when your pollen was shed?
2. Your teacher will give you some background reading. Based on this information, what time period do you think your layer corresponds to?
3. Using everyone's data, graph the temperature shifts through time on the board, with 'time' on the x-axis and 'temperature' (warm,cool,cold) on the y-axis. Discuss the results.
4. What was the overall pattern of climate change during the last 16,000 years?
   What might have caused these changes?
5. Using the graph shown by your teacher, what is currently happening with the climate in relation to the past?
6. When looking at the cumulative data collected by your class, what trends do you notice?

Lesson 5

Climate Change in Oral History

Hudson River Estuary
Sea Grant New York
New York State Water Resources Institute
Cornell University

Climate and Oral History

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Mathematical Analysis

- M2.1a Interpolate and extrapolate from data.
- M2.1b Quantify patterns and trends.

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

- S1.3 Represent, present, and defend their proposed explanations of everyday observations so that they can be understood and assessed by others.
- S1.4 Seek to clarify, to assess critically, and to reconcile with their own thinking the ideas presented by others, including peers, teachers, authors, and scientists.
- S2.3c Collect quantitative and qualitative data.
- S3.1a Organize results, using appropriate graphs, charts, and data tables.
- S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.
- S3.2h Use and interpret graphs and data tables.

Standard 2: Information Systems

- 1.2 Use spreadsheets and database software to collect, process, display, and analyze information. Students access needed information from electronic databases and on-line telecommunication services.

Standard 6: Interconnectedness

- 5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Living Environment

- 7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Standard 4: The Physical Setting

- 2.2i Weather describes the conditions of the atmosphere at a given location for a short period of time.
- 2.2j Climate is the characteristic weather that prevails from season to season and year to year.
- 2.2q Hazardous weather conditions include thunderstorms, tornadoes, hurricanes, ice storms, and Humans can prepare for and respond to these conditions if given sufficient warning.
- 2.2r Substances enter the atmosphere naturally and from human activity. Some of these are carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.

Next Generation Science Standards

Science and Engineering Practices:

2. Developing and using models
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Grade 6

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

Grade 7

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

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.7

Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.ELA-Literacy.WHST.6-8.1b

Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

CCSS.ELA-Literacy.WHST.6-8.8

Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Common Core State Standards - Mathematics

Standards for Mathematical Practice

CCSS.Math.Practice.MP2

Reason abstractly and quantitatively.

CCSS.Math.Practice.MP4

Model with mathematics.

Grade 6

CCSS.Math.Content.6.NS.C.8

Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

CCSS.Math.Content.6.SP.A.2

Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

CCSS.Math.Content.6.SP.B.5c

Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

Grade 7

CCSS.Math.Content.7.SP.A.2

Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions.

Climate Change in Oral History

This lesson is adapted from a Smithsonian National Museum of Natural History curriculum, Forces of Change: http://forces.si.edu/arctic/pdf/ACT%202_CHANGES.pdf

Introduction

In this lesson, students will interview community members about their perceptions of local climate during their lifetimes. Students will them compare these interview data with 30-year local temperature and precipitation data.

Objectives

Students will be able to

- Compile and summarize community survey results on local climate change
- Analyze local climate data and calculate averages
- Compare survey results with climatic data
- Communicate the results of their investigations

Materials Required

- Laptops or tablets for students to use. (If computers are not available, then access and print out the data for your area for students to use in the Elaborate section of the lesson.)

Advanced Preparation

- Identify some local community members who will have some historic knowledge of your area. Some resources to consider are partnering with a local seniors group, or reaching out to school/district alumni so that students who are newcomers to the area will have people to interview.
- Make copies of Activity Sheets 1 and 2 (one copy per student) and 3 (two copies per student).
- If possible, bookmark the following website: http://www.ncdc.noaa.gov/cag/ on each student computer.

Engage

Ask students to describe the weather during the past week. Would a description of one week's weather be adequate to describe the climate where they live? Why or why not? How do weather and climate differ?

How much would they say their lives are affected by climate? List ways their climate can affect them. (Examples include: Winter snows can cause school to close. Rains can trigger mudslides. Spring rains can flood the softball field. A mild climate allows me to bike year-round. A hurricane caused us to be without electricity for several days. A warm climate allows me to swim outside year round, etc.).

What, if any, changes have they observed in the climate since they were old enough to go to school? How do they think their observations would compare with observations by older people in their community?

Explore

- Tell students that each one (or a pair of students) will interview three longtime residents of the community. The interview subjects should have lived in the community for at least two or three decades. Discuss why they are surveying long-time residents. (Climate is a long-term record of weather.)
- Discuss who they might consider interviewing. (Subjects could include teachers, family members, and neighbors. Teachers might consider contacting a local senior center where students could conduct their interviews. Teachers should collect names of intended interview subjects ahead of time to verify that each student has a different interview subject.) Emphasize that the subjects they interview should remain anonymous.
- Distribute and discuss the survey (see note) form on Activity Sheet 1. Delete questions that are not relevant to your area. Add questions if they like. (Alternatively the class can design its own form.)
- Distribute Activity Sheet 2. Students summarize the results of their interviews on this form. It is very important that students understand Part 3 on Activity Sheet 2. Here, they calculate the average for the number of years their three subjects lived in the community. If necessary, review the steps for calculating an average. Students will need this number to complete the exercise in Step 3 on page 3.
- Give students a week or so to conduct their interviews and summarize their data.

Explain

Note: To save time, begin the ***Elaborate*** *during the time that students are completing their interviews and compiling their findings.*

Facilitate a class discussion of the survey results. Discuss the relationship between the survey results and the historical weather records for their community.

- What were the results of the survey? Were responses similar or different among the residents surveyed? Did responses vary based on the amount of time subjects spent outdoors in their work or hobbies?
- How did the responses of long-time residents compare with the students' observation? If they differed, why might that be the case? (examples: age, work, hobbies.)

As a class, choose three of the most interesting questions on the survey. Create a data table in which you can compile class findings.

Have students create a bar graph of the class data for those three findings. Then, discuss students' observations based on the graph.

(Alternatively, compile the data for all questions and have groups of students create graphs for different questions.)

Elaborate

Tell students they will use the Internet to acquire historical weather records for their city. They will be using this data to determine if the results of their surveys agree or disagree with actual changes in climate over the same time period.

Explain that the data they use will be annual mean (average) temperature and precipitation records. Review the term "mean." A mean is computed by summing the values and dividing by the number of values. The arithmetic mean is commonly referred to as an "average."

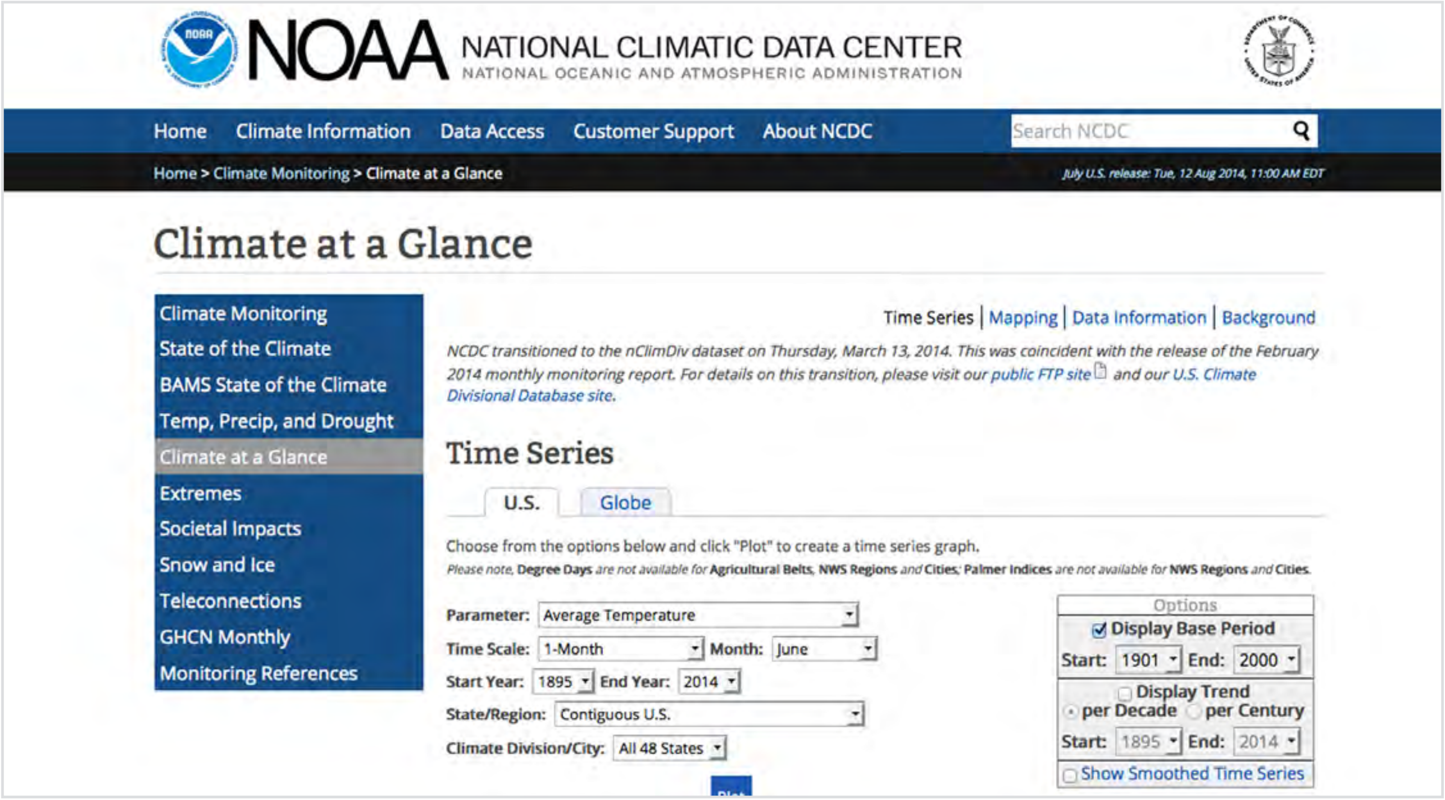
Distribute Activity Sheet 3.

NOAA's National Climatic Data Center (NCDC) provides public access to the Nation's climate and historical weather data. You may want to review the NCDC Climate Data Online Search tool www.ncdc.noaa.gov/cdo-web/search to help you understand the breadth of data available.

This lesson utilizes the NCDC Climate at a Glance interactive tool located at http://www.ncdc.noaa.gov/climate-information/climate-us

If possible, bookmark this page on student computers http://www.ncdc.noaa.gov/cag/

Show students how to select data for the Hudson Valley (under Location>New York>Hudson Valley) and how to change the dates for the first 10 years of their interviewees' lives as well as for the past 10 years. They will get this information from Activity sheet 2.



Repeat above steps and select "Precipitation." Print the data on the "Climate at a Glance Table" for annual mean precipitation. (See Teacher Reference #1 for how to calculate these averages—you may wish to share this reference page with students). Note that you can download the data into Excel, and have student calculate an average that way if you prefer.

Use data to complete Activity Sheet 3. With the data they access, the students calculate an average for the first ten years in the record and an average for the last ten years in the record. They then calculate the difference between the two averages. They complete this exercise for both annual average temperatures and average annual precipitation. *Note that the data is tabular.*

Once students have completed their calculations, discuss their findings and how they relate to the survey they conducted.

- What did the historical weather records tell you about climate change during the period of time your subjects lived in the community?
- Have temperatures been warming, cooling, or about the same? Has precipitation increased, decreased, or stayed the same?
- Did the observations made by your subjects agree or disagree with the actual records of temperatures and precipitation? Do you think the actual changes have been large enough for people to notice?
- How did your interviewees' recollections compare to the historical data?
- When are oral histories important?
- Why are scientific data important? Evaluate

Student Activity Sheet 1 Climate Change in Oral History

Student Name **Interview participant #**

Use a separate form for each of the three people you interview. Do not use the participant's name. Just enter a number 1, 2, 3, etc.

Before you begin:

1> Introduce yourself.

2> Explain the purpose of the survey: to collect observations from people in your community about changes in local climate. You are interested in talking to them because they have lived here for many years.

3> Define the term "climate:" Climate is the average weather in a location over a long period of time: Climate tells us what the weather is usually like in a particular place.

Ask each subject the following questions.

1 > How many years have you lived in the area? ______

2 > Overall, would you say that the climate has changed during the time you have lived here? If so, how has it changed?

______

3 > Do you (or did you) spend a lot of time outdoors in you work or your hobbies? Explain.

______

Ask each subject to respond to the following statements. *(Circle one answer for each question)*

1 > Compared to the past, today's summer temperatures are:
much hotter / somewhat hotter / same/ somewhat cooler / much cooler / not sure

2 > Compared to the past, today's winter temperatures are:
much colder / somewhat colder / same / somewhat warmer / much warmer / not sure

3 > Compared to the past, the number of unusually hot days now is:
much more / somewhat more / same/ somewhat fewer / fewer / not sure

4 > Compared to the past, the number of unusually cold days now is:
much more / somewhat more / same / somewhat fewer / fewer / not sure

5 > Compared to the past, our climate today is:
much wetter / somewhat wetter / same / somewhat drier / much drier / not sure

6 > We have more heavy downpours now than in the past: strongly agree / agree/ disagree / strongly disagree / not sure

7 > We have more droughts now than in the past: strongly agree / agree / disagree / strongly disagree / not sure

8 > We have more snow now compared to the past: strongly agree / agree / disagree / strongly disagree / not sure

9 > How much would you say your life today is affected by climate: significantly / somewhat / not at all

10 > How much was your life in the past affected by climate: significantly / somewhat / not at all

Student Activity Sheet 2 Climate Change in Oral History

Student Name

STEP 1 > Tally the responses from each person you surveyed for each of the 10 questions you asked. For each question, write in how many of your subjects—0, 1, 2, or 3—selected each of the possible choices. For example, if three of your subjects chose "much hotter," place a "3" in the blank next to "much hotter." You will share this data during a class discussion.

