Remote Sensing
High School Lesson Plan

Overview

Science and technology have become almost inseparable in recent decades. Advances in scientific understanding lead to new technological applications, which in turn allow even greater understanding in the scientific disciplines.

The following teaching unit on remote sensing explores this relatively new technology, which has spawned a new view of the world – both literally and figuratively. Today, as satellites circle the globe, they convey back to earth an immense array of data. Images of reflectivity of the earth's surfaces are now collected in spectra previously invisible to the human eye. On earth, remotely placed sensors can continuously relay vital information about conditions in various environments. Together these tools are allowing for a better understanding of our earth and a greatly improved ability to predict changes in and on this planet.

Introduction

This unit provides students with opportunities to explore some basic principles of oceanography. It involves a study of the Gulf of Maine using remote sensing data. The concepts addressed are changes in sea surface temperature, winds, and plankton populations. The premise for the exploration is an understanding of the role plankton communities may play in Gulf of Maine productivity and in providing a sink for excess atmospheric carbon dioxide. Hence scientists want to understand more fully the life cycles and population cycles of these microscopic organisms. Students are asked to explore what factors they may want to monitor in order to track when plankton blooms might occur

Time Allotment

This teaching unit requires between five and seven 45-minute class periods.

Accessing Prior Knowledge

Most of the activities in this unit require only good observation skills and the ability to apply critical thinking skills. The final project anticipates that students will have had experience in experimental design. Students will derive more benefit from the activities if they have already had some exposure to such oceanographic concepts such as currents, ocean circulation, and plankton communities.

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Concepts to Clarify

Students often have difficulty understanding that molecules cycle between living and nonliving materials. It may be a challenge for them to accept that microscopic plankton can take up carbon dioxide, then use the carbon to form shells. It may also be difficult for them to comprehend the vast numbers of plankton in a bloom; thus they may not be able to see how these tiny creatures can reduce the amount of carbon dioxide in the atmosphere and slow the impact of global warming.

CONNECTIONS TO THE STANDARDS

National Science Education Standards	Benchmarks for Science Literacy	Maine Learning Results	New Hampshire Curriculum Framework	Vermont Learning Standards
D1. Heating of the earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles	4B. Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans and air.	F.2. Analyze potential effects of changes in the earth's oceans and atmosphere.	4b. Students will demonstrate an increasing ability to understand that the Earth is a complex planet with five interacting systems, which consists of the solid Earth (lithosphere), air (atmosphere), water (hydrosphere), ice (cryosphere), and life (biosphere). – Explain the roles of water and weather in distributing the Sun's heat energy. – Use a variety of weather measurement instruments and recording methods such as barometers, anemometers, and charts. –Demonstrate how living things alter the Earth's atmosphere, lithosphere, and hydrosphere	The Universe, Earth and the Environment – Theories, Systems, and Forces: 7.15. Students demonstrate understanding of the earth and its environment, the solar system, and the universe in terms of the systems that characterize them, the forces that affect and shape them over time, and the theories that currently explain their evolution. This is evident when students: (7.15.ccc) Identify, model, explain, and analyze the interrelated parts and connections between earth systems (e.g., sun, radioactive decay, and gravitational energy; weather and climate)

	3A: Technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.	M 4. Analyze the impacts of various scientific and technological developments.		

Materials Needed

- TV with VCR
- QUEST *Remote Sensing* video
- Overhead or computer projector (optional)
- Computers with Internet access for student use

  Copies of GoMOOS images for each team (for use with Student Handouts 5 and 7)
- One copy per student of each of the following reproducible handouts:
- Student Handout 1: Letter from Dr. James Questions
- Student Handout 2: Questions About Measuring Climate Change
- Student Handout 3: Remote Sensing Video Prompts
- Student Handout 4: Second Letter from Dr. James Questions
- Student Handout 5: Data Analysis Sheet 1
- Student Handout 6: Pulling It All Together
- Student Handout 7: Data Analysis Sheet 2
- Student Handout 8: Quest At Home: Data, Data Everywhere

Extension Activity (per team)

- Four 8-oz plastic cups
- Hot water, ice water, tap water
- Eyedropper
- Food coloring in 4 different colors
- Large beaker
- Small portable lamp
- Small segment of hose for siphoning

1. Introducing the Concepts

Activity 1

This activity helps to set the context for students. They are being requested to assist an oceanographic researcher in his investigation of plankton blooms in the Gulf of Maine.

Step 1

Pose the following question to students: Why do you think scientists are predicting that a population increase of microscopic organisms in the ocean could slow the global warming process? Accept all answers, then tell students that the activity they are about to do will help them answer this question more fully.

Step 2

Form research teams of three students each. Distribute copies of Student Handout 1 (the letter from Dr. Questions). Have students read the letter and discuss the "challenge" in their teams.

