Santa Cruz-Watsonville Inquiry-Based Learning in Environmental Sciences

An NSF GK-12 Program at UC Santa Cruz

http://scwibles.ucsc.edu

Environmental Science From Space

Remote sensing and the electromagnetic spectrum

Overview

Students learn what remote sensing is, how it works, and how scientists use it, with a focus on Landsat satellite and imagery. Students create and then interpret a remote sensing image of a planet and remote sensing imagery available on the Internet. Students review the structure of a wave; solve problems using speed, wavelength, and frequency; and discuss the uses of each type of radiation in the electromagnetic spectrum. Finally, students examine and analyze a remote sensing image of a rain forest. By the end of the module students should be able to: 1. Define remote sensing and describe its purposes; 2. Label the structure of a wave and solve problems involving frequency, wavelength, and speed; 3. Recite the order and describe the 7 types of radiation of the electromagnetic spectrum; and 4. Explain why remote sensing is an efficient way to study Earth and other planets.

Concepts

Remote Sensing, Mapping, Satellites, Electromagnetic Radiation, Wavelength, Frequency, Electromagnetic Spectrum

Skills

Interpreting Remote Sensing Imagery, Calculating Wave Frequency & Wavelength

Module Type

Interactive lectures with two short activities

Duration

2 hr 20 min (may be split into multiple days as necessary)

Key Materials

- Whiteboard/Chalkboard
- Projector
- Computers w/ PowerPoint and Java plug-in
- Colored pencils

Authors

Kristin McCully, PhD Candidate, Ecology and Evolutionary Biology UC Santa Cruz

Jack Horner, Integrated Science and Biology Teacher, Watsonville High School

Science Education Standards

National: Physics; Earth & Space Sciences; Life Sciences; Science & Technology; Science as Inquiry

California: Physics 4. Waves; Earth Sciences; Investigation and Experimentation

Next Gen Science Standards: Core Ideas PS4 (Waves and Their Applications in Technologies for Information Transfer) and ESS2.D Weather and Climate; Practices 2 (Developing and using models) and 4 (Analyzing and interpreting data)

Field Tested

9th grade Integrated Science, Watsonville High School, Watsonville, CA (Spring 2012)

Navigate: Background Materials &Time Starting Point Procedures Standards Supplemental

Background for Teachers

Remote Sensing

According to the Canada Center for Remote Sensing (2012), "remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." More simply, remote sensing is “learning about objects without touching them, usually using satellites and airplanes.”

Scientists use remote sensing images in many different ways to learn about our environment (USGS 2011):

- Geographers look for changes on the Earth’s surface that need to be mapped.
- Foresters gather information about what type of trees are growing and if they have been affected by disease, fire, or pollution.
- Environmental scientists detect, identify, and follow the movement of pollutants such as oil slicks on the ocean.
- Geologists seek areas that have valuable minerals.
- Farmers monitor how crops are growing and if they have been affected by drought, floods, disease, or pests.
- Ship captains plot the best route through polar ice packs.
- Firefighters send out crews based on information about the size and movement of a forest fire.

Remote sensing uses satellites or airplanes to sense reflected or emitted radiation (any band of the electromagnetic spectrum) and scientists or technicians analyze that data.

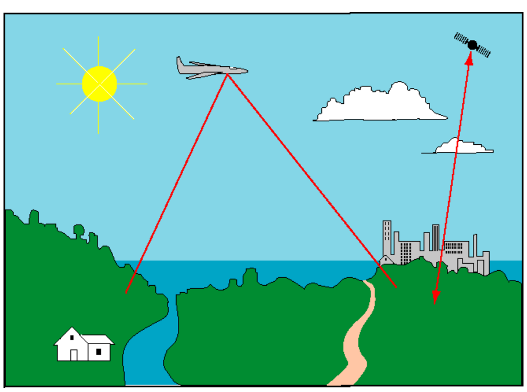

Figure 1: NASA diagram of how remote sensing from satellites and airplanes works. (Source: http://www.nasa.gov/centers/langley/news/factsheets/RemoteSensing.html)

Because remote sensing is a major application of the all parts of the electromagnetic spectrum, it is a good way to introduce students both to the electromagnetic spectrum and its applications and to a tool that they see used every day.

Assumed Background:

This module should follow a discussion of waves, frequency, wavelength, and the speed of light in a physics or integrated science course. This is reviewed, but not covered in detail, in the module.