1 > Compared to the past, today's summer temperatures are:

___much hotter ___somewhat hotter ___same ___somewhat cooler ___much cooler ___not sure

2 > Compared to the past, today's winter temperatures are:

___much colder ___somewhat colder ___same ___somewhat warmer ___much warmer ___not sure

3 > Compared to the past, the number of unusually hot days now is:

___much more ___somewhat more ___same ___somewhat fewer ___fewer ___not sure

4 > Compared to the past, the number of unusually cold days now is:

___much more ___somewhat more ___same ___somewhat fewer ___fewer ___not sure

5 > Compared to the past, our climate today is:

___much wetter ___somewhat wetter ___same ___somewhat drier ___much drier ___not sure

6 > We have more heavy downpours now than in the past:

___strongly agree ___agree ___disagree ___strongly disagree ___not sure

7 > We have more droughts now than in the past:

strongly agree ___agree ___disagree ___strongly disagree ___not sure

8 > We have more snow now compared to the past:

___strongly agree ___agree ___disagree ___strongly disagree ___not sure

9 > How much would you say your life today is affected by climate:

___significantly ___somewhat ___not at all

10 > How much was your life in the past affected by climate:

___significantly ___somewhat ___not at all

Student Activity Sheet 2 Climate Change in Oral History

Student Name

STEP 2 >

Subject #1

1 > Subject has lived in my community for ______ years, since ____________.
(Subtract the number of years lived here from the current year.)

2 > Summarizing this subject's responses, he/she observed that the climate has changed *(circle one)*
Significantly
Somewhat
None
They were not sure

Subject #2

1 > Subject has lived in my community for ______ years, since ____________.
(Subtract the number of years lived here from the current year.)

2 > Overall, this subject observed that the climate has changed *(circle one)*
Significantly
Somewhat
None
They were not sure

Subject #3

1 > Subject has lived in my community for ______ years, since ____________.
(Subtract the number of years lived here from the current year.)

2 > Overall, this subject observed that the climate has changed *(circle one)*
Significantly
Somewhat
None
They were not sure

STEP 3 >

1 > Calculate an average number of years lived here for your three subjects and enter it here. ____________

2 > Subtract the average you calculated in #1 from the current year and enter it here ____________. (You will enter this year as the "beginning year" and the "base period year" on the NOAA Web site to access historical weather records.)

Student Activity Sheet 3 Climate Change in Oral History

Student Name

DATA FROM "CLIMATE AT A GLANCE" TABLE

STEP 1 >

Calculate an average **temperature** for the **most recent** ten years from your "Climate at a Glance" Table. Enter it here___________.

Calculate an average **temperature** for the **first 10** years from your "Climate at a Glance" Table. Enter it here___________.

Compare the two averages. How much of an increase or a decrease has there been? ___________

STEP 2 >

Calculate an average **precipitation** for the **most recent 10** years from your "Climate at a Glance" Table. Enter it here___________.

Calculate an average **precipitation** for the **first 10** years from your "Climate at a Glance" Table. Enter it here___________.

Compare the two averages. How much of an increase or a decrease has there been? ___________

Lesson 6

Energy Walkabout

Energy Walkabout

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

S2.3c Collect quantitative and qualitative data.

S3.1 Design charts, tables, graphs, and other representations of observations in conventional and creative ways to help them address their research question or hypothesis.

S3.2a Accurately describe the procedures used and the data gathered.

S3.2c Evaluate the original hypothesis in light of the data.

S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.

S3.2h Use and interpret graphs and data tables.

Standard 1: Analysis, Inquiry and Design/Engineering Design

T1.1a Identify a scientific or human need that is subject to a technological solution which applies scientific principles.

T1.3a Generate ideas for alternative solutions.

Standard 6: Interconnectedness

5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 7: Interdisciplinary Problem Solving

1.1 Analyze science/technology/society problems and issues at the local level and plan and carry out a remedial course of action.

1.3 Design solutions to real-world problems of general social interest related to home, school, or community using scientific experimentation to inform the solution and applying mathematical concepts and reasoning to assist in developing a solution.

Standard 4: The Living Environment

7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Standand 4: The Physical Setting

4.1d Different forms of energy include heat, light, electrical, mechanical, sound, nuclear and chemical. Energy is transformed in many ways.

4.5b Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.

Next Generation Science Standards

Science and Engineering Practices:

4. Analyzing and interpreting data
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Grade 6

ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

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

ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Grade 7

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

ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Grade 8

ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

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

CCSS.ELA-Literacy.RST.6-8.9
Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

CCSS.ELA-Literacy.WHST.6-8.1a
Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

CCSS.ELA-Literacy.WHST.6-8.1b
Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

CCSS.ELA-Literacy.WHST.6-8.2b
Develop the topic with relevant, well-chosen facts, definitions, concrete details, quotations, or other information and examples.

CCSS.ELA-Literacy.WHST.6-8.2d
Use precise language and domain-specific vocabulary to inform about or explain the topic.

CCSS.ELA-Literacy.WHST.6-8.8
Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Common Core State Standards - Mathematics

Standards for Mathematical Practice

CCSS.Math.Practice.MP2 Reason abstractly and quantitatively.

CCSS.Math.Practice.MP4 Model with mathematics.

Energy Walkabout

This lesson is modified from educational materials produced by U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy: http://www1.eere.energy.gov/education/pdfs/efficiency_energyauditchecklist.pdf

Introduction

Learning about climate change can often be overwhelming and discouraging to students. One way to mitigate these feelings is to identify ways that they can personally make changes that relate to climate through energy use.

In this activity, students will apply the energy conservation measures to perform an energy audit of the school building using a data table that they create. Photos of energy behaviors—good, bad, and ugly— and survey results can be used in educational posters and presentations to students and faculty on why we need to work on energy conservation and how easy it can be to save energy by simply keeping doors and windows closed, shutting things off when they are not in use, etc. Discuss this activity with your colleagues and let them know that your students will be visiting their classrooms. Consider inviting the custodian into your class following the students' audit to discuss overall building energy use concerns, e.g., the boiler, timers on lights and heat, etc.

This lesson is best implemented following a lesson on types of energy (i.e., electrical, chemical), energy transfer, and efficiency. Additionally, it is recommended that students have some background in climate change and how fossil fuel use is contributing to the problem in order for them to understand how energy decisions are related to the issue.

Additional Resources:
http://www.eia.gov/kids/energy.cfm?page=3
http://www.energystar.gov/index.cfm?c=kids.kids_index
http://www.consumerenergycenter.org/tips/schools.html
http://www.fi.edu/PECO/saving-guide-family.pdf
http://usgovinfo.about.com/library/weekly/blearthday2002.htm

Time Estimate: Approximately three 45-minute class periods.

Objectives

Students will be able to

- create a template for assessing energy use in their school and home environments.
- perform an energy audit of their school and home environments.
- provide written recommendations for conserving energy based on findings from the energy audit.

Engage

Ask students to create a list of all the ways they have used energy already today. If necessary, give them a few ideas to get started, e.g., charging a cell phone, listening to music, cooking breakfast, lighting, heating or air conditioning, etc.

Discuss ways to conserve energy in everyday life. As a class, generate a list on the board. Examples might include:

- Unplugging chargers when not in use
- Turning off lights
- Closing windows when the heat is on
- Being sure windows and doors are sealed, not allowing a draft.
- Turning off computers at the end of the day

You may need to model some of the ideas, e.g., how to feel/assess whether a window or door is weather-sealed.

Explore

Part I: Creating the Instrument

Explain to students that they will be creating a data table that they will use to assess energy conservation at school and at home—an energy audit. If necessary, show them an example, such as the table below:

Room Number			
Lights off when unoccupied			
Unnecessary electronics Unplugged			
. . .			
Comments			

In small groups, have students create their own data table. Then, bring the whole class together to create a class table so that all groups are using the same instrument to assess energy conservation. There may be categories that require students to ask questions of faculty members, custodians, or other school personnel. For example: Are computers turned off at night?

Either create a table and make copies for the whole class, or have students copy it down.

Part II: Assessing Energy Conservation

Be sure that all students are clear on how to use the table. If possible, students can also use cell phone or other cameras to take pictures of energy wasting during their audit.

Divide the school into sections based on the number of groups of students in your class. Send small groups of students to each section to perform the audit and take pictures. Give a set amount of time to do this, e.g., 20 minutes.

Explain

Students should share their findings with the class. Groups should add other students' findings to their table. If possible, the building custodian should visit your class to discuss overall building energy concerns, e.g., whether timers are used, how the heat is set, etc.

Based on the findings, students should answer the following questions:

- What are the most common energy-wasting problems identified? How common are these problems?
- What are some recommendations for saving energy that you would make based on these findings?

Support your recommendations with evidence.

Have students share their recommendations with the class. Compile a list in which the class prioritizes these recommendations based on importance, feasibility, and how much energy they would save.
Consider presenting the list to the principal.

Elaborate

Ask students how they would modify their data table for use at home. Invite each student to go home and complete the same assignment, including identifying the most common energy-wasting problems and making recommendations.

In addition, either in class or at home, students should conduct background research using outside websites, books, or their textbook to answer the following:

- Why is conserving energy important?
- Why are our findings about energy conservation in our homes and school important?
- What suggestions can you make for improvement? Why?

Evaluate

For homework, have students complete the following writing assignment:

- Pretend you are explaining to a third grader about energy conservation and some ways that they can better conserve energy. In an essay, poster, PowerPoint presentation, or other method, explain to these third graders:
  - Some things that they use energy for at home and at school.
  - Some ways that they can conserve energy and why this is important.

- Be sure to support your statements with:
  - Evidence from your energy audit (home, school, or both).
  - Facts from your background research.
  - Pictures or graphics that engage your readers.

Evaluate Rubric

Criterion/Score	3	2	1
Identification of Energy-using items	Clearly identifies five or more household (or school) items that require energy	Identifies three or more household (or school) items that require energy	Identifies one or more household or school) items that require energy
Identification of ways to conserve energy	Accurately identifies three or more ways to conserve energy	Accurately identifies two or more ways to conserve energy	Ways to conserve energy are inaccurate or only one way is identified.
Support from Energy Audit	Clearly supports ideas using specific findings from the energy audit.	Supports ideas by referring to the energy audit.	Does not support ideas with energy audit findings
Facts from background research	Clearly supports ideas using relevant facts from the background research	Supports ideas with background research	Background research ideas may include facts and opinions, or support is unclear.
Includes graphics	Well-selected graphics clearly communicate information about energy conservation	Graphics are relevant, but do not lead to clearer understanding of the topic	Graphics are irrelevant to the topic or inappropriate

Lesson 7

Earth's Albedo

Earth's Albedo

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

S1.2a Independently formulate a hypothesis.
S2.1c Design and conduct an experiment to test a hypothesis.
S2.1d Use appropriate tools and conventional techniques to solve problems about the natural world, including: measuring, observing, describing, classifying, sequencing.
S2.3c Collect quantitative and qualitative data.
S3.2c Evaluate the original hypothesis in light of the data.
S3.2d Formulate and defend explanations and conclusions as they relate to scientific phenomena.
S3.2h Use and interpret graphs and data tables.

Standard 6: Interconnectedness

5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Living Environment

7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Standard 4: The Physical Setting

4.4b Light passes through some materials, sometimes refracting in the process. Materials absorb and reflect light, and may transmit light. To see an object, light from that object, emitted by or reflected from it, must enter the eye.
2.2j Climate is the characteristic weather that prevails from season to season and year to year.
2.2q Hazardous weather conditions include thunderstorms, tornadoes, hurricanes, ice storms, and blizzards. Humans can prepare for and respond to these conditions if given sufficient warning.
2.2r Substances enter the atmosphere naturally and from human activity. Some of these are carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.
4.5b Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.

Next Generation Science Standards

Science and Engineering Practices:

2. Developing and using models
3. Planning and carrying out investigations.
4. Analyzing and interpreting data
6. Constructing explanations

Grade 6

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

Grade 7

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

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Common Core State Standards - Mathematics
Standards for Mathematical Practice

CCSS.Math.Practice.MP2
Reason abstractly and quantitatively.
CCSS.Math.Practice.MP4
Model with mathematics.

Grade 6

CCSS.Math.Content.6.NS.C.8
Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Earth's Albedo

Adapted from the Climate Discovery Teacher's Guide, National Center for Atmospheric Research: http://eo.ucar.edu/educators/ClimateDiscovery/ESS_lesson4_10.19.05.pdf

Introduction

Students experiment and observe how the color of materials that cover the Earth affects the amounts of sunlight our planet absorbs.

Background Information

What Is Albedo?

While the Earth's temperature is dependent upon the greenhouse-like action of the atmosphere, the amount of energy retained by the Earth is strongly dependent on the albedo of Earth surfaces. Just as some clouds reflect solar energy into space, so do light-colored land surfaces.

Scientists use the term albedo to define the percentage of solar energy reflected back by a surface. This surface albedo effect strongly influences the absorption of sunlight. Forests, grasslands, ocean surfaces, ice caps, deserts, and cities all absorb, reflect, and radiate solar energy differently. Sunlight falling on a white glacier surface strongly reflects back into space, resulting in minimal heating of the surface and lower atmosphere. Sunlight falling on a dark soil or rock is strongly absorbed, and contributes to significant heating of the Earth's surface and lower atmosphere.

