SMILE Teacher Workshop
2007 Winter Teachers Workshop
How Satellites See

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This activity is adapted from Gulf of Maine Aquarium activities “Visible and Infrared Imagery” http://octopus.gma.org/surfing/sensing/imagery.html
and “How Well Can a Satellite See” http://octopus.gma.org/surfing/sensing/seeing.html
Information on Sea Surface Temperature images is from the NOAA CoastWatch program: http://coastwatch.noaa.gov/

Introduction

This activity will expand on some of the material covered in last workshop’s “Remote Sensing” activity. Students will learn about different types of satellite images and practice interpreting them. They will then explore the concept of scale and resolution in imagery.

Materials

(Materials in bold are provided by SMILE)
Atlas/Map
Colored Pencils
Graph paper (two different size grids (i.e. 4 cm x 4 cm and 1 cm x 1 cm)

Handouts:
Electromagnetic Spectrum
Visible and Infrared Imagery
Map Worksheet
Images of the Earth at different resolutions

Background

Some review (from the Remote Sensing Activity at the Summer 2006 workshop):

Satellites have sensors on them that measure the amount of electromagnetic energy reflected off the earth (or another planet) at specific wavelengths. Some of these sensors send out an electromagnetic wave and measure the returning wave that reflects off of the earth – these are called active sensors like the ones that measure altimetry. Other sensors are passive sensors and simply measure the radiation coming off the earth without sending out their own signal. Most optical satellite sensors are passive sensors.

Like on a digital camera, satellites have different sensors for different sections of the electromagnetic spectrum. A temperature sensor detects electromagnetic rays in the mid infrared zone: 3-8 μm (μm = micrometers = 0.000001m = 1 x 10-6). A chlorophyll-a sensor detects a narrow band of green light that is given off by chlorophyll-a 667 nm (a type of chlorophyll produced by many marine algae). These properties are displayed in visible colors for ease of interpreting, but are not truly visible features. For satellite images in the visible range of the spectrum (400-700 nm, nm is a nanometer or 0.000000001m = 1 x10-9) satellites use three cameras a blue, a red, and a green to capture the range of visible light. Satellites like the Landsat take images in this range. You can find Landsat images of your community at this website: http://www.bsrsi.msu.edu/.

Types of Satellite Imagery:

Visible:

Visible satellite images are similar to pictures a photographer might record in that they rely on and display reflected light. As long as light is available, land features like mountains, river courses, lakes, silt run-off from rivers into the sea, and coastlines are clearly visible. Clouds appear white to us because they reflect light. Since visible imagery depends on available light, it can only be detected during the day.

Infrared:

Infrared images display gradients of temperature differences. Infrared sensors pick up data both day and night. They show the pattern of heat (infrared radiation) released from the Earth. Heat-producing areas, such as warm water currents or cities (with heat-absorbing concrete and asphalt and heat-producing cars, people, and factories) are bright spots on infrared images. Clouds appear in varying shades of grey, depending on their temperature, which is determined by their height above Earth.

Water Vapor:

In addition to visible and infrared images, satellites also produce images of water vapor. Water vapor images are useful for pointing out regions of moist and dry air, which also provides information about tropospheric wind patterns and jet streams. Darker colors indicate drier air while the brighter the shade of white, the more moisture in the air.

Color Enhancement:

Color enhancement is a procedure where specified levels of energy are given a specific color. This makes locations with the desired energies easier to locate. Though the data is the same, color enhanced images use colors ranging from purple to red to make certain features stand out. Such features are not as easily observed in gray scale images.

Sea Surface Temperature:

Sea surface temperature (SST) images may be created using infrared data. NOAA has been producing sea surface temperatures (SSTs) from satellite data since 1972. Beginning in 1982, multichannel infrared (IR) data became available to provide more accurate SSTs making it possible to correct for the intervening atmosphere. SST images are developed using data from NOAA's Geostationary Operational Environmental Satellites (GOES) and Polar Orbiting Environmental Satellites (POES), as well as NASA's Earth Observing Satellites (EOS), Aqua and Terra. These images can be found online at the CoastWatch web site: http://coastwatch.noaa.gov/cw_dataprod_sst.html. CoastWatch SST products are produced at high spatial resolution for the coastal waters of the United States.

Image Resolution:

Image resolution describes how large an object must be in order to be resolved by a satellite sensor. A pixel is the smallest complete sample of a digital image and is an abbreviation for <u>pi</u>cture <u>el</u>ement. A matrix of pixels can also be called a bitmap. In a 4 kilometer-resolution APT (Automatic Picture Transmission) image each pixel is 4 km x 4 km; in a 1 km-resolution HRPT (High Resolution Picture Transmission) image, each pixel is 1 km. x 1 km. The smaller the area in each pixel, the more detail in the image.

Activity: Exploring Imagery

1. Explain to students that wavelengths of light can be separated into visible and invisible ranges. Show them the range of the electromagnetic spectrum.

2. Provide pairs of students with both visible and infrared images of the Pacific coast. Discuss the differences between infrared and visible satellite images as explained in the background to this activity. Then ask students to work together to decide which image is in the visible spectrum and which is infrared. (Key: 1 – Infrared; 2 – Water Vapor; 3 – Visible)

3. Have students use a map or atlas to find geographic features on the images. Identify Oregon, Vancouver Island, and the Canadian border. Find other areas of interest. Mark these on your worksheet map of the western US.

4. Ask students to identify coastal upwelling in the infrared image, if possible. Compare this image with the SST image. In dark blue pencil, outline and then color the area of upwelling on the worksheet map. Color the surrounding water lighter blue.

5. On the visible image, have students look for clouds and areas where rivers are emptying into the ocean. They may see silt washing into the ocean. Can you see these features on the SST image? What other features can be seen on the visible image that are not detected by infrared sensors?

6. By examining the cloud patterns, can the students guess which areas are sunny and which may have rain on this day? Compare the visible and infrared images with the water vapor image. Have students lightly shade in the areas that are under cloud cover on their worksheet maps of the eastern US.

7. Take a look at some of the color enhanced images. Do these images tell you anything new about the data?

Use your artwork to demonstrate differences