Module Description

Materials:

- Projector
- Computer with Powerpoint
- Colored pencils
- Photocopied handouts
- Computers with Java plug-in installed – one per pair of students

Preparation:

Make sure free Java plug-in is installed on all computers to run Barro Colorado Island activity. If it is not installed, it can be downloaded for free from www.java.com. Students need only an Internet browser with Java plug-in for this activity. You may save time by having computers booted and the first page (http://earthobservatory.nasa.gov/Experiments/ICE/panama/) open when students enter the computer lab. Alternatively, you could put the link on your class webpage or as a favorite on the computers.

We recommend no more than 2 students per computer in the final activity. If more students are assigned to each computer, most students are not able to see the screen and are not engaged in the activity.

Timeline:

1. Introduce remote sensing (15 minutes)
2. Creating & Interpreting Remote Sensing Images activity (30 minutes)
3. Interactive lecture on Electromagnetic Spectrum (45 minutes)
4. Interactive lecture on Mapping Vegetation (10 minutes)
5. Barro Colorado Island activity (40 minutes)

Detailed Procedure:

1. **Introduce remote sensing using Powerpoint presentation** (see notes in presentation) [beginning of pg. 3 of worksheets]

Define **remote sensing** by breaking down the meanings of the two words. Students use a “remote control” to control their TV without touching it, so remote means “at a distance or without touching”. We use our senses to learn about objects and the world around us. We can add that most remote sensing images, like the one on the first slide of San Francisco and Monterey Bays, are obtained by satellites or airplanes, although we also use ships, helicopters, hot air balloons, and much more. Using a cell phone and GPS are even types of remote sensing because they are a form of acquiring information at a distance. Therefore, a simple definition of remote sensing is “learning about objects without touching them, usually using satellites & airplanes”. You can either use the first part of the Notes worksheet here or as a review after one or both activities [slides 1-4]

Demonstrate how remote sensing works, how we use it, and where LandSat is right now using links below [slide 5]:

- LandSat video: http://landsat.gsfc.nasa.gov/about/
- Terra orbit animation (although this is for a different satellite, it has the same type of orbit

as LandSat): http://earthobservatory.nasa.gov/Experiments/ICE/panama/panama_mov2.php

- Watch live broadcast of LandSat: http://earthnow.usgs.gov/

Explain how LandSat has 7 different sensors that each read a different type (**band**) of light. We can combine the data from these sensors together to make a color image (**true-color** like you would see with your eyes or **false-color** that is different than you would see with your eyes) and to classify each **pixel** as a particular feature (e.g., land, water, specific types of rocks or plants) because each feature reflects or emits at particular wavelengths. [slides 6-11]

2. **Creating & Interpreting Remote Sensing Images activity** [pgs. 1-2 of worksheets]

Note: This activity is derived from “Creating and Interpreting Remote Sensing Images” activity (problem 56) of NASA’s Remote Sensing Math Educator’s Guide (http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Remote_Sensing_Math.html).

Have students read paragraphs introducing activity.

Lead students in a discussion to determine colors and RGB code for the 5 features in the key (either on the board or in slide 13). The “symbol” is always the first letter of the feature (e.g., S for sky). The color is the color of the feature in an image (students may think of sky as blue, but they probably know the sky surrounding a planet in space is usually shown as black). The hardest part is figuring out the RGB values. Students are used to thinking of colors as a combination of red, blue, and yellow, but the three primary colors of light are actually red, green, and blue. One way to illustrate this is to play with the custom colors of a pixel or object in Paint or PowerPoint, where each color has a value between 0 and 255 for red, green, and blue. To simplify, here we’re just using values of 0 and 1 for no light and light. Students know plants are green, so they’ll figure out that green uses green light but no red or blue light, so the RGB value for plants must be 010. You might need to remind students that white includes all colors of light and black is the absence of light, so white is 111 and black is 000.

Put a 9 column x 8 row table on the board so the class can do one row together. You can do this by projecting the Powerpoint presentation onto a white board, using a document camera, or just drawing the table on the board. Choose an example row to write the data values in red, green, and blue on the table as students read them. Help students convert the RGB codes in the example row to colors and features. It works better to choose a complicated row with several different features, such as row 5 or 6. Divide the class into 7 groups to work through the other 7 rows and then have them write the symbols (letters) for all the rows on the board. Then have students copy all the symbols, color in the image on top of the symbols, and describe or sketch it. If one student finishes early, he or she could color in the table on the Powerpoint presentation (in progress on Figure 3 below).