Understanding local, regional, and global albedo effects is critical to predicting global climate change. Light colored ice and snow are very weakly absorptive, reflecting 80-90% of incoming solar energy.

Dark-colored land surfaces, are strongly absorptive and contribute to warming, reflecting only 10-20% of the incoming solar energy. If global temperatures increase, snow and ice cover may shrink. The exposed darker surfaces underneath may absorb more solar radiation, causing further warming. The magnitude of the effect is currently a matter of serious scientific study and debate.

How Much Are Glaciers Melting?

Currently glaciers cover about 10% of the Earth's land surface. In most areas of the world, mountain glaciers are melting. Between 1961 and 1998, small glaciers lost an average of 7 meters of ice thickness. Glaciers in mountainous areas near the equator have been particularly hard-hit.

According to global climate models, all of the glaciers in Glacier National Park in Montana will be gone by the year 2030. Snow and ice cover near the North Pole is currently decreasing at approximately 0.4% per year.

Arctic sea ice has been decreasing at about 2.9% per decade. Since 1974, seven ice shelves, most in Antarctica, have retreated by a total of approximately 13,500 square kilometers.

Bhutan Glacier

About the Image The image used in this activity is of retreating mountain glaciers in Bhutan. It is a satellite image taken by the ASTER instrument aboard NASA's Terra satellite. Visible in the image are several glaciers in the Himalayan Mountains of Bhutan. The glaciers have been melting over the past few decades, and lakes have formed on the surfaces and near the termini of many of the glaciers. Some of the glaciers are white as the ice is covered with snow pack. Other parts are rocky and have the same color as the surrounding land.

Objectives

Students will be able to

- conduct an experiment to examine the heating of different colored materials
- explain how the color of materials affects heat absorption
- support experimental conclusions with evidence
- relate their experiment to warming of Earth materials

Advanced Preparation

- Copy Student Page for all students.
- Make color copies of the Bhutan glacier image (see previous page). Laminate these photos for use with multiple classes.

Materials Required

(for each group of about three students):

- Copies of the Student Page
- 2 Thermometers
- One copy of the Bhutan glacier photo (p.4)
- Tape
- Watch or stopwatch
- Small heating lamps (laboratory lamps or small desk lamps will work fine), alternatively you can conduct the activity outdoors in direct sunlight
- Graph paper

Engage

Ask students if they have ever noticed that different colored materials are hotter in the hot sun than others. For instance,

- Does dark-colored asphalt or light-colored sidewalk feel hotter?
- Do you feel hotter wearing a black or white shirt in the hot sun?

Show students a picture of the Earth from space. Ask:

- What colors do you see?
- What are the lightest colors? The darkest? What Earth features do they represent?
- Where do they expect that most sunlight will be absorbed?
- Where do they expect that the least sunlight will be absorbed?

Show students the photo of the Bhutan glaciers. Explain that this picture was taken from a satellite high above the Earth. Ask students to share what they observe in the picture.

- The dark reddish parts of the picture are land (rocks).
- The white sections are ice and snow.
- This ice and snow is in glaciers. Define glacier. Parts of the glaciers are light blue in color. These are made of blue ice, sand and gravel. The very dark patches are lakes that form from the glacier melt water.

Explore

1. Divide students into groups of 2-4. Provide each group a Student Page and a set of materials. Ask students to designate who in their group is going to record the data, who is going to read the ice thermometer, who is going to read the land thermometer and who is going to be the timekeeper.
2. Ask students to make a hypothesis about which areas of the photograph they think would absorb the most solar energy and which would absorb the least. Remind of them of their prior experiences with the topic, as discussed in the Engage, e.g., wearing a dark shirt, walking on asphalt. Students should write the hypothesis on the Student Page.
3. Instruct students to fix their thermometers to the back of the picture using tape. One thermometer bulb should be under a section of light-colored ice and the other thermometer bulb under a section of dark red land. Remember to place the thermometers so that when you lay the picture down on a table, the thermometers are right side up and can be read.
4. Place the light (not turned on) directly above the picture, about a foot above. Do not turn it on yet!
5. The two students read their thermometers before the light is turned on and give the numbers to the data collector. The thermometer readings should be approximately the same.
6. Once they have the initial readings, groups should turn on their light and the timekeeper begins timing. Students should take temperature readings every 2 minutes for 8 minutes total. Advise students to read the thermometers without shading the light if possible.

Explain

1. Next, students should create a graph and explain what they think their graph shows. You may wish to have students complete this task individually on graph paper.
2. Assign pairs of student teams to compare their graphs with one another and list some similarities and differences between the teams' data.
3. At the same time, compile all data into a table on a computer, blackboard, or overhead transparency so that all groups can see it.
4. Students should then calculate the class averages for land and ice temperatures.
5. Have individual students create a graph of the class data, with two different lines for the ice and land data.

6. Discuss the findings as a class. Important questions to ask students include:
    a. What overall pattern do you observe?
    b. Was your hypothesis supported? How do you know?
    c. Did any groups' findings seem out of line with the rest of the class? If so, why do you think that might have happened?
    d. What do these findings tell you about Earth materials?

Explain to students that the proportion of light energy that surface reflect is known as **albedo**. If surfaces reflect a lot of the light that they receive, they have high albedo. If they absorb most of the light that they receive, they have low albedo.

Discuss

a. On Earth, what types of land coverings do you think absorb the most energy? ***Ocean, dark soil, dense forest***
b. Reflect the energy? ***Ice, snow, light colored sand***
c. When energy hitting glaciers, ice caps, and other high albedo surfaces is reflected, where does it go?

Elaborate

Share the following statistics with students (from the Background Information):

- Currently glaciers cover about 10% of the Earth's land surface. In most areas of the world, mountain glaciers are melting.
- Between 1961 and 1998, small glaciers lost an average of 7 meters of ice thickness.
- Glaciers in mountainous areas near the equator have been particularly hard-hit.
- According to global climate models, all of the glaciers in Glacier National Park in Montana will be gone by the year 2030.
- Snow and ice cover near the North Pole is currently decreasing at approximately 0.4% per year. Arctic sea ice has been decreasing at about 2.9% per decade.
- Since 1974, seven ice shelves, most in Antarctica have retreated by a total of approximately 13,500 square kilometers.

Discuss

- What do these statistics tell us? ***The overall amount of ice on Earth is decreasing.***
- How will Earth's albedo be different if this trend continues? ***The albedo will decrease.***
- If the albedo decreases, what does that mean for Earth***? If the snow and ice melt, there land below has a lower albedo. That is, the land will absorb more energy, causing the Earth to warm.***

Evaluate

Direct students to write two paragraphs in response to the following prompts:

1. Describe what you did in your experiment. What conclusion can you make based on your investigation? Use data from the experiment to support your conclusion.
2. Imagine you were building an outdoor doghouse for your pet to enjoy while playing outdoors. Would you use dark or light-colored materials for the roof? Defend your answer based on what you know about albedo and results from your experiment.

Evaluate Rubric

Component/Score	3 Exemplary	2 Satisfactory	1 Needs Improvement
Procedure	Accurately and completely describes the procedure used.	Description is mostly accurate and mostly complete.	Description contains several inaccuracies or omits important steps
Conclusion	Conclusion is reasonable and well-supported by specific data from the experiment	Conclusion is reasonable with some support from the experiment	Conclusion is not reasonable or not supported by experimental findings
Roof color	Student explains that a dark roof would better heat the doghouse, whereas a light roof would reflect heat, keeping it cooler	Student explains that either a dark roof will absorb heat or a light roof will reflect heat	Student suggests roof color but does not explain why
Support with evidence	Student supports suggestion by describing the concept of albedo and relating their design to the experiment they conducted	Student supports suggestion by describing the concept of albedo OR relating their design to the experiment they conducted	Student does not adequately support suggestion with evidence

Student Activity Sheet Earth's Albedo

Name ______________________________ Date __________ Class ______________

Take a look at the photograph of the Bhutan Glacier.
Place the bulb of one thermometer under the light colored snow and ice part of the photo.
Place the bulb of the other thermometer under the dark colored land part of the photo.
(Make sure both thermometers are facing so that you can read them easily.)

What is your hypothesis?
(What do you think will happen to the thermometers under the ice colored parts of the photo and the land colored parts of the paper?

____

____

Collect the data!
Use the table below to help you collect the temperature data.

Time	Temperature under ice picture	Temperature under land picture
0 minutes		
2 minutes		
4 minutes		
6 minutes		
8 minutes		

What do YOU think?
How is this different than the real world?

What does the data mean?
Graph your data by plotting the points and connecting them into two lines:
One line for the ice photo temperature
One line for the land photo temperature
(Remember to fill in the temperature axis and the key.)

Key:
☐ Ice
☐ Land

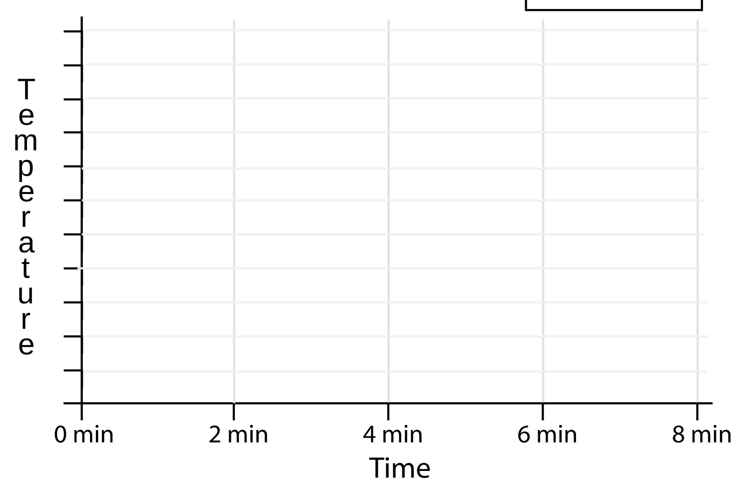
Explain what you think it shows in the space below.

____

____

____

____



Lesson 8

Carbon Through the Seasons

Carbon Through the Seasons

NYS Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

S3.1a Organize results, using appropriate graphs.
S3.2h Use and interpret graphs and data tables.

Standard 6: Interconnectedness

5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Living Environment

6.2b The major source of atmospheric oxygen is photosynthesis. Carbon dioxide is removed from the atmosphere and oxygen is released during photosynthesis.
6.2c Green plants are the producers of food which is used directly or indirectly by consumers.
7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Standard 4: The Physical Setting

2.2j Climate is the characteristic weather that prevails from season to season and year to year.
2.2r Substances enter the atmosphere naturally and from human activity. Some of these include carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.

Next Generation Science Standards

Science and Engineering Practices:

2. Developing and using models
4. Analyzing and interpreting data

Grade 6

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

Grade 7

ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

Common Core State Standards

ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy.RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Common Core State Standards - Mathematics
Standards for Mathematical Practice

CCSS.Math.Practice.MP2
Reason abstractly and quantitatively.
CCSS.Math.Practice.MP4
Model with mathematics.

Grade 6

CCSS.Math.Content.6.NS.C.8
Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Carbon Through The Seasons

Understanding the carbon cycle is essential for climate literacy. This lesson plan, Carbon Through The Seasons is from the US Environmental Protection Agency, and was adapted from a carbon cycle lesson developed by the National Oceanic and Atmospheric Administration (NOAA): www.esrl.noaa.gov/gsd/outreach/education/poet/CO2-Seasons.pdf

CARBON THROUGH THE SEASONS

DESCRIPTION

In this lesson plan, students learn about the carbon cycle and understand how concentrations of carbon dioxide (CO_2) in the Earth's atmosphere vary as the seasons change. Students also learn that even with these seasonal variations, the overall amount of CO_2 is increasing in the atmosphere as a result of people's activities, which are changing the natural carbon cycle.

BACKGROUND

Carbon is a chemical element that is found all over the world and in every living thing. Oxygen is another element that's found in the air we breathe. When carbon and oxygen bond together, they form a colorless, odorless gas called CO_2. In the Earth's atmosphere, CO_2 is a greenhouse gas, which means it traps heat. This "greenhouse effect" naturally helps to keep the Earth's temperature at a level that can support life on the planet.

The atmosphere isn't the only part of the Earth that has carbon. The oceans store large amounts of carbon, and so do plants, soil, and deposits of coal, oil, and natural gas deep underground. Carbon constantly moves from one part of the Earth to another through a natural repeating pattern called the carbon cycle. The carbon cycle helps to maintain a balanced level of CO_2 in the Earth's atmosphere.

But right now, people are changing this natural balance by adding more CO_2 to the atmosphere whenever we burn fossil fuels (such as coal, oil, and natural gas)—whether it's to drive our cars, use electricity, or make products. This extra CO_2 is being added to the atmosphere faster than natural processes can remove it, causing the atmosphere to trap more heat and causing the Earth's average temperature to rise. Scientists have found that the recent levels of CO_2 in the atmosphere are abnormally high compared with the long-term historical trend, and these levels are continuing to increase at an unprecedented rate.

The amount of CO_2 found in the atmosphere varies over the course of a year. Much of this variation happens because of the role of plants in the carbon cycle. Plants use CO_2 from the atmosphere, along with sunlight and water, to make food and other substances that they need to grow. They release oxygen into the air as a byproduct. This process is called photosynthesis. Another process that is part of the carbon cycle is respiration, by which plants and animals take up oxygen and release CO_2 back into the atmosphere.