Step 3

Distribute copies of Student Handout 2 (Questions About Measuring Climate Change). Have students complete the handout individually, discussing their answers with team members only after they have finished. Finally, with the entire class, brainstorm a list of common types of tools that can be used to measure changes in weather, forests, and oceans.

Brainstorming possibilities include the following: **Weather change measurement tools** – for cloud cover: radar; for temperature: thermometer; for barometric pressure: barometer; for wind speed and direction: anemometer. **Forest change measurement tools** – for sunlight/shade: photometer; for reflectance in various wavelengths: radiometer; for air temperature: thermometer; for soil temperature and moisture: soil thermometer. **Ocean change measurement tools** – for currents: current meter; for water temperature: thermometer; for air temperature: thermometer; for wind speed and direction: anemometer, radar; for reflectance in various wavelengths: radiometer; for wave height and direction: radar.

Step 4

Distribute copies of Student Handout 3 (Remote Sending Video Prompts). Tell students that they will be completing these handouts while they view a video on remote sensing. To help students gather their information most effectively, consider one or more of the following suggestions: (1) Teams can distribute the workload by assigning certain handout questions to individual team members to take notes on during the video. (2) While viewing the video, you can stop the tape periodically to allow students to write notes. (3) You can view the entire video without having students take notes, then replay it a second time for note taking.

Step 5

Watch the *QUEST Remote Sensing* video. When the tape is done, replay any sections that students need to see again for note taking or for better comprehension.

Step 6

Direct team members to share amongst themselves what they have learned from the video in response to their questions. By the end of the discussion, each team member should have a complete set of responses to all of the questions on Student Handout 3. Then, as a whole class, review all responses to the handout questions; clarify as needed.

Answers to Student Handout 3:

1. Remote sensing is the use of any instrument that detects a quantity without having to remove that quantity from its environment.
2. The use of satellites has given us a new perspective of the earth. We can now see it as one large interacting system with many subsystems. This has led to the establishment of earth systems science, which explores how these subsystems interact.
3. These technologies include: expanded computing power and speed, digital sensors, sensors for all wavelengths in the electromagnetic spectrum, rocketry, cellular phones, new fabrication materials with higher endurance and greater sensitivity, modeling capability and programming on computers, etc.
4. Types of data collected include ocean currents, temperature, color – reflectivity in all wavelengths, salinity, chlorophyll.
5. Phytoplankton can act as biological pumps removing carbon dioxide from the atmosphere through photosynthesis. This slows the rate of greenhouse gas buildup. Some phytoplankton (coccolithophores) can use carbon to form platelets, which will eventually fall to the ocean bottom when the organisms die. In this manner, the carbon is stored in an inactive form.
6. A bloom is what happens when phytoplankton multiply rapidly. It is thought that there are more coccolithophore blooms today because of the increased amount of carbon in the atmosphere and oceans.

Step 7

To your original brainstormed list, add any additional tools for measurement mentioned in the video. Have students identify which of these are remote sensing tools. Prompt them to identify what technological advances were necessary in order for remote sensing tools to be developed.

Acceptable answers include:

Rocketry made satellites possible; computers made modeling possible; sensors and other materials made reflectivity in broad wavelengths possible; portable computers, telecommunications, and cellular technology made remote data logging possible; noncorrosive materials made in situ sensors possible; software made Geographic Information Systems possible; the Internet made shared data possible.

2. Exploring the Concepts

The following activities allow students to explore remote sensing data gathered from the Gulf of Maine. By comparing measurements of a given parameter taken on different dates, students can see how various components of the Gulf of Maine environment change over time. By responding to questions about the data, they can begin to find relationships between the parameters. Students can begin to ask questions, predict relationships, and see if the data verify their thinking

Activity 2

Step 1

Distribute copies of Student Handout 4 (the second letter from Dr. Questions of the Northern New England Global Study Center) and Student Handout 5 (Data Analysis Sheet). Review both handouts with students, clarifying as needed.

Step 2

To complete this activity, you will either need to provide students with copies of the images referred to, or, if possible, have them view the images at the GoMOOS Web site. Directions for locating and downloading the images are as follows:

To view or download the images for sea surface temperature, go to:
http://www.gomoos.org/buoy/satellite.php. Under the heading "GoMOOS displays three kinds of satellite information," select Sea Surface Temperature. A new browser window will appear, AVHRR will appear in the bar, along with drop-down boxes for selecting the desired location, year, and month of the image. Select Gulf of Maine for location, 2001 for year, and March for month. Then click Submit. Multiple images for every day in March will appear. Scroll down to March 17 n12.0176.2130.gif. Download the file to view later. Click the Back button on your browser. Now select Gulf of Maine, 2001, April. Scroll down to April 28, n14.01118.1002.gif, and download the image.