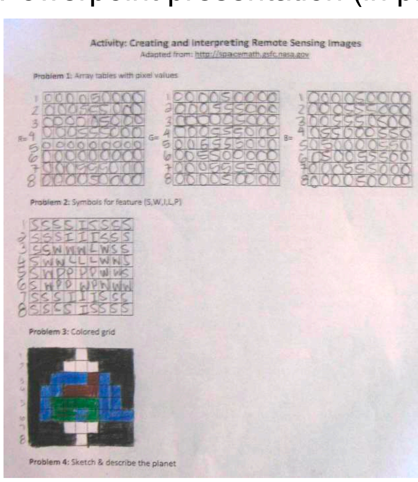

Figure 2: Student’s completed worksheet (early version with symbols and colors on separate grids)

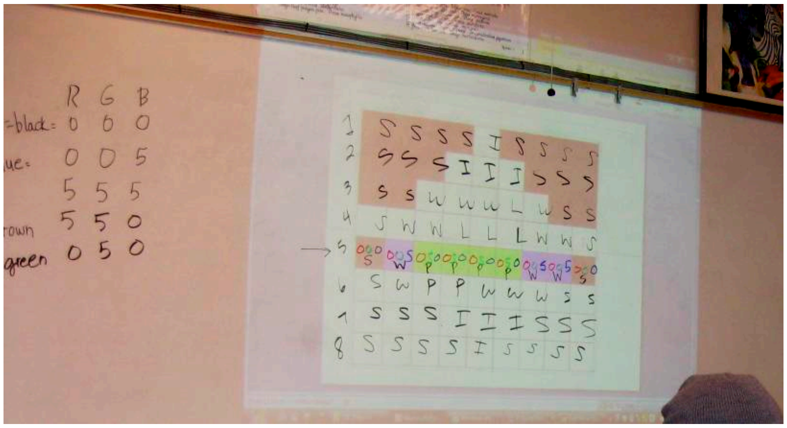

Figure 3: Symbol and color grid projected on white board, on which whole class worked together on row 5 and each group filled in the other rows.

3. **Interactive lecture on Electromagnetic Spectrum** [most of pgs. 3-4 in worksheets]

This section starts with slide 17 "Electromagnetic Spectrum."

Start by reviewing waves mostly on whiteboard – label trough, crest, wavelength on wave. Review that speed = wavelength * frequency and that speed of light is specifically mentioned in Science Standards, so students should actually learn the numbers and may see them on standardized tests. All electromagnetic radiation travels at the speed of light, but has different wavelengths and frequencies. Because they're multiplied together to calculate the constant speed of light, as wavelength increases, frequency decreases and vice-versa. Once way to emphasize the speed of light is to put it in scales students are used to – for instance, light can travel between Watsonville and Los Angeles 800 times in 1 second!!

The main goals of this section are to have students learn the 7 different types of electromagnetic radiation, their order by wavelength/frequency, and their main uses. This is interspersed with "problems," which students could do to review what they've learned by themselves, in groups, or as a whole class, depending on how much math background and previous discussion of waves they've had. Calculating wavelength, frequency, and speed are specifically mentioned in Science standards. Students may need calculators to do the problems. Have students fill in the names of types of radiation on the figure when they see slide 20 or as they go through the different types. They'll use this in Problem #3. Have the students fill in the name & uses of each type of electromagnetic radiation in the table as you go through the types in the Powerpoint presentation (slides 21-34).

It is also possible to skip this section and focus entirely on remote sensing and the two activities or teach the electromagnetic spectrum using this Powerpoint or in another way on a previous day. At least an introduction to the EM spectrum, with a focus on visible light and infrared light, is necessary for sections 4 & 5 though. If the class skips or minimizes section 3, the entire module would fit in one 1 hr 45 minute period.

4. **Interactive lecture on Mapping Vegetation** [end of pg. 4 of worksheets]

This section starts with slide 35 "Mapping Vegetation" and introduces the use of remote sensing to map vegetation using the **Normalized Difference Vegetation Index (NDVI)**, which is correlated with leaf area and the amount of chlorophyll in an area. It uses a problem to demonstrate that healthy vegetation reflects more infrared radiation and much less red radiation and therefore has higher NDVI than unhealthy/stressed vegetation. It then reviews how remote sensing combines different **bands** into color images and introduces the Barro

Colorado Island activity.