When plants are growing, photosynthesis outweighs respiration. As a result, plants take more CO_2 out of the atmosphere during the warm months when they are growing the most. This can lead to noticeably lower CO_2 concentrations in the atmosphere. Respiration occurs all the time, but dominates during the colder months of the year, resulting in higher CO_2 levels in the atmosphere during those months.

TIME:

Introduction: 60–90 minutes

LEARNING OBJECTIVES:

Students will:

- Learn about the carbon cycle
- Understand how seasonal variations affect global atmospheric CO_2 concentrations
- Understand how CO_2 concentrations in the atmosphere are changing overall in recent decades

NATIONAL SCIENCE STANDARDS:

- Content Standard A: Science as inquiry
- Content Standard D: Earth and space science
- Content Standard E: Science and technology

ADAPTED FROM:

National Oceanic and Atmospheric Administration (NOAA): http://www.esrl.noaa.gov/gsd/outreach/education/poet/CO2-Seasons.pdf.

CARBON THROUGH THE SEASONS

Carbon Sources and Sinks

A *carbon source* is any process or activity that releases carbon into the atmosphere. Both natural processes and people's activities can be carbon sources. A *carbon sink* takes up or stores carbon on the Earth.

The Northern and Southern Hemispheres have opposite seasons. If both hemispheres had roughly the same amount of plant life, we might expect their seasonal effects on the carbon cycle to cancel each other out. However, if you look at a map, you'll see that the Northern Hemisphere has more land than the Southern Hemisphere and a lot more plant life (especially considering that Antarctica has almost none). As a result, global CO_2 concentrations show seasonal differences that are most heavily influenced by the growing season in the Northern Hemisphere.

Scientists monitor the amount of CO_2 and other gases in the atmosphere at stations such as the Mauna Loa Observatory in Hawaii. The Mauna Loa Observatory is one of the sites that have helped scientists determine that CO_2 levels in the atmosphere have increased significantly in recent decades and that these levels are continuing to rise at a rapid rate. CO_2 stays in the atmosphere for long enough that it is able to spread fairly evenly around the world, so even measurements from a single site (like Mauna Loa) can be representative of global average CO_2 concentrations.

GROUPS

Students should work in teams (group size of five is optimal). Each group should be assigned one set of years of "Mauna Loa Observatory Data" (see worksheets; each group will receive 10 to 12 years of data), and each student should receive one copy of his/her group's assigned data.

MATERIALS

- "Mauna Loa Observatory Data:" assign one time period per group, and give a copy of the data for the selected time period to each student in the group.
- A copy of the "Mauna Loa Worksheet" for each group
- A copy of the "Mauna Loa Monthly Average CO_2 Concentrations, 1958 to 2011" graph for each group
- Calculators
- Graph paper for each group
- Colored pencils

CARBON THROUGH THE SEASONS

VOCABULARY

Carbon:
A chemical element that is essential to all living things. Carbon combines with other elements to form a variety of different compounds. Plants and animals are made up of carbon compounds, and so are certain minerals. Carbon combines with oxygen to make a gas called carbon dioxide (CO_2).

Carbon cycle:
The movement and exchange of carbon through living organisms, the ocean, the atmosphere, rocks and minerals, and other parts of the Earth. Carbon moves from one place to another through various chemical, physical, geological, and biological processes.

Carbon dioxide:
A colorless, odorless greenhouse gas. It is produced naturally when dead animals or plants decay, and it is used by plants during photosynthesis. People are adding carbon dioxide into the atmosphere, mostly by burning fossil fuels such as coal, oil, and natural gas. This extra carbon dioxide is the main cause of climate change.

Greenhouse gas:
Also sometimes known as "heat-trapping gases," greenhouse gases are natural or manmade gases that trap heat in the atmosphere and contribute to the greenhouse effect. Greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and fluorinated gases.

Parts per million (ppm):
A unit of measurement that can be used to describe the concentration of a particular substance within air, water, soil, or some other medium. For example, the concentration of carbon dioxide in the Earth's atmosphere is almost 400 parts per million, which means 1 million liters of air would contain about 400 liters of carbon dioxide.

Photosynthesis:
The process by which green plants use sunlight, water, and carbon dioxide to make food and other substances that they use to grow. In the process, plants release oxygen into the air.

CARBON THROUGH THE SEASONS

Mauna Loa on the World Map

Scientists monitor the amount of CO_2 and other gases in the atmosphere at stations such as the Mauna Loa Observatory in Hawaii. The Mauna Loa Observatory is one of the sites that have helped scientists determine that CO_2 levels in the atmosphere have increased significantly in recent decades and that these levels are continuing to rise at a rapid rate.

Image source: Carbon Dioxide Information Analysis Center: http://cdiac.ornl.gov/.

INSTRUCTIONS

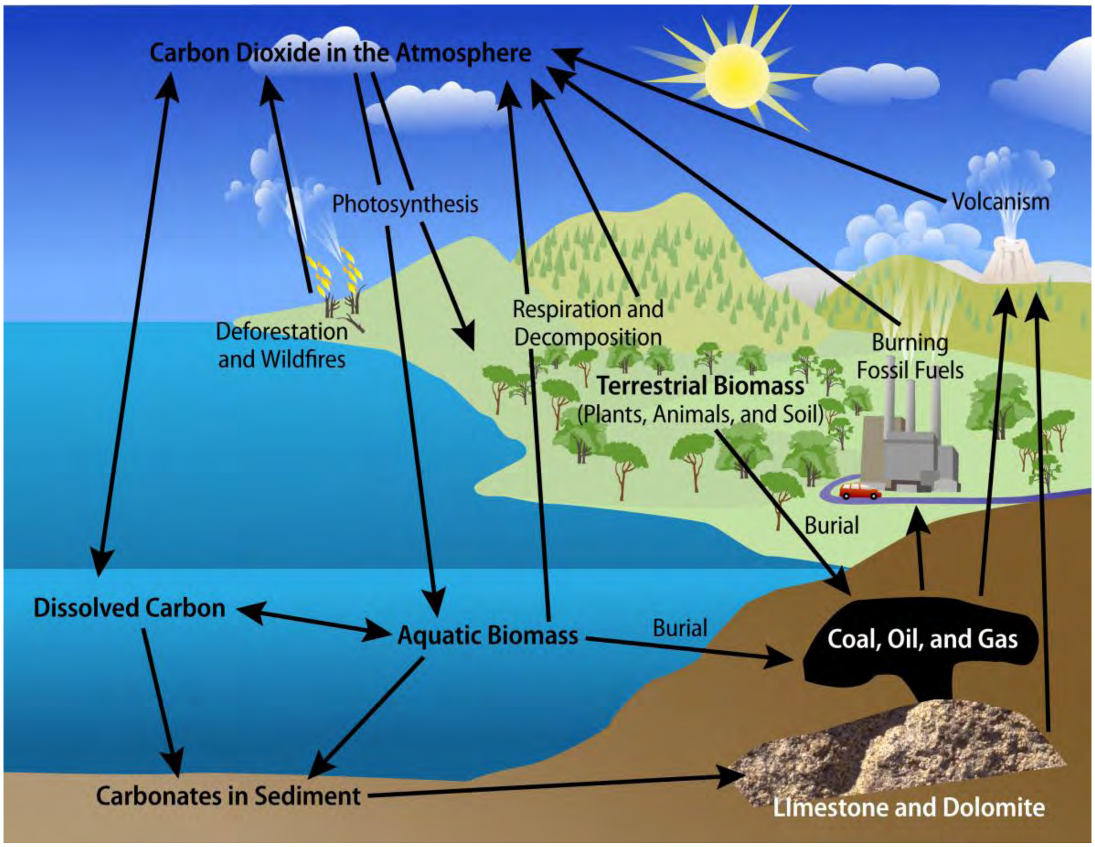
Part 1: Plotting Monthly Atmospheric CO_2 Data

1. Tell the students that they will be learning about the carbon cycle by looking at monthly atmospheric CO_2 concentration data from 1959 to 2011. Explain that these data come from the Mauna Loa Observatory in Hawaii, and show students where the observatory is located on a map. Explain that because CO_2 spreads throughout the world's atmosphere, measurements from Mauna Loa are actually representative of global average CO_2 levels.

2. Show the class a short video about the carbon cycle and how people are changing this natural cycle at "Learn the Basics: Today's Climate Change" on EPA's *A Student's Guide to Global Climate Change* website (http://www.epa.gov/climatechange/students/basics/today/carbon-dioxide.html). You can also show a diagram of the carbon cycle (see box below), or demonstrate how the carbon cycle works by drawing it on the chalkboard.

CARBON THROUGH THE SEASONS

The Carbon Cycle



Adapted from: CO_2logic: http://www.co2logic.com/home.aspx/html/Images/carbon%20cycle.jpg.

3. Discuss the processes of respiration and photosynthesis in plants and how these processes influence the amount of CO_2 in the atmosphere during the course of a year.

4. Break the students into groups of approximately five. Assign each group a set of data from the "Mauna Loa Observatory Data" tables (each group will get 10 to 12 years of data), and pass out one copy of the assigned data per student. Also provide each group with a sheet of graph paper and a copy of the "Mauna Loa Worksheet."

5. Discuss what parts per million (ppm) means.
[Answer: Parts per million or ppm is a unit of measurement that can be used to describe the concentration of a particular substance within air, water, soil, or some other medium. For example, the concentration of carbon dioxide in the Earth's atmosphere is almost 400 parts per million, which means 1 million liters of air would contain about 400 liters of carbon dioxide.]

CARBON THROUGH THE SEASONS

6. Tell students that each group will be graphing their data on the graph paper. Explain that students in each group should work as a team by taking turns to plot data points on the same graph paper. Ask students to follow the "Instructions for Plotting the Graph" on the "Mauna Loa Data Worksheet" to plot their data.

7. When students have finished plotting their graphs, hand out a copy of the "Mauna Loa Monthly Average CO_2 Concentration, 1958 to 2011" graph to each group. Tell students that this is how the entire Mauna Loa Observatory data series looks when it is plotted in one graph.

8. Discuss the following questions in class:

   - What patterns do you notice in your graph? (Ask students to keep these patterns in mind as you ask them additional questions.)
     [Answer: An increase in CO_2, followed by a decrease in CO_2, creating a repeating pattern of peaks and troughs much like a wave. Another pattern is an increase in heights of both peaks and troughs over time.]

   - What does the increase in the height of the peaks and troughs mean?
     [Answer: The overall amount of CO_2 in the atmosphere is increasing.]

   - According to your data, during what month and during what season are the CO_2 concentrations highest? Lowest?
     [Answer: highest concentrations in April and May (spring), lowest in August and September (early fall)]

   - Explain how the seasonal changes of CO_2 concentration in the atmosphere and the growing season for plants and are related?
     [Answer: CO_2 in the atmosphere decreases during the growing season and increases during the rest of the year, which leads to maximum buildup in April and May before photosynthesis begins to take over again. Photosynthesis, in which plants take up CO_2 from the atmosphere and release oxygen, dominates during the growing season (the warmer part of the year). Respiration, by which plants and animals take up oxygen and release CO_2, occurs all the time but dominates during the colder months of the year.]

   - Are the seasons the same in the Northern and Southern Hemispheres?
     [Answer: No, the seasons in the Northern and Southern Hemispheres are opposite.]

   - How does this difference affect CO_2 concentrations in the atmosphere?
     [Answer: While CO_2 concentrations in the atmosphere are increasing in the Northern Hemisphere, CO_2 concentrations are decreasing in the Southern Hemisphere, and vice versa.]

   - There is more land in the Northern Hemisphere than in the Southern Hemisphere. How might this difference affect CO_2 concentrations in the atmosphere?
     [Answer: The carbon cycle is more pronounced in the Northern Hemisphere (which has relatively more land mass and terrestrial vegetation) than in the Southern Hemisphere (which is more dominated by oceans).]

   - Earlier, you noticed that your line graph has a repeating pattern. Explain.
     [Answer: The variations within each year are the result of the annual cycles of photosynthesis and respiration.]

CARBON THROUGH THE SEASONS

Part 2: Calculating Annual Average CO_2 Concentrations

[This portion of the lesson can be done in another class period or assigned as homework. It can be done as a group or individual exercise.]

1. Have each group of students complete the "Annual Average CO_2 Concentrations" chart on the "Mauna Loa Data Worksheet" for their set of data. Discuss the following questions:
   - Is there a particular pattern in the change in annual average CO_2 concentration for your set of years? *[Answer: Yes, CO_2 concentration increases every year. (Each group's dataset shows this same pattern.)]*
   - Ask the students what this pattern means. *[Answer: It means more CO_2 was added to the atmosphere.]*
2. Tell students that people are changing this Earth's natural carbon balance by adding more CO_2 to the atmosphere when we burn fossil fuels (such as coal, oil, and natural gas)—whether it's to drive our cars, power our homes, or make products. This extra CO_2 is being added to the atmosphere faster than natural processes can remove it, causing the atmosphere to trap more heat and causing the Earth's average temperature to rise.

EXTENSION

There are many monitoring stations like Mauna Loa Observatory that collect data about atmospheric CO_2 levels. Some scientists even use ice cores and tree rings to learn about the amount of CO_2 in the atmosphere hundreds of thousands of years ago.

- Tell students that the CO_2 levels in the past hundred years are abnormally high compared with natural historical levels, and that these levels are continuing to increase at an unprecedented rate.
- Explain that scientists can compare the amount of CO_2 in the atmosphere with the amount trapped in ancient ice cores, which show that the atmosphere had less CO_2 in the past.
- Show this three-minute YouTube video about the history of global atmospheric CO_2. (http://www.youtube.com/watch?feature=player_embedded&v=bbgUE04Y-Xg).The video starts with an animated graph of seasonal CO_2 variations observed at stations around the world from 1979 to 2011, then looks at patterns back to 800,000 years ago.

CARBON THROUGH THE SEASONS

MAUNA LOA OBSERVATORY DATA

Mauna Loa CO_2 Monthly Average Concentrations, 1959 to 1969 (ppm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1959	315.62	316.38	316.71	317.72	318.29	318.15	316.54	314.80	313.84	313.26	314.80	315.58
1960	316.43	316.97	317.58	319.02	320.03	319.59	318.18	315.91	314.16	313.83	315.00	316.19
1961	316.93	317.70	318.54	319.48	320.58	319.77	318.57	316.79	314.80	315.38	316.10	317.01
1962	317.94	318.56	319.68	320.63	321.01	320.55	319.58	317.40	316.26	315.42	316.69	317.69
1963	318.74	319.08	319.86	321.39	322.25	321.47	319.74	317.77	316.21	315.99	317.12	318.31
1964	319.57	320.07	320.73	321.77	322.25	321.89	320.44	318.70	316.70	316.79	317.79	318.71
1965	319.44	320.44	320.89	322.13	322.16	321.87	321.39	318.81	317.81	317.30	318.87	319.42
1966	320.62	321.59	322.39	323.87	324.01	323.75	322.39	320.37	318.64	318.10	319.79	321.08
1967	322.07	322.50	323.04	324.42	325.00	324.09	322.55	320.92	319.31	319.31	320.72	321.96
1968	322.57	323.15	323.89	325.02	325.57	325.36	324.14	322.03	320.41	320.25	321.31	322.84
1969	324.00	324.42	325.64	326.66	327.34	326.76	325.88	323.67	322.38	321.78	322.85	324.11

Data source: National Oceanic and Atmospheric Administration (NOAA): http://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html. Accessed August 2012.

Mauna Loa CO_2 Monthly Average Concentrations, 1970 to 1979 (ppm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	325.03	325.99	326.87	328.13	328.07	327.66	326.35	324.69	323.10	323.16	323.98	325.13
1971	326.17	326.68	327.18	327.78	328.92	328.57	327.34	325.46	323.36	323.57	324.80	326.01
1972	326.77	327.63	327.75	329.72	330.07	329.09	328.05	326.32	324.93	325.06	326.50	327.55
1973	328.54	329.56	330.30	331.50	332.48	332.07	330.87	329.31	327.51	327.18	328.16	328.64
1974	329.35	330.71	331.48	332.65	333.19	332.12	330.99	329.17	327.41	327.21	328.34	329.50
1975	330.68	331.41	331.85	333.29	333.91	333.40	331.74	329.88	328.57	328.36	329.33	330.59
1976	331.66	332.75	333.46	334.78	334.78	334.06	332.95	330.64	328.96	328.77	330.18	331.65
1977	332.69	333.23	334.97	336.03	336.82	336.10	334.79	332.53	331.19	331.21	332.35	333.47
1978	335.10	335.26	336.61	337.77	338.01	337.98	336.48	334.37	332.33	332.41	333.76	334.83
1979	336.21	336.65	338.13	338.94	339.00	339.20	337.60	335.56	333.93	334.12	335.26	336.78

Data source: National Oceanic and Atmospheric Administration (NOAA): http://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html. Accessed August 2012.

CARBON THROUGH THE SEASONS

MAUNA LOA OBSERVATORY DATA

Mauna Loa CO_2 Monthly Average Concentrations, 1980 to 1989 (ppm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	337.80	338.28	340.04	340.86	341.47	341.26	339.34	337.45	336.10	336.05	337.21	338.29
1981	339.36	340.51	341.57	342.56	343.01	342.49	340.68	338.49	336.92	337.12	338.59	339.90
1982	340.92	341.69	342.85	343.92	344.67	343.78	342.23	340.11	338.32	338.39	339.48	340.88
1983	341.64	342.87	343.59	345.25	345.96	345.52	344.15	342.25	340.17	340.30	341.53	343.07
1984	344.05	344.77	345.46	346.77	347.55	346.98	345.55	343.20	341.35	341.68	343.06	344.54
1985	345.25	346.06	347.66	348.20	348.92	348.40	346.66	344.85	343.20	343.08	344.40	345.82
1986	346.54	347.13	348.05	349.77	350.53	349.90	348.11	346.09	345.01	344.47	345.86	347.15
1987	348.38	348.70	349.72	351.32	352.14	351.61	349.91	347.84	346.52	346.65	347.95	349.18
1988	350.38	351.68	352.24	353.66	354.18	353.68	352.58	350.66	349.03	349.08	350.15	351.44
1989	352.89	353.24	353.80	355.59	355.89	355.30	353.98	351.53	350.02	350.29	351.44	352.84

Data source: National Oceanic and Atmospheric Administration (NOAA): http://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html. Accessed August 2012.

Mauna Loa CO_2 Monthly Average Concentrations, 1990 to 1999 (ppm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	353.79	354.88	355.65	356.27	357.29	356.32	354.89	352.89	351.28	351.59	353.05	354.27
1991	354.87	355.68	357.06	358.51	359.09	358.10	356.12	353.89	352.30	352.32	353.79	355.07
1992	356.17	356.93	357.82	359.00	359.55	359.32	356.85	354.91	352.93	353.31	354.27	355.53
1993	356.86	357.27	358.36	359.27	360.19	359.52	357.42	355.46	354.10	354.12	355.40	356.84
1994	358.22	358.98	359.91	361.32	361.68	360.80	359.39	357.42	355.63	356.09	357.56	358.87
1995	359.87	360.79	361.77	363.23	363.77	363.22	361.70	359.11	358.11	357.97	359.40	360.61
1996	362.04	363.17	364.17	364.51	365.16	364.93	363.53	361.38	359.60	359.54	360.84	362.18
1997	363.04	364.09	364.47	366.25	366.69	365.59	364.34	362.20	360.31	360.71	362.44	364.33
1998	365.18	365.98	367.13	368.61	369.49	368.95	367.74	365.79	364.01	364.35	365.52	367.08
1999	368.12	368.98	369.60	370.96	370.77	370.33	369.28	366.86	364.94	365.35	366.68	368.04

Data source: National Oceanic and Atmospheric Administration (NOAA): http://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html. Accessed August 2012.

CARBON THROUGH THE SEASONS

MAUNA LOA OBSERVATORY DATA

Mauna Loa CO_2 Monthly Average Concentrations, 2000 to 2011 (ppm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	369.25	369.50	370.56	371.82	371.51	371.71	369.85	368.20	366.91	366.99	368.33	369.67
2001	370.52	371.49	372.53	373.37	373.82	373.18	371.57	369.63	368.16	368.42	369.69	371.18
2002	372.45	373.14	373.93	375.00	375.65	375.50	374.00	371.83	370.66	370.51	372.20	373.71
2003	374.87	375.62	376.48	377.74	378.50	378.18	376.72	374.31	373.20	373.10	374.64	375.93
2004	377.00	377.87	378.73	380.41	380.63	379.56	377.61	376.15	374.11	374.44	375.93	377.45
2005	378.47	379.76	381.14	382.20	382.47	382.20	380.78	378.73	376.66	376.98	378.29	379.92
2006	381.35	382.16	382.66	384.73	384.98	384.09	382.38	380.45	378.92	379.16	380.18	381.79
2007	382.93	383.81	384.56	386.40	386.58	386.05	384.49	382.00	380.90	381.14	382.42	383.89
2008	385.44	385.73	385.97	387.16	388.50	387.88	386.42	384.15	383.09	382.99	384.13	385.56
2009	386.93	387.42	388.77	389.46	390.19	389.44	387.91	385.92	384.79	384.39	386.00	387.27
2010	388.45	389.82	391.08	392.46	392.95	392.03	390.13	388.15	386.80	387.18	388.59	389.68
2011	391.19	391.76	392.40	393.28	394.16	393.68	392.39	390.08	389.00	388.92	390.20	391.80

Data source: National Oceanic and Atmospheric Administration (NOAA): http://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html. Accessed August 2012.

CARBON THROUGH THE SEASONS

MAUNA LOA DATA WORKSHEET

NAME: ______________________________ **DATE:** ____________________

Instructions for Plotting the Graph

1. On the graph paper, label the x-axis as "Year and Month." Begin numbering from left to right on the x-axis from 1 to 12 at intervals of 1. Each point represents a month of the year: 1 is January, 2 is February, and so on. Label this first group of 12 points (or months) below the x-axis as the first year of your assigned data. Continue numbering points on the x-axis in sets of 12 months for the next years.
2. On the y-axis (on the left-hand side of the paper), number the parts per million for CO_2 concentrations. Begin with 300 at the lower end, and number up to 400 ppm, counting by intervals of 10. Label the axis.
3. Using information from the "Mauna Loa Observatory Data," table, plot the points corresponding to each monthly average atmospheric CO_2 concentration for the years assigned to your group.

Instructions for Filling Out the Changes in Annual Average CO_2 Concentrations

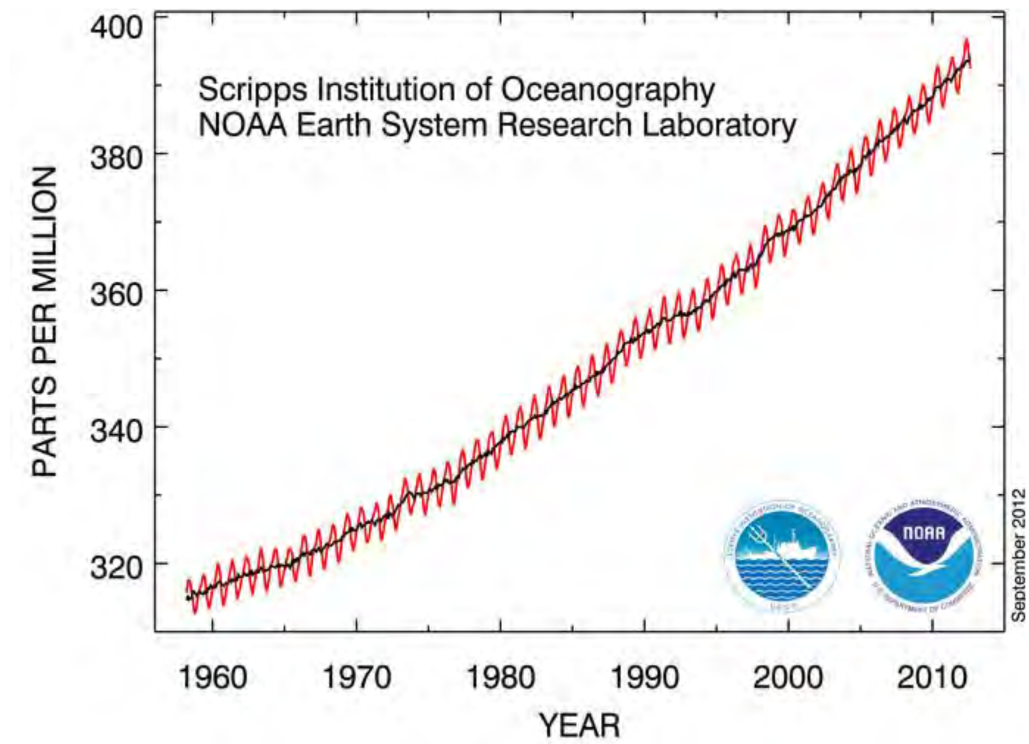
Fill in the years of your individual dataset in the chart below. Calculate 1) the average (mean) CO_2 concentration (ppm) for each of the years in your dataset, 2) the amount of change (ppm) from the previous year, and 3) the direction of change (whether it has increased, decreased, or remained unchanged).

Annual Average CO_2 Concentrations

Year	Annual average	Difference from previous year	Direction

CARBON THROUGH THE SEASONS

Mauna Loa Monthly Average CO_2 Concentration, 1958 to 2011



The Mauna Loa Observatory is one of the sites that have helped scientists determine that CO_2 levels in the atmosphere have increased significantly in recent decades and that these levels are continuing to rise at a rapid rate. CO_2 stays in the atmosphere for long enough that it is able to spread fairly evenly around the world, so even measurements from a single site (like Mauna Loa) can be representative of global average CO_2 concentrations.

Image source: National Oceanic and Atmospheric Administration (NOAA): http://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_data_mlo.png. Accessed September 2012.

For the latest version, please see the graph in the "Full Mauna Loa CO_2 Record" section of NOAA's page at http://www.esrl.noaa.gov/gmd/ccgg/trends/mlo.html.

CARBON THROUGH THE SEASONS

ANNUAL AVERAGE CO_2 CONCENTRATIONS—ANSWER KEY

Year	Annual average	Difference from previous year	Direction
1959	315.97		
1960	316.91	0.93	Increase
1961	317.64	0.73	Increase
1962	318.45	0.81	Increase
1963	318.99	0.54	Increase
1964	319.62	0.62	Increase
1965	320.04	0.43	Increase
1966	321.38	1.34	Increase
1967	322.16	0.77	Increase
1968	323.05	0.89	Increase
1969	324.62	1.58	Increase
1970	325.68	1.06	Increase
1971	326.32	0.64	Increase
1972	327.45	1.13	Increase
1973	329.68	2.22	Increase
1974	330.18	0.50	Increase
1975	331.08	0.91	Increase
1976	332.05	0.97	Increase
1977	333.78	1.73	Increase
1978	335.41	1.63	Increase
1979	336.78	1.37	Increase
1980	338.68	1.90	Increase
1981	340.10	1.42	Increase
1982	341.44	1.34	Increase
1983	343.03	1.59	Increase
1984	344.58	1.55	Increase
1985	346.04	1.46	Increase
1986	347.38	1.34	Increase
1987	349.16	1.78	Increase
1988	351.56	2.40	Increase
1989	353.07	1.50	Increase
1990	354.35	1.28	Increase

(CONTINUED)

Lesson 9

New York Explores Sea Level Rise: A Field Based Activity

Sea Grant New York
New York State Water Resources Institute
Cornell University
Hudson River Estuary

New York Explores Sea Level Rise

New York State Intermediate Level Science

Standard 1: Analysis, Inquiry and Design/Scientific Inquiry

- S1.2c differentiate among observations, inferences, predictions, and explanations
- S2.1d use appropriate tools and conventional techniques to solve problems about the natural world, including: measuring, observing, describing, classifying, sequencing
- S2.3b conduct a scientific investigation
- S2.3c collect quantitative and qualitative data
- S3.1a organize results, using appropriate graphs, charts, and data tables
- S3.2d formulate and defend explanations and conclusions as they relate to scientific phenomena
- S3.2h use and interpret graphs and data tables

Standard 6: Interconnectedness

- 5.2 Observe patterns of change in trends or cycles and make predictions on what might happen in the future.

Standard 4: The Physical Setting

- 2.2i Weather describes the conditions of the atmosphere at a given location for a short period of time.
- 2.2j Climate is the characteristic weather that prevails from season to season and year to year.
- 2.2r Substances enter the atmosphere naturally and from human activity. Some of these include greenhouse gases such as carbon dioxide, methane, and water vapor. These substances can affect weather, climate, and living things.
- 7.2d Since the Industrial Revolution, human activities have resulted in major pollution of air, water, and soil. Pollution has cumulative ecological effects such as acid rain, global warming, or ozone depletion. The survival of living things on our planet depends on the conservation and protection of Earth's resources.

Next Generation Science Standards

Science and Engineering Practices:

2. Developing and using models
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Grade 7

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

Common Core State Standards - ELA in the Content Areas - Grades 6-8

CCSS.ELA-Literacy. RST.6-8.7
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.ELA-LITERACY. WHST.6-8.2
Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Standards for Mathematical Practice
CCSS.Math. Practice.MP2
Reason abstractly and quantitatively.

CCSS.Math.Practice.MP4
Model with mathematics.
Grade 6: CCSS.Math.
Content.6.NS.C.8
Solve real world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

New York Explores Rising Sea Level: A Field-Based Introduction

Adapted from: "Climate Change and Sea Level Rise Data Collection," by Margie Turrin, Education Coordinator, Lamont-Doherty Earth Observatory, Columbia University Earth Institute. Additionally, Steve Stanne, Estuary Education Coordinator, NYSDEC Hudson Estuary Program/NYS Water Resources Institute and Meghan Marrero, Ed.D edited the activity.[1]

Introduction

In this activity, students will use the science community's current predictions for sea level rise to map the slope of their field area. They will mark how far inland water is predicted to reach as sea level rises, and assess how that flooding might impact habitat, vegetation, and structures made by people.

The first part of the activity may take place in the classroom, the second part outside on the shoreline of a tidal water body. Students can then wrap up in the classroom.

Background Information

What Is Climate Change?

Climate refers to long-term changes in patterns of temperature, precipitation, humidity, wind, and seasons. Climate varies by region but overall the earth's climate has been warming. Global temperatures over both land and ocean surfaces have risen ~0.85°C (1.5°F) since 1880.[2] The U.S. is warming at ~0.72°C (1.3°F) per century[3].

Is Global Sea Level Rising?

According to the International Panel on Climate Change (IPCC), the scientific body set up to look into this, during the 20th century global sea level has risen about 1.7 mm/year (0.07 inches). A newer data set with more accurate sea level measurements made from satellites shows that since 1993, global sea level has been rising at a rate of ~ 3 mm/yr (0.12 inches) – nearly double the previous half century. Coastal tide gauge measurements confirm this conclusion.

Global rates are important for assessing overall trends in sea level change. However, climate models predict that sea level will not rise uniformly around the world, and satellite data and local tide gauge measurements show that this is true. In some places, like the Chesapeake Bay, rates are up to several times the global mean rise. In other regions, like areas of Alaska, sea level is falling. This variability is in large part due to local circumstances of geology, ice history, temperature, salinity, and ocean currents.[4]

---

1 *This activity is adapted from: "Climate Change and Sea Level Rise Data Collection". by A. Baldwin and C. Samis at Assateague State Park, further edited in 2013 by Amanda Sullivan, Maryland Department of Natural Resources.*

2 *Sources: IPCC, 2013: "Climate Change 2013: The Physical Science Basis. Summary for Policymakers: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" [Stocker, T., D. Qin, G-K. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P. Midgley (eds.)]. IPCC, Switzerland. http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf*

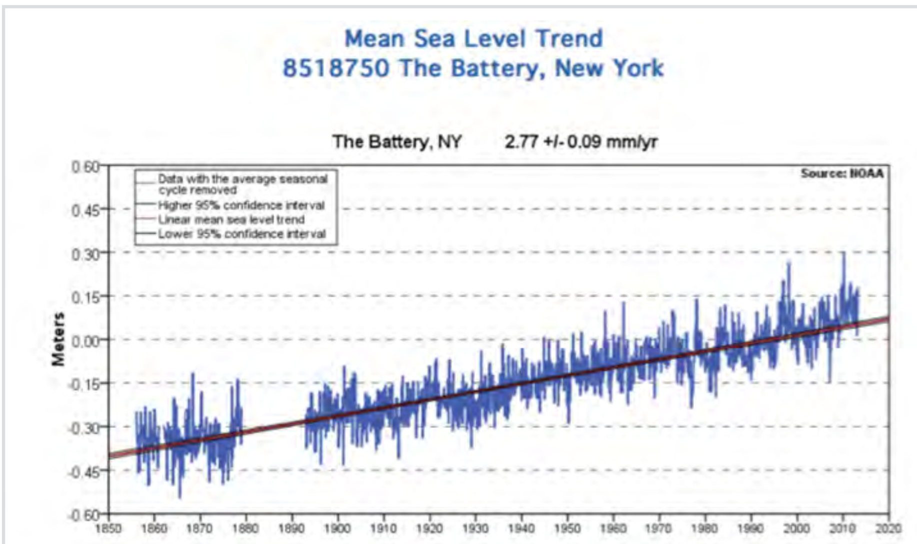
3 *NOAA's National Climate Data Center*

Why Is The Sea Level Rising?

- There are two major causes of global sea level rise: (1) thermal expansion of ocean water and (2) melting of land-based ice. The ocean is absorbing much of the additional heat trapped by greenhouse gases in our atmosphere. As it warms, ocean water expands, causing sea level to rise. Approximately 50% of the rise in sea level is due to this expansion. At the same time, warmer temperatures across the globe are causing land glaciers and sections of the Greenland and Antarctic Ice Sheets to melt. No longer locked up in ice, this meltwater eventually reaches the oceans and also causes sea level to rise.

What About New York?

A tide gauge at the Battery in New York City measures local or 'relative' sea level, and provides evidence that sea level has risen close to 2.77 mm/year over the last 150 years. For the last 100 years this amounts to a rise of 27.7 cm (~ 11 inches)[5].



The mean sea level trend is 2.77 millimeters/year with a 95% confidence interval of +/- 0.09 mm/yr based on monthly mean sea level data from 1856 to 2006 which is equivalent to a change of 0.91 feet in 100 years.

What Does This Mean For Our Future?

In 2013 and 2014 reports, the IPCC suggests that sea level rise will continue to accelerate over the next ~100 years. How much sea level rises will depend on how well carbon dioxide emissions are controlled. If emissions are greatly reduced, sea level rise is predicted to be 28-61 cms (11-24 inches). If carbon dioxide emissions are not well-controlled, sea level rise may be closer to 52-98 cms (20-39 inches).[6] What will this mean on your local waterfront? Let's get outside and see!

4 *IPCC, 2013: "Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change: Chapter 13, Sea Level Rise", Coordinating Lead Authors Church, J.A. and P. U. Clark. IPCC, Switzerland. http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter13_FINAL.pdf*

5 *http://tidesandcurrents.noaa.gov/sltrends/*

Major Concepts

- Our warming climate is causing sea level to rise.
- We measure this change globally with satellites and locally with tide gauges.

OBJECTIVES

Students will be able to

- Analyze the IPCC's predictions for global sea level rise, and compare these to local sea level changes over the past 100 years.
- Apply IPCC report predictions for global sea level rise to the physical coastline at their field site, using rudimentary tools.
- Use real time, remotely sensed water level data to examine sea level impacts throughout a tidal cycle.

Materials Required

- Dry erase board or flip chart paper
- Footwear, clothing, and sun protection suitable for fieldwork, including water shoes or boots for students on the water's edge

Supplies for each group of 4-5 students:

- Pole approximately 1.5 meters long (can use a tide stick)
- 'Line level' (or string level) ~3 inches in length. Often come two in a kit and may come with surveyors' string. Found in hardware stores.*Note that there is a level app for cell phones and tablets, which students may enjoy using instead of a traditional level. They will need to hold the phone or tablet under the string.
- Surveyor's string or line – allow for plenty of length at your site
- Tape (colored painter's or electrical tape) to mark off elevation on the 1.5 meter pole
- A meter tape measure
- 3 stakes (if the ground is soft) or colored chalk, cones or other types of physical markers that can be used to mark locations for three different sea level scenarios
- A field copy of the graph sheet (attached) on a clipboard
- 3 pens/pencils of different colors
- Times for High Tide / Low Tide at your site (available from NOAA tides & currents page: *http://tidesandcurrents.noaa.gov/tide_predictions.html?gid=62#listing*

Engage

Pre-Activity

Prior to reviewing the background information and starting the field activity, pose two sets of questions on a dry erase board or a flip-chart that you can use in the field. Have the students vote, and record the results using a tally mark for each possible answer in the following sets of questions.
(Note: For each of the questions provide a range of answers to help guide the responses. Without any guide student responses have a tendency to be extreme, wide-ranging and often unrealistic.)

---

6 *IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.*

1) Question Set #1: How much do you think sea level has risen in NYC over the last 100 years? [Suggested response categories could include: 1) 0-9 cm (0-3.5 inches); 2) 10-19 cm (4-6 inches); 3) 20-29cm (8-11 inches); 4) 30-45cm (12-17.5 inches).]
2) Question Set #2: How much do you think sea level will rise in the next 100 years? 1) Less than it has in the last 100 years; 2) As much as it has in last 100 years ; 3) Double the rate of the last 100 years; 4) Triple the rate of the last 100 years.

Place these answers where the students can see them and move on with the activity. You will discuss them during the background and field activities.

Next, have students review the background information (see student worksheet), either as a class or in small groups. Consider using a reading strategy to assist students in unpacking the text.

As you read the final two background sections, review the students' responses to the first pre-activity question re: projected change in the last 100 years. Discuss what they had relied on when they answered this question i.e., other students' answers; news coverage they had heard; strictly a 'guess'; other?

Explore

Field Activity

Start by asking: *How will climate change affect this shoreline?*
Allow students to share some of their predictions, and point out particular shoreline features or landmarks that may be affected by rising sea levels. Discuss where the shoreline will be as sea level rises.

Tell students they are going to work in teams of 4-5 students. Each team will make measurements allowing them to predict what the shoreline will look like as sea level rises. Explain that they are going to look at what would happen based on three IPCC projected levels of sea level rise (see student worksheet):

a) 28 cm (11 inches) anticipated with aggressive emission reductions
b) 52 cm (20.5 inches) anticipated with reductions at a lesser scale
c) 98 cm (39 inches) anticipated with 'business as usual' – few reductions.

Begin the activity.

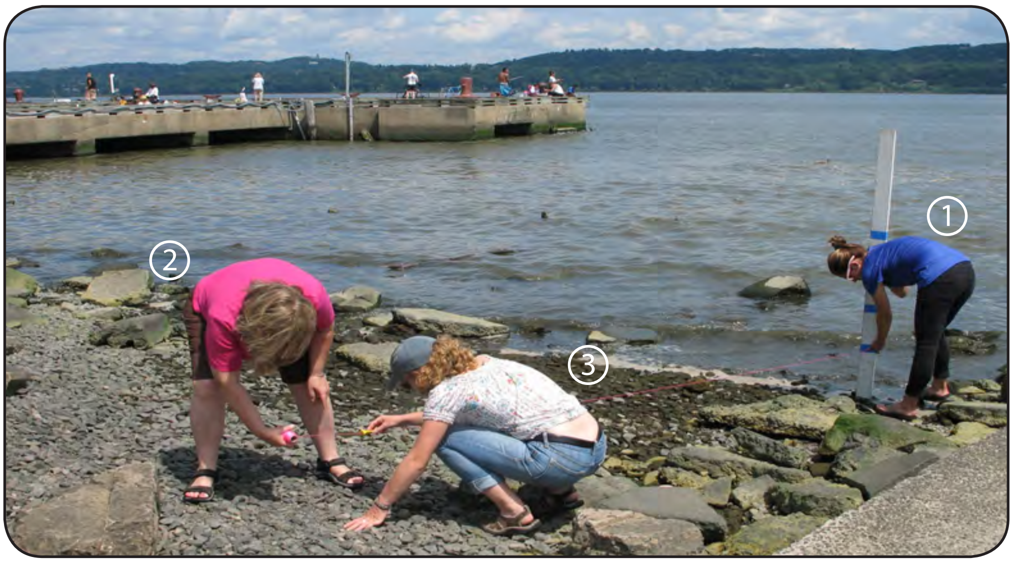
1. Divide the class into groups of 4-5 students.

2. Give each group their set of field supplies. Spread the groups out along the waterfront, not too far apart as they will need to plot their locations together with those of the other groups. For younger students, you may wish to assign a spot, e.g., every 5 meters along the water's edge. Alternatively, have the groups choose their own locations.
Note: This activity will work best at sites with a fairly straight shoreline, lacking irregular coves and points. The groups can then be spread out more or less evenly along the shore, and their transects – run perpendicular to the shoreline – will not overlap.

3. Model for students how they will mark the three different IPCC measures on their poles with color tape. Then have them mark their poles.

4. Student #1 for each group holds the measuring pole vertically at the water's edge with his/her back to the water (may require water footwear). This is the starting point for their transect.
   Note that they are measuring change added to the tide height at this time; it doesn't matter how high the tide is when you start the activity. They will discuss how tides may influence what happens later, back in the classroom.

5. Tie the survey line around the pole where it is marked for 28 cm (11 inches) elevation. Student #2 walks straight away from the water with the survey line, trying to hold it level to where it is tied on the pole.



Student #1 is holding the pole.
Student#2 is holding the line.
Student#3 is hanging the level.

Student groups are spaced along the shoreline.

6. Student #3 will hang the level on the survey line and direct student #2, helping them to keep the bubble in the line level evenly positioned as the string is extended until it intersects with the shore (in other words, it hits ground). Student #4 marks this location 'A' with a stake or other marker. (See photographs of this activity on the previous page.)

7. Move the survey line up the pole to the second mark at 52 cm (20.5 inches). Extend the string until it is level and touching the ground. Mark with stake 'B'.

8. Move the survey line up to the third mark on the pole (98 cm or 39 inches). Extend and level the string. Mark where it meets the ground with stake 'C'.

9. Have student #4 use the tape to measure and record on the bottom of the grid sheet how far the water would extend inland from its present edge under each of the three scenarios.

10. Have a couple of students measure and record the distances between Student #1 in each team, starting at one end of the field site and working to the other. They should base their measurements on where Student #1 was standing. These distances will determine the start point for charting each group's transect on the grid sheet.

11. Each group should enter the information requested at the bottom of their sheet.

If time allows, have the groups share their data and plot the results on their grid sheets while in the field, as directed below. Then move on to the Explain section.

If time is short, bring the class back together after students have placed the markers showing where shorelines will be with higher predicted sea levels. Briefly discuss the new sea level 'contours' before leaving. Set aside time for students to plot the data and discuss their observations more intensively back at school.

Plot The Data
(May be done at the site or back in the classroom)

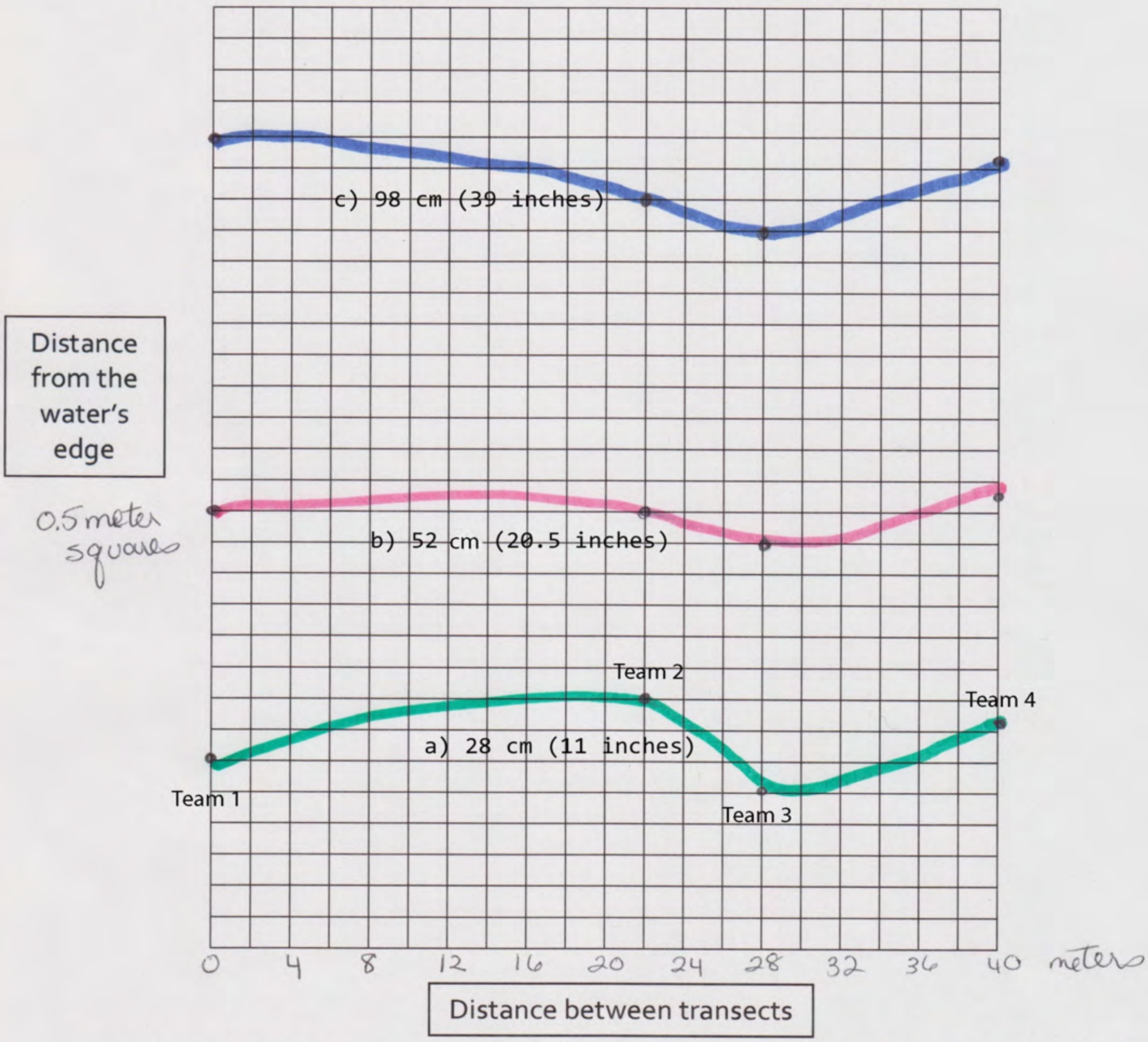
Have each group share its data with the others to complete their grid sheets. Each team should have a complete set of all teams' data-points and the measurements of the distances between the transects.

Have students determine the range of each data set. How far inland will the new shorelines be? How far apart are the two outermost transects? They then choose suitable scales for each grid axis and label each one with appropriate numbers. On the vertical axis, the scale must extend beyond the greatest distance measured from the existing water's edge to a new shoreline. On the horizontal axis, the scale must cover the distance between the transects at either end of the field site's shoreline.

Student should locate each transect at its proper point along the X axis and then – above that point – plot the three sea level data points for that transect. Then have them draw a line connecting across all the points 'A', another connecting all points 'B', and a third connecting points 'C'. Use a different color for each line. This will create a diagram of sea level change 'contours'. Students can add labels for each contour, corresponding to the three scenarios on which they are based.

Waterfront Profile

Draw 3 different shoreline profiles using 3 colors, one for each of the 3 scenarios (A,B,C).



DATE OF DATA COLLECTION 8/4/14 TIME OF COLLECTION 1:30PM
LOW TIDE TIME 10:21AM HIGH TIDE TIME 4:23PM TIDAL RANGE FOR AREA ~3ft.
TEAM NAME TEAM #1 @ zero marker
FOR YOUR TEAM: Measurement to Point A 3m. Point B 7m Point C 13m

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Explain

(May be done at the site or back in the classroom)

Discuss with the students what the effect of sea level rise will be on this shoreline region. What sorts of structures and land areas – including plants, animals and habitats – will be impacted by this projected sea level rise? If this is done back in the classroom, teachers and/or students may wish to snap a picture of the site to help in the discussion of impacts.

Remind students that we looked at a range of IPCC estimates based on data from the last 100 years and adding in the effects of our warming environment and changes in glaciers. Point out that the IPCC projections are not a guess; they are based on carefully made actual measurements. Entered into computer models, these data allow scientists to make realistic predictions for the future.

Ask the students where the tide was when their measurements were made. High? Low? Somewhere in between? What is the tidal range in this area? What will happen as the water level changes through the daily tidal cycle? If students have studied spring and neap tides discuss how these would affect water levels at their site[7].

As sea level rises it magnifies the effects of storm surge. During superstorm Sandy, storm surge – the rise in water level as Sandy approached and passed over the area – was added to high tide, resulting in 10-14 foot high storm tides. What might that look like at your site? If sea level continues to rise, future storms won't need to be as severe as Sandy to have the same impacts.

Discuss

Is there anything we can do to slow the rate of sea level rise?
Suggested Answer: The IPCC discusses reducing greenhouse gas emissions by reducing our burning of fossil fuels and our carbon footprint to slow the build-up of greenhouse gases in the atmosphere and therefore trap less heat. Challenge your students to think of personal changes they can make.

Are there ways to develop land differently when it is at or near a coastline?
Ideas: Build back from the shoreline and above the projected sea level rise marks. Discuss the benefits of keeping our shorelines as natural as possible to allow them to respond to changes in sea level. Incorporate designs that can flood and recover.

---

7 http://oceanservice.noaa.gov/facts/springtide.html

Elaborate

As a class, use the Hudson River Environmental Conditions Observing System [HRECOS] to look at the effects of sea level change over a tidal cycle:

1. Go to http://www.hrecos.org, then to 'Current Conditions'.
2. You can click on the top of the control panel to list the stations from North to South so you can locate the stations geographically.
3. Chose the site closest to your sample site and select 'Depth' or 'Elevation' to show the tidal cycle at this location.
4. Select the date on which you made your measurements.
5. Measure the tidal range for this site. In each 24 hour period there are two cycles of high and low tides. Select the cycle with the greatest difference between high and low points, and measure the difference between those two water levels – the tidal range. You can do this visually using the graph or you can download the actual measurements in Excel to your computer.
6. Refer back to your field data. During what part of the tidal cycle did your team collect data? Was the tide high, low, in between? How much would you predict you might have to adjust the sea level contours on your grid if you did not measure at the highest part of the tidal cycle? Use a pencil to sketch it on your grid.

For accelerated students, use Google Maps to create an image of your field site. Be sure the image includes a scale bar. Have the students transfer their data to the map image using the measurements on the map and on their graphs.

Evaluate

Assign the short writing activity (see student worksheet) for homework. By reviewing students' responses, you can assess whether they understood what they were doing in the field and the larger picture of climate change and sea level rise.

Student Worksheet New York Explores Sea Level Rise

Name ___________________________

WHAT IS CLIMATE CHANGE?
Climate refers to long-term changes in patterns of temperature, precipitation, humidity, wind, and seasons. Climate varies by region but overall the earth's climate has been warming. Global temperatures over both land and ocean surfaces have risen ~0.85°C (1.5°F) since 1880. The U.S. is warming at ~0.72°C (1.3°F) per century.

IS GLOBAL SEA LEVEL RISING?
According to the International Panel on Climate Change (IPCC), the scientific body set up to look into this, in the 20th century global sea level has risen about 1.7 mm/year (0.07 inches). A newer data set with more accurate sea level measurements made from satellites shows that since 1993, global sea level has been rising at a rate of ~ 3 mm/yr (0.12 inches) – nearly double the previous half century. Coastal tide gauge measurements confirm this conclusion.

Global rates are important for assessing overall trends in sea level change. However, climate models predict that sea level will not rise uniformly around the world and satellite data and local tide gauge measurements show that this is true. In some places like in the Chesapeake Bay, rates are up to several times the global mean rise. In other regions, like areas of Alaska, sea level is falling. This variability is in large part due to local circumstances of geology, ice history, temperature, salinity and ocean currents.

WHY IS THE SEA LEVEL RISING?
There are two major causes of global sea level rise: (1) thermal expansion of ocean water and (2) melting of land-based ice. The ocean is absorbing much of the additional heat trapped by greenhouse gasses in our atmosphere. As it warms, ocean water expands, causing sea level to rise. Approximately 50% of the rise in sea level is due to this expansion. At the same time, warmer temperatures across the globe are causing land glaciers and sections of the Greenland and Antarctic Ice Sheets to melt. No longer locked up in ice, this meltwater eventually reaches the oceans and also causes sea level to rise.

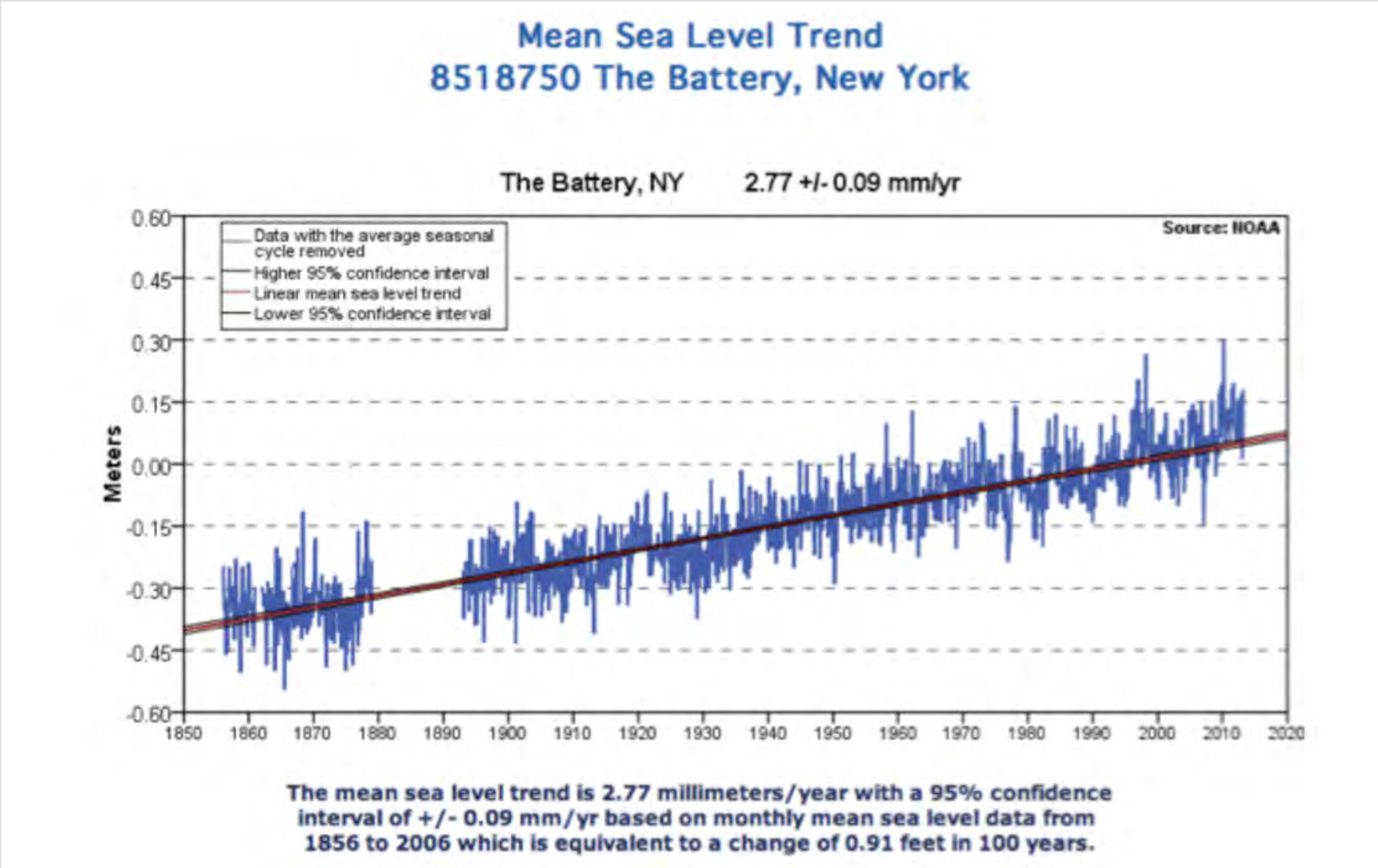
WHAT ABOUT NEW YORK?
A tide gauge at the Battery in New York City measures local or 'relative' sea level, and provides evidence that sea level has risen close to 2.77 mm/year over the last 150 years. For the last 100 years this amounts to a rise of 27.7 cm (~ 11 inches) (see graph on next page).

WHAT DOES THIS MEAN FOR OUR FUTURE?
In 2013 and 2014 reports, the IPCC suggests that sea level rise will continue to accelerate over the next ~100 years. How much sea level rises will depend on how well carbon dioxide emissions are controlled. If emissions are greatly reduced, sea level rise is predicted to be 28-61 cms (11-24 inches). If carbon dioxide emissions are not well controlled, sea level rise may be closer to 52-98 cms (20-39 inches). What will this mean on your local waterfront? Let's get outside and see!

Lamont-Doherty Earth Observatory
Columbia University | Earth Institute

Hudson River Estuary · Sea Grant New York · New York State Water Resources Institute · Cornell University

Student Worksheet New York Explores Sea Level Rise



FIELD ACTIVITY

1. Your class will work in teams of 4-5 students. Each team will make measurements allowing you to make an accurate prediction of what the shoreline will look like as sea level rises. You are going to look at what would happen based on three IPCC projected levels of sea level rise:

a) 28 cm (11 inches) anticipated with aggressive emission reductions
b) 52 cm (20.5 inches) anticipated with reductions at a lesser scale
c) 98 cm (39 inches) anticipated with 'business as usual' – few reductions

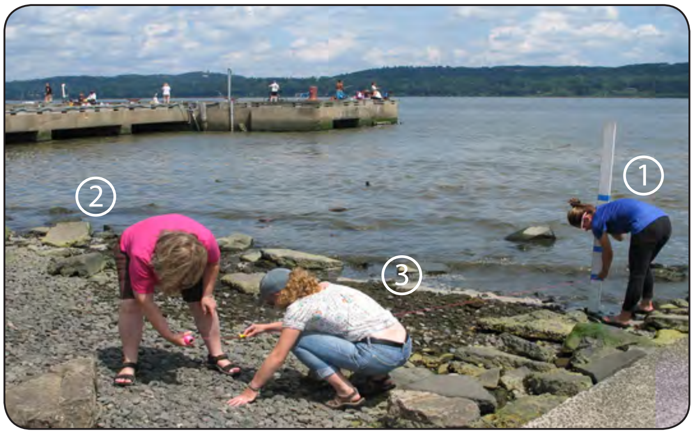
2. Your teacher will give each group a set of field supplies. Once you have these, spread out along the waterfront, not too far apart as you will end by combining your information with the other groups to plot the larger waterfront location.

3. Mark the three different IPCC measures on your pole with the marking tape.

4. Student #1 for each group holds the measuring pole vertically at the water's edge with his/her back to the water (may require water footwear). This is the starting point for your sea level rise transect, which will extend inland from the water's edge.

Student Worksheet New York Explores Sea Level Rise

5. Tie the survey line around the pole where it is marked for 28 cm (11 inches) elevation. Student #2 walks straight away from the water with the survey line, trying to hold it level to where it is tied on the pole.



Student #1 is holding the pole. Student#2 is holding the line. Student#3 is hanging the level.

Student groups are spaced along the shoreline.

6. Student #3 will hang the level on the survey line and direct student #2, helping them to keep the bubble in the line level evenly positioned as the string is extended until it intersects with the shore (in other words, it hits ground). Student #4 marks this location 'A' with a stake or other marker

7. Move the survey line up the pole to the second mark at 52 cm (20.5 inches). Extend the string until it is level and touching the ground. Mark with stake 'B'.

8. Move the survey line up to the third mark on the pole (98 cm or 39 inches). Extend and level the string. Mark where it meets the ground with stake 'C'.

9. Have student #4 use the tape to measure and record on the bottom of the grid sheet how far the water would extend inland from its present edge under each of the three scenarios.

10. Your teacher will select a couple of students to measure and record the distances between Student #1 from each team, starting at one end of the field site and working to the other. They should base their measurements on where Student #1 was standing. These distances will determine where each group's transect is charted on the grid sheet.

11. Enter the information requested at the bottom of your group's grid sheet.

If time allows, all the groups will share their data and plot the results on their grid sheets while in the field, as directed below. If time is short, the class will return and complete this grid in school. Before heading back, take a look at the placement of the markers showing where shorelines will be with higher predicted sea levels. What will these new sea level 'contours' mean for this waterfront and its structures, plants, animals and habitats?

Student Worksheet New York Explores Sea Level Rise

PLOT THE DATA
(May be done at the site or back in the classroom)

Your group should share its data with the others to complete the grid sheets. Each team should have a complete set of all teams' data-points and the measurements of the distances between the transects.

What is the range of each data set? How far inland will the new shorelines be? How far apart are the two outermost transects? Choose suitable scales for each grid axis and label each one with appropriate numbers. On the vertical axis, the scale must extend beyond the greatest distance measured from the existing water's edge to a new shoreline. On the horizontal axis, the scale must cover the distance between the transects at either end of the field site's shoreline.

Locate each transect at its proper point along the X axis and then – above that point – plot the three sea level data points for that transect. Draw a line connecting across all the points 'A', another connecting all points 'B', and a third connecting points 'C'. Use a different color for each line. This will create a diagram of sea level change 'contours'. Add labels for each contour, corresponding to the three scenarios on which they are based and be ready to discuss your chart.

WHAT ABOUT THE TIDES?
In your group explore the following:

1. Where was the tide when your measurements were made? High? Low? Somewhere in between? What is the tidal range in this area? What will happen as the water level changes through the daily tidal cycle?

2. As sea level rises it magnifies the effects of storm surge. During superstorm Sandy, storm surge – the rise in water level as Sandy approached and passed over the area – was added to high tide, resulting in 10-14 foot high storm tides. What might that look like at your site? If sea level continues to rise, future storms won't need to be as severe as Sandy to have the same impacts.

EVALUATION
In 1-2 paragraphs, describe the field activity you conducted with your classmates. Be sure to include:

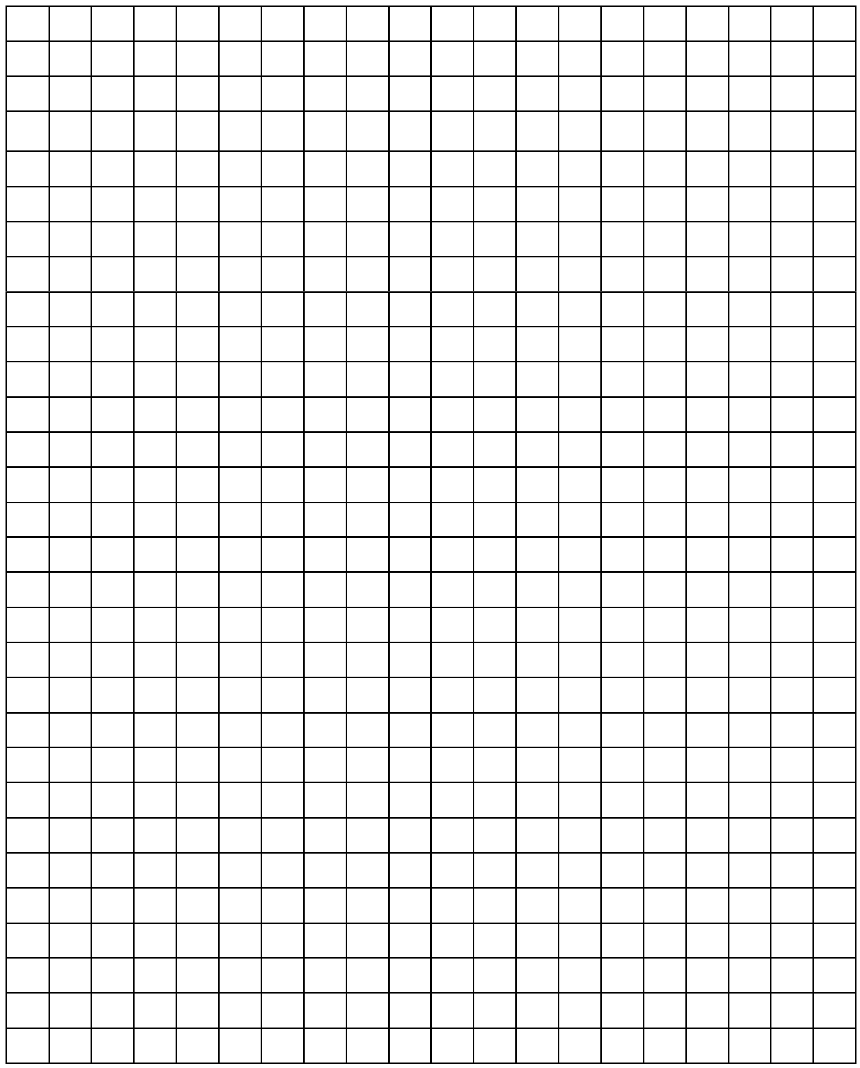
- The reasons for conducting the activity
- The procedures your team followed
- What you learned from the experience and why it is important

Student Worksheet New York Explores Sea Level Rise

Waterfront Profile

Draw 3 different shoreline profiles using 3 colors, one for each of the 3 scenarios (A,B,C).

Distance from the water's edge



Distance between transects

DATE OF DATA COLLECTION______________________ TIME OF COLLECTION___________

LOW TIDE TIME__________ HIGH TIDE TIME_________ TIDAL RANGE FOR AREA_________

TEAM NAME____

FOR YOUR TEAM: Measurement to Point A_________ Point B________ Point C _________

Hudson River Estuary
Climate Change
Lesson Project

www.nyseagrant.org
http://www.dec.ny.gov/lands/

New York State
Water Resources Institute

Cornell University

CARBON THROUGH THE SEASONS

ANNUAL AVERAGE CO_2 CONCENTRATIONS—ANSWER KEY (CONTINUED)

Year	Annual average	Difference from previous year	Direction
1991	355.57	1.22	Increase
1992	356.38	0.82	Increase
1993	357.07	0.69	Increase
1994	358.82	1.76	Increase
1995	360.80	1.97	Increase
1996	362.59	1.79	Increase
1997	363.71	1.12	Increase
1998	366.65	2.95	Increase
1999	368.33	1.67	Increase
2000	369.53	1.20	Increase
2001	371.13	1.61	Increase
2002	373.22	2.08	Increase
2003	375.77	2.56	Increase
2004	377.49	1.72	Increase
2005	379.80	2.31	Increase
2006	381.90	2.10	Increase
2007	383.76	1.86	Increase
2008	385.59	1.82	Increase
2009	387.37	1.79	Increase
2010	389.78	2.40	Increase
2011	391.57	1.79	Increase