Hint: It is helpful to have a blank document open in a word-processing program while you are downloading the GoMOOS image. When the image is displayed on the GoMOOS Web site, click the right button on your mouse. A menu will appear; select Copy. Then go to the word-processing document and, from the Edit menu, select Paste. When you have downloaded both sea surface temperature images, close that browser window and return to the GoMOOS Web site browser window. If possible, make an overhead of the images so that everyone can look at them together.

Note: While you are at the GoMOOS Web site, you may also want to download the images for the GoMOOS moored buoy map, as well as the sea winds and ocean color images, for use later in this activity.

Step 3

Begin by exploring the data on sea surface temperature with the class. Review the first two questions on

Student Handout 5 to make sure that students understand what the colors represent and what the black areas represents. (This is explained in Dr. Questions' second letter.) Be sure that all students understand what the colors and black areas represent for every set of images they proceed to analyze.

With the whole class, look at the first NOAA image representing sea surface temperature in March. At the same time, have students looking at the GoMOOS moored buoy map.

To download the GoMOOS moored buoy map, go to:

http://gyre.umeoce.maine.edu/GoMoos/gommrg.phtml

Download the image by right-clicking on it.

The moored buoys collect a wide array of data that are beamed back to a database via a cell phone and made available over the Web (yet another type of remote transmitting device, which should be added to the list of measurement tools and techniques done in Activity 1). At the surface, the buoys record air temperature, wind speed and direction, and visibility. In the water, the buoys record water temperature, salinity, dissolved oxygen, wave heights, and current speed and direction. The measurements of currents, salinity, water temperature, and dissolved oxygen are made throughout the water column, sometimes as deep as 240 meters. Additionally, there are four buoys that measure the amount of sunlight that reaches the water and chlorophyll-a content from phytoplankton (microscopic plants). The buoy data serve two functions: (1) to verify (or "ground-truth") the information being collected from the satellites, and (2) to provide more detailed information about conditions under the surface of the sea.

Step 4

Using the moored buoy maps, students should compare points of longitude and latitude to help them identify geographic features such as Cape Cod, Casco Bay/Portland, Penobscot Bay and Bar Harbor, the Bay of Fundy and Nova Scotia, etc., on the sea surface temperature image. Then, on Student Handout 5, student teams should complete the first half of the sea surface temperature chart (for one month). Discuss their responses as a class before having them proceed to the second half of the chart (the next month), followed by the Summary Questions.

When everyone has finished, discuss the teams' responses.

Note: The sea surface images are from the National Oceanic and Atmospheric Administration's (NOAA's) Advanced Very High Resolution Radiometer (AVHRR). This device scans the visible, near infrared, and infrared electromagnetic spectrum as it travels around the globe. The satellite orbits the planet 14 times a day at 833 km above the surface of the earth. If possible, allow the students to view the satellite data on the GoMOOS site (http://www.gomoos.org). The buoy data are also available from that site. Information on the site is in real time, meaning that it is always the latest information for that day.

Step 5

In the sea surface temperature chart on Student Handout 5, there is a category called Water Movement. Discuss what information students used to formulate their answers (or guesses) for this category.

Step 6

Now tell students that they will be moving on to the section on the handout labeled Wind. Tell them that another remote sensing device is NASA's SeaWinds instrument, located on board the QuikSCAT satellite. Using this tool, scientists can determine wind speed and direction. Show the class the corresponding wind map for each of the sea surface temperature days. (If you are unable to provide each team with a color copy of the maps, share them via an overhead.) Ask student teams whether their predictions about water movement were right. If students have made wrong guesses, probe why they think they might have done so.

Note: At this point, you may want to inform the class that SeaWinds is a specially designed spaceborne radar instrument called a scatterometer. The radar operates at a microwave frequency that penetrates clouds. This, coupled with the satellite's polar orbit, makes the wind systems over all of the world's oceans visible to SeaWinds on a daily basis. The measurements provide detailed information about ocean winds, waves, currents, polar ice features, and other phenomena. This information benefits meteorologists, climatologists, oceanographers, and mariners.

SeaWinds was launched on June 19, 1999. Engineers and scientists have successfully calibrated the satellite and verified the accuracy of its data over the past few months. To learn more about this device, students can visit *http://www.earth.nasa.gov/education/edreports/eseedfeb00.html*

To view or download the SeaWinds images, go to: *http://www.gomoos.org/buoy/satellite.php*
Under the heading "GoMOOS displays three kinds of satellite information," select Winds. Another browser window will open with SeaWinds in the bar, as well as drop-down menus for the year and month. Select 2001 and March. Scroll down the images to March 31, 2001 des2001_090.jpeg and download the image. Return to the top, and select April 2001. Scroll down to April 28m 2001 des2001_118.jpeg and download that image as well.

Optional Extension Activity

If your students are not familiar with convection currents in water, you may want to do the following extension activity.

Step 1

Give each team of students four 8-ounce clear plastic cups. Instruct teams to fill one cup with hot water, one with ice water, and two with room-temperature water. Next, they should place a drop or two of differently colored food coloring in each of the four cups.

Step 2

Each team should fill an eyedropper with cold water. Immersing the eyedropper into the bottom of each cup, they should gently squeeze out a few drops and observe what happens for a few minutes. They should then gently place a drop of colored ice water onto the surface water of one of the cups of room-temperature water. Again, teams should note what happens. Have teams draw the results of each of this test.

Step 3

Now each team should empty the eyedropper back into the ice-water cup and rinse the eyedropper with clean water. Next, they should fill the eyedropper with hot water. Immersing the eyedropper into the bottom of the second room-temperature cup, they should gently squeeze out a few drops of hot water and watch what happens. Now they should gently place a few drops of hot water on the surface water of the second room-temperature cup. Have teams observe and draw a picture of each step in this test.

Step 4

Teams should now place a few drops of the hot water on the surface of the cup holding the cold water. Next, they should immerse their eyedroppers into the bottom of the cold-water cup and squeeze out a few more drops. Have them observe what happens.

Ask: What do you think will happen if you place cold water in the bottom and on the top of the cup holding the hot water? Students should back up their suggestions with proof from their recent observations.

Step 5

Discuss as a class how these experiments could relate to the Gulf of Maine. Have students consider the following questions:

- What would happen if there was a heavy rain washing down the rivers into the Gulf of Maine?
- Where would the water go?
- Would this vary by the season?
- What would happen if a strong surface wind pushed all of the warm water off the Gulf? Would it depend on where the wind occurred?

Step 6

Have teams work together to decide how they could make a stratified colored water column – cold blue water on the bottom and warm red water on the top – in a large beaker. Their models should be designed to reproduce the effects on the water of a sunny day. Suggest to students that they place a lamp over the beaker to mimic a warming sun. To model the wind blowing the top water offshore, show them how to slowly siphon water off the top on one side.

Have teams demonstrate these effects with their models, observing what happens. Ask: Can you model an upwelling if you control the rate at which you withdraw the surface water? Discuss all responses.

3. Developing the Concepts

In performing this activity, students will develop a deeper understanding of how data that are collected by scientists through remote sensing can be used to increase our understanding of the systems of the natural world.

Activity 3

Step 1

The following articles, all available on the Internet, should be assigned to student teams for reading homework. Each student can select one of the articles to read so that the workload is distributed.

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Herring, David, "What is phytoplankton?"
http://earthobservatory.nasa.gov/cgi-bin/texis/webinator/printall?/Library/Phytoplankton/index.html

Herring, David, "How do phytoplankton influence global change?"
http://earthobservatory.nasa.gov/Library/Phytoplankton/phytoplankton2.html

Sage, Sandy, *Research Bulletin*, Bigelow Laboratory for Ocean Sciences
http://www.bigelow.org/bulletin_jul02.html

Step 2

Teams should gather during the next class to report the results of their reading. Distribute Student Handout 6 (Pulling It All Together). Have teams read and discuss these questions together, then write their responses.

Answers to Student Handout 6:

1. Coccolithophores, like all phytoplankton, are photosynthesizers. Thus they take in carbon dioxide and release oxygen. In addition, however, they remove carbon from the carbon cycle by storing it. Coccolithophores take carbon dioxide from the surface waters, which in turn draw carbon dioxide from the atmosphere. They use the carbon atoms to make calcium carbonate plates as shells. Periodically, coccolithophores shed their shells, or, when they die, their plates fall to the ocean floor. This causes the carbon to remain inert until tectonic plate movement exposes the carbon again to the atmosphere.
The more blooms there are, the more carbon dioxide that is removed from the atmosphere. Since carbon dioxide is a greenhouse gas, it causes global warming by trapping heat in the atmosphere. If the amount of carbon dioxide that is removed increases the rate of atmospheric warming will decrease.
2. It is being theorizsed that the more blooms there are, the more carbon dioxide can be removed from the atmosphere. Since carbon dioxide is a greenhouse gas, it causes global warming by trapping heat in the atmosphere. If the amount of carbon dioxide that is removed increases, then the rate of atmospheric warming may decrease. (This assumes that the release of carbon dioxide into the atmosphere remains the same.)
3. Physical, biological and chemical conditions were all favorable. To determine the physical conditions, scientists could have measured waves, currents, and temperature; to determine the biological conditions, they could have measured the life cycle of species and specific conditions for the reproductive process; to determine the chemical conditions, they could have measured salinity and nutrients.

Activity 4

The third set of images that students are now ready to review involve ocean color. Scientists have been able to correlate ocean color with phytoplankton abundance. In particular, plankton blooms can be located using this kind of information. The plankton cause an increase in the scattering of light waves, changing the color of the water to a lighter blue. Since plankton are the base of the oceanic food web, an increase in plankton populations typically indicates higher ocean productivity.

The ocean color images are produced by SeaWiFS. A scanner that receives eight channels produces the SeaWiFs imagery. Each channel measures just one specified wavelength of the electromagnetic spectrum. The satellite carrying the Sea WiFS instrument flies at 705km above the earth.

Step 1

Distribute copies of Student Handout 7 (Data Analysis Sheet 2). Review the sheet with students.

Step 2

To download or view the ocean color images, go to: *http://www.gomoos.org/buoy/satellite.php*
Under "GoMOOS displays three kinds of satellite information," select Ocean Color. A separate browser window will open; SeaWiFS will appear in the bar, along with drop-down menus for location, year, and composite type. Select Gulf of Maine, 2001, and month. Select March – seawifs2001marchGOM. Download the image. Repeat for April – seawifs2001AprilGOM.

Step 3

Have students review the ocean color images in the same way they looked at the sea surface temperature images. Then have them complete the chart on Student Handout 7 and answer the Summary Questions. When everyone has finished, discuss student responses to the questions.

Step 4

To close this activity, lead a whole-class discussion about the limitations of the data set that Dr. Questions sent. (Examples of such limitations might include the following: the data represent only one year, this is only a "snapshot" of an occurrence, we do not know what type of phytoplankton caused the change in color image, etc.)

4. Applying the Concepts

Students will now see how all three sets of the data they have reviewed relate to one another. They can make a conjecture about this interrelationship and determine the types of data needed to follow up on their ideas.

Activity 5

Step 1

Have student teams review all three sets of images for both March and April. Ask them to think about possible relationships among the three sets of data for each month. Can students find a relationship between temperature and plankton population? Between temperature and wind, and so on?

Students can begin by looking at the one day portrayed in March. Have them describe what they can determine from the images. Examples include the following:

- The images show a strong wind out of the north swinging to the northwest.
- There was a large area of very cold water in the southeastern end of the Gulf.
- There was little phytoplankton, except over Georges Banks in the southeast corner of the Gulf.

Repeat the process for April. Observations include the following:

- Winds were light in the Gulf itself, but strong out of the Gulf to the south.
- Waters were coldest in the northeast and warmest in the southwest.
- There were intense plankton blooms in the north and northeast, and over the Georges Banks area; some populations extended into the Atlantic.

After considering these facts, student teams might be led to conclude the following possible interrelationships:

- Strong winds from the north pushed surface waters out of the Gulf and allowed for an upwelling of nutrient-rich, cold bottom waters.
- Plankton blooms seems to occur in areas with colder waters.
- Plankton are surface water floaters which drift with the winds.

Note: Be sure to Emphasize with students that relationships such as these cannot be established with just one set of data. To establish that a relationship excists, many years of data would need to be exhamined, collected, and statixtically analyzed.

Step 2

Have individual teams come up with a hypothesis about a relationship. Going over what they know about remote sensing, and by reviewing their list of measurement tools, each team should also design a monitoring plan to test their hypothesis. They should be sure to consider the following factors as they draw up their plans:

- What measurements would they take? How might they take them?
- How might they ground-truth the information?
- How often would they take the measurements?

Step 3

Ask each team to present their relationship findings supported by data. Their presentation should also include their hypothesis as well as their monitoring design for the next year. Presentations should be no longer than 10 minutes. Teams should include visuals in their presentation; they should also include pertinent data and a data-collection strategy. Other students should be encouraged to ask questions for clarification. All team members should be prepared to respond to questions from their classmates.

Proficiency Guidelines

General Requirements

Student teams should present a theory on the interrelationship among temperature, wind, and productivity based on their understanding of factors that influence plankton populations. If they are uncertain about any component of their theory, they should be encouraged to do research within time constraints that are determined by you.

All theories should be substantiated with evidence from the data sets. Their suggestions for further research should include the possibility of overcoming the constraint of the momentary "snapshot" by expanding the number of samplings done through remote sensing.

Components

Each presentation will include three components: (1) a written one-page summary that can serve as a handout, (2) a visual and/or model, and (3) an oral presentation that incorporates the other two components.

- *One-Page Written Summary*: This component should clearly explain the team's idea. The one-page handout should include bulleted supportive reasoning. The handout should be easily understood and should avoid overly technical language, but it should present a sound understanding of population dynamics. The physical appearance of the handout should not be too dense with text, nor should it look as if the font and spacing have been greatly enlarged simply to fill space. It can include a minor visual for emphasis, but it must not repeat the material included in the visual presentation (see below) unless it is to convey an identity for the team.

- *Visual & Model:* This second component should be completely germane to the team's overall theory. It should be a visual representation of data that clarifies and enriches the group's written and oral presentation of the facts. All parts of the model/visual should be well labeled. Limited text may be used, but it should not be redundant of any information included in the handout.

- *Oral Presentation:* This third component should present the team's theory in a way that enhances the bulleted information in the handout and ties it to the visual representation of the data. The presenter should not read from either source but should refer to both. Facts should be presented and the theory explained with a clear understanding of the audience, who are most likely interested in the topic but do not have prior knowledge in this area. The use of analogies, or additional demonstrations, can be seen as going above and beyond basic proficiency.

Note: Each team member is responsible for one of these components and will be assessed on that component.

Assessment
The class should help you establish criteria for the assessment. A clear description of proficient work for each component should be readily available to every student.

Execution
It is best to have this project done in class with materials supplied by the school. This will assure that each student is actually doing the work and that they all have equal access to resources.

Students should demonstrate good teamwork skills. The individual component of the presentation for which each team member is responsible should also be rated based on how well that particular team member related to the others.

As a whole team, moreover, they should present one coherent theory and a well-supported argument. The three individual components should complement each other to form a persuasive argument.

Step 4
Have each student respond individually to the following prompt:

"Select one type of measurement your team has proposed to take. Explain how the technology for collecting this data has changed, and what the benefit of this new technology is for scientists."

Proficiency Guidelines
Assessment standards for this task should be reviewed and determined by the class, with input from you. Some possible aspects of the task that may be measured are:

1. **Terminology** – Each student should use appropriate terminology to identify the instrument, the parameters it measures, and the units the measurements are taken in.

2. **Research Design** – Each student should be able to identify that remote sensing enables more data to be collected on a schedule. This allows scientists to measure the variations in the system more frequently and more regularly. Through the use of statistics, scientists can determine a more refined description of the system, its interactions, and its variability.

5. Extending the Concepts

Activity 6

This take-home activity encourages students to link their classroom learning to the nonacademic world and to share their knowledge with family members. It also helps them see how many real-world applications there are for remote sensing.

Step 1
Distribute copies of Student Handout 8 Quest At Home: Data, Data Everywhere. Review the handout with the class, clarifying where needed. Set a deadline for students to return to class with the findings from their community research.

Step 2
On the appointed day, have students come to class with their findings and share them with their peers.

Career Opportunities
The world of remote sensing offers a wide array of possible careers. Remote sensing is used in almost every field of natural science: hydrology, forestry, oceanography, geology, etc. There are also opportunities in the development and launching of the satellites that carry remote-sensing technology into space. In addition, there is a sizable field of data processing, as all of the information returned from the satellites as raw data must be processed to develop the images. In addition, many of these images are then converted into files for use with Geographic Information Systems, where many layers of data can be displayed simultaneously and queries made to identify relationships in the data.

Community Connections
Many state offices and universities participate in GIS (Geographic Information Systems) Day each November. State offices that use GIS data provide tours of their facilities. Contact your state's GIS office for details:

Maine Office of GIS: apollo.ogis.state.me.us
New Hampshire GRANIT: *http://www.granit.sr.unh.edu*
Vermont Geographic Information System: *http://www.vcgi.org*

Resources

Advanced Very High Resolution Radiometer (AVHRR): Overview
http://www.ngdc.noaa.gov/seg/globsys/avhrr.shtml

About the Gulf of Maine
http://www.gulfofmaine.org/watershed/index.html

The Gulf of Maine
http://www.at-sea.org/missions/maineevent3/maine.html

Earth Observatory
http://earthobservatory.nasa.gov/masthead.html

Gulf of Maine Ocean Observing System
www.gomoos.org

The Satellite Oceanography Data Laboratory at the University of Maine
http://wavy.umeoce.maine.edu

Bigelow Laboratory for Ocean Sciences
www.bigelow.org

Satellite Oceanography Data Lab
http://wavy.umeoce.maine.edu

Student Handout 1

INVESTIGATING OUR WORLD

Dear Students,

Some of my graduate students and I are working on a research project, the Northern New England Global Study. We are concerned about the changes occurring in the climate. We have heard of scientists predicting that microscopic organisms in the Gulf of Maine could absorb some of the excess carbon dioxide in the atmosphere. This may be why global warming is not occurring at a faster rate. I have suggested to your teacher that you might read an article by one of the Maine research teams. They are examining the populations of the coccolithophores in the Gulf of Maine. Coccolothophores use carbon dioxide from the atmosphere to make calcium carbonate shells. For more information on coccolithophores, you can visit the Earth Observatory web site at:
http://earthobservatory.nasa.gov:81/Library/Coccolithophores/coccolith_1.html

My students and I are following potential changes in the Gulf of Maine across all plankton species. Our primary interest is observing phytoplankton populations and trying to determine the factors that trigger their annual blooms. Phytoplankton are the "producers" of the ocean. Since they form the base of the oceanic food web, the productivity of the Gulf of Maine depends on their populations. The most prominent blooms of phytoplankton are in the spring, usually between March and May.

To begin our study we are examining historic data for the Gulf of Maine region. A wonderful Web site at www.gomoos.org,, called The Gulf of Maine Ocean Observing System (GoMOOS), contains a wide variety of data. There are a number of remote sensing images taken by NASA and NOAA satellites that are posted there daily. Sensors in space capture the light being reflected off the planet. Measurements are taken across the full electromagnetic spectrum, including the portions that are invisible to the human eye. These data are processed and made into images we can use to compare locations and conditions on earth day after day. These are wonderful tools for examining change in ecosystems.

As you know, the sunlight falling on earth warms the atmosphere and ocean. Warm air and water are lighter than cold air and water. Thus, they move upward -- toward the upper atmosphere or toward the water's surface. This movement causes winds and currents. Water and winds, along with sunlight and nutrients, interact and form an environment in which the phytoplankton live. It is in understanding the influences of these wind/water interactions that we want your help.

Our challenge is to analyze all of these data. I have asked your teacher if you could examine some of the data we have been studying to see if you can see any relationships that we have missed. Your teacher, thankfully, has agreed to let you participate.

Due to time constraints, you will only be examining two months' worth of data. In our study, however, we are looking at all of the pertinent data ever collected in this area. Some information is 100 years old! We are compiling the data in an effort to identify patterns and trends in the climate of the Gulf of Maine.

We look forward to working with you. Thank you for your help!

Sincerely,

Dr. James Questions
Northern New England Global Study

Questions About Measuring Climate Change

1. What do you think Dr. Questions means when he speaks about "global change"?

2. The Gulf of Maine is a "sea within a sea" – it is the body of water that lies off the coast of Maine, New Brunswick, Nova Scotia, New Hampshire, and Massachusetts. If you were to study how this body of water was changing over the past 100 years what might you measure to see if it had changed?

3. Plankton are microscopic organisms that float in the oceans. Phytoplankton are the photosynthesizing plants that are the base of the oceanic food web. Like plants on earth, they use energy from the sun to make their own food. Through the process of photosynthesis, they take in carbon dioxide, water, and the sun's energy to produce simple sugars and release oxygen.

Phytoplankton are food for zooplankton (microscopic animals), which in turn are eaten by small fish, which in turn are eaten by larger fish, and so on. However, some large mammals, such as baleen whales, feed entirely on plankton because it is so abundant. A teaspoon of ocean water may hold as many as a million photoplankton.

As in terrestrial food webs, a healthy population of producers is necessary for a healthy population of aquatic consumers. Based on what you know about food webs on land, and what plants on land need for growth, what would you suppose would be important factors for the growth of phytoplankton?

4. There are many types of data that we see regularly that have been gathered via remote sensing. Think about weather reports, ski reports, or mariners' reports.

5. What kinds of measurements are taken remotely? (For example, which types of measurements might a satellite take?) List the types of remote sensing data that you think are gathered on a regular basis. Also list the instruments that take these measurements.

Remote Sensing Video Prompts

1. What is remote sensing?

2. How has our view of the world changed with advances in remote sensing?
   How has the development of remote sensing led to the study of earth systems science?

3. What technologies have allowed remote sensing capabilities to advance?

4. What types of data are collected about the ocean?

5. Why should we be studying the oceans when we are studying climate change?

6. What is a plankton bloom? How might they be connected to global change?

Student Handout 4

INVESTIGATING OUR WORLD

Hello, Students,

Enclosed with this letter I have sent your teacher directions for accessing and viewing the data that my graduate students and I have been examining. We focused on March and April because these are traditionally the months for the first spring plankton blooms.

The first set of images displays the temperature of the surface waters in the Gulf of Maine for one day in March and one day in April. Since the satellite cannot collect any data on cloudy days, you will sometimes see black in an image. This is an indication of where cloud cover was on that day. I have tried to include files with as full an image as possible. Colors range from purple, which is 0 0C, to orange, which is 240 C.

The second set of images shows wind direction and speed for the same two days in March and April. These were also collected with a sensor on a satellite. Again, black areas indicate times of cloud cover that day. Wind speed goes from 0 knots, which is blue, to 20 knots, which is red.

The third set of data show ocean color. We have compiled all of the daily images into one composite for each month. Color indicates the concentration of chlorophyll (a pigment found in all phytoplankton); the color ranges from purple, for .1 mg/m, to dark red, for 10 mg/m.

I have also included a map of the GoMOOS moored buoy locations. On this map you may find some familiar coastal landmarks. The GoMOOS Web site contains data from these buoys if you are interested in seeing more data from a particular site or date. These buoys measure and collect:

- Wind gust
- Wind speed
- Wind direction
- Visibility
- Air temperature
- Wave height
- Current direction 2m
- Current speed 2m
- Water temperature 1m
- Water temperature 2m
- Water temperature 20m
- Salinity 1m
- Salinity 20m

In my last letter, I also mentioned a team of Maine researchers who were examining a particular species of phytoplankton that blooms later in the summer: the coccolithophore. These are the species that can utilize excess carbon dioxide from the atmosphere to make calcium carbonate shells. You will see in one of the articles I am sending along that the researchers found a very large bloom in August 2002 using yet another type of NASA remote sensing satellite imagery – the Terra MODIS. Here is the Web site for MODIS: *http://modis.gsfc.nasa.gov*
Another site where you can view a global image of calcite concentrations, which would be an indicator of coccolithophores, is:
ftp://modis.gsfc.nasa.gov/pub/Data_Sets/CDROM/OCEAN/JPEGcolor/MO36MM22.calcite_conc.ADD2000336.003.2001310174639.Q0-0.jpg

Hope you enjoy reviewing these images. Once you are done, we would like to hear your ideas on the relationships you feel might exist among the various measurements.

Looking forward to hearing from you,

Dr. James Questions
Northern New England Global Study

Data Analysis Sheet 1

A. Sea Surface Temperature

1. What do the black areas on the image represent?

2. What do the colors on the image represent?

Month	Predominant Color/Temp	Highest Temp/Location	Lowest Temp/Location	Water Movement	Comments

Summary Questions

1. What did you find that surprised you?

2. What could you conclude about waters to the south of the Gulf of Maine?

3. What could you conclude about waters to the north of the Gulf of Maine?

B. Wind

1. What do the black areas on the image represent?

2. What do the colors and arrows on the image represent?

Month	Predominant Color/Temp	Highest Temp/Location	Lowest Temp/Location	Water Movement	Comments

Summary Questions

1. What did you find that surprised you?

2. Can you make any guess about circulation in the Gulf of Maine?

Pulling It All Together

1. What about the coccolithophore makes it a likely carbon sink – a reservoir in the environment in which extra carbon might be stored?

2. Why would it be beneficial for the Gulf of Maine to have many plankton blooms of coccolithophores?

3. What type of conditions were favorable to allow the plankton bloom observed by the Bigelow scientists? Name some specific measurements that could have been taken to determine whether those conditions existed.

Data Analysis Sheet 2

Ocean Color

1. What do the black areas on the image represent?

2. What do the colors on the image represent?

Month	Predominant Color/Richness	Highest Richness/Location	Lowest Richness/Location	Comments

Summary Questions

1. What did you find that surprised you?

Data, Data Everywhere --

You're on a QUEST!

There are many organizations collecting data near you at this very moment. Many stores collect data regularly through remote cameras. Ski mountains collect temperature readings to product the best snow. Highway departments will often collect traffic data with counters on the pavement. This activity will help you identify areas in your community where collecting data is essential to our very lives!

Materials needed

- Computer with Internet access
- Pen and paper for notes
- Local map showing mountains, foothills, roads and highways(optional)

Investigate with your family!

■ What technology does your family use on a daily basis? How does your family collect data (e.g., via phone, computer, newspaper, etc.)? What other types of information might your family rely on to live on a daily basis?

Many state offices use Geographic Information Systems (GIS). Here is a list of helpful GIS Web sites:

Maine Office of GIS: *http://apollo.ogis.state.me.us/*
New Hampshire GRANIT: *http://www.granit.sr.unh.edu*
Vermont Geographic Information System: *http://www.vcgi.org*

Walk or take a drive with your family through your neighborhood or town. Try to identify the number of ways in which people are collecting data remotely.

Organization/Business	Type of Data Gathered	Measurement Tool

If there were a natural disaster in your area, what might emergency planners need to evaluate the conditions in your neighborhood or town? Consider the type of roads (gravel or paved) number of fire stations and emergency vehicles, and the distance it takes for emergency vehicles to get to your area. Interview city planners and emergency planners in your town to get their perspective on the information they would need to assist in such an emergency.

Make notes of what you find:

Electronic Quest!

You'll find a load of information from these sites on remote sensing and collecting data to protect our environment, track our weather, natural resources data, and read an article about a project in Burgundy, France that applies remote sensing to an archeological research!

U.S. Department of the Interior, U.S. Geographic Information Systems
http://info.er.usgs.gov/research/gis/title.html

GIS Resources on the Web
http://www.gsd.harvard.edu/~pbcote/GIS/web_resources.html

NASA Jet Propulsion Laboratory
http://southport.jpl.nasa.gov/

GIS and Remote Sensing for Archeology: Burgundy, France
http://www.informatics.org/france/france.html

Maine Mathematics and Science Alliance

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Maine Forest Products Council · Irving Woodlands, LLC