5. **Barro Colorado Island activity** [pg. 5 of worksheets]

This activity is based on and makes use of the NASA Earth Observatory's "Rainforest at the Crossroads" Activity (http://earthobservatory.nasa.gov/Experiments/ICE/panama/). The website's teacher's guide for Exercises 1 and 2 may be helpful. The worksheet says to use Internet Explorer, but any internet browser with the Java plug-in should work.

Answer questions 1-4 on the activity as a class using the electromagnetic spectrum on slide 40 before going to the computer lab. Slide 35 shows answers to questions 2 and 3 if necessary.

The main point of question 5 should be that water (the river) reflects blue radiation the most and vegetation (rain forest) reflects infrared radiation the most.

This activity works best with no more than 2 students per computer, which may require the use of a computer lab.

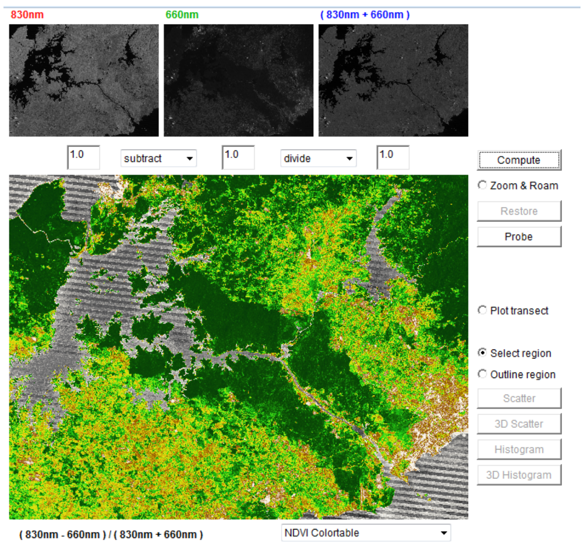

Figure 4: Screenshot of NDVI image (items 7 & 8 on worksheet)

Assessment Methods:

Class discussion
Worksheet(s) on Powerpoint presentations
Activities and accompanying worksheets
Test on electromagnetic spectrum and uses of remote sensing (not included)

Notes to Teachers:

Most students are probably familiar with maps and remote sensing images (even if they don't know them as such) in newspapers, books, and Google Earth. However, they probably are not aware of how remote sensing is used every day for many purposes. Instructors may also want to emphasize the career implications – people who know how to use GIS and remote sensing are in demand in many career fields, including government and industry.

The two activities are somewhat complicated, so it may be helpful to have other adults who have tried the activities there to help.

Feel free to use any parts of this activity that are appropriate for your class. You may want to do the EM spectrum section first or in another way and do all the remote sensing parts on another day. You may decide that the Barro Colorado Island activity is too difficult for your students.

Glossary:

Band = wavelength interval in the electromagnetic spectrum that a sensor measures or that a substance absorbs or reflects

False-color image = an image in which parts of the non-visible EM spectrum are assigned to the red, green, and blue components of the image, so that the colors produced do not match the colors that we see with the naked eye

Frequency = number of wave oscillations per unit time or the number of wavelengths that pass a point per unit time

Normalize = adjust values measured on different scales to a common scale (and/or easy-to-use scale ranging from 0 to 1 or -1 to 1)

Normalized Difference Vegetation Index (NDVI) = commonly-used mathematical index using values of near-infrared and visible (red) radiation in remote sensing images to quantify the density of plant growth, ranging between -1 and 1. Vigorously growing healthy vegetation has low red-light reflectance and high near-infrared reflectance, and hence, high NDVI values (near 1). NDVI values near zero and decreasing negative values indicate non-vegetated features such as barren surfaces (rock and soil) and water, snow, ice, and clouds.. Mathematical formula: NDVI = (NIR - VIS)/(NIR + VIS)

Pixel = individual element of a digitized image arranged in a grid of rows and columns. In remote sensing, a pixel is the smallest unit of ground area measured by the sensor (e.g., 30 m x 30 m on LandSat ETM+ and 2.4 m x 2.4 m on QuickBird). Higher numbers of pixels for the same area on the ground or the same area of a monitor screen (like your television or computer screen) represent higher spatial resolution. Shortened version of “picture element”. Students may be familiar with numbers of pixels on a television or computer monitor screen or taken by a digital camera.

Remote sensing = the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information" (Canada Center for Remote Sensing 2012). More simply, remote sensing is “learning about objects without touching them, usually using satellites and airplanes.”

RGB code = series of three numbers (usually ranging from 0 to 255) representing intensity of light in red, green, and blue bands (e.g., red is 255,0,0 and white is 255,255,255) usually used on computers. You can easily demonstrate this by playing with custom colors on Microsoft PowerPoint or Paint programs.

True-color image = an image in which the bands which most closely represent visible red, green, and blue have been assigned to red green and blue, thus producing an image which is similar in color to what we see with the naked eye

Wavelength = distance between successive wave crests or other equivalent points in a harmonic wave

Suggested Extensions:

Many additional activities on remote sensing are available in the references cited below. One of the most obvious is completing exercises 3 and 4, as well as 1 and 2, of the NASA's Earth Observatory's "Rainforest in the Crossroads" activity (http://earthobservatory.nasa.gov/Experiments/ICE/panama/).

List of References and Supplemental Resources:

- U.S. Geological Survey. 2011. Tracking change over time: U.S. Geological Survey General Information Product 133. http://pubs.usgs.gov/gip/133/

  Lesson plan for students in grades 5-8 about remote sensing and tracking the changing Earth over time. Students use free software Multispec to actually analyze LandSat images themselves.

- Canada Center for Remote Sensing. 2012. Fundamentals of Remote Sensing. http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/11810

  Offers an introduction to remote sensing, which may be useful to teachers. Also offers a variety of remote sensing activities for students of all ages.

- NASA Earth Observatory. 2012. Remote Sensing. http://earthobservatory.nasa.gov/Features/RemoteSensing/

  Introduction to the history, science behind, methods, and interpretation of remote sensing.

- NASA. 2011. Mission Science: Tour of the Electromagnetic Spectrum. http://missionscience.nasa.gov/ems/index.html

  Good introduction to the electromagnetic spectrum and its applications for everyday life and remote sensing. Main source of information and images for the Powerpoint presentation.

- NASA 2012. NASA Education. http://www.nasa.gov/offices/education/about/index.html

  Includes many lessons and activities for students of all ages about remote sensing and space. Both activities were derived from NASA activities found here.

Science Education Standards Addressed

National Science Standards (NSES)

A. Science As Inquiry (Use technology and mathematics to improve investigations and communication, p.175),
B. Physical Sciences (Interactions of Energy and Matter, p. 180),
C. Life Sciences (Matter, Energy, and Organization in Living Systems, p.181-187),
D. Earth and Space Sciences (Energy in the Earth System, p. 189),
E. Science and Technology (Understandings about Science and Technology, p. 192

California Public Schools Standards (SCSCPS)

Physics

4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:
   a. Students know waves carry energy from one place to another.
   b. Students know how to solve problems involving wavelength, frequency, and wave speed.
   c. Students know radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3.8E8 m/s (186,000 miles/second).

Earth Sciences

Energy in the Earth System

4. Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept:
   b. Students know the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.

Investigation and Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:
   a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

Next Generation Science Standards (NGSS)

Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer
- PS4.A: Wave Properties
- PS4.B: Electromagnetic Radiation
- PS4.C: Information Technologies and Instrumentation

Core Idea ESS2: Earth's Systems
- ESS2.D Weather and Climate
  - The foundation for Earth's global climate system is the electromagnetic radiation from the sun as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's reradiation into space.

Science & Engineering Practices:
2. Developing and using models
4. Analyzing and interpreting data

NSES (http://www.nap.edu/catalog/4962.html);
SCSCPS (http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf);
NGSS (http://www.nextgenscience.org, http://www.nap.edu/openbook.php?record_id=13165)

Guide to supplemental materials

1) Powerpoint Presentation (focused on Monterey and San Francisco Bay areas)
2) Worksheets
    - Activity: Creating and Interpreting Remote Sensing Images (pgs. 1 & 2)
    - Notes: Remote Sensing and the Electromagnetic Spectrum (pgs. 3 & 4)
    - Activity: Barro Colorado Island (pg. 5)
2) Key to Worksheets
    - Activity: Creating and Interpreting Remote Sensing Images (pgs. 1 & 2)
    - Notes: Remote Sensing and the Electromagnetic Spectrum (pgs. 3 & 4)
    - Activity: Barro Colorado Island (pg. 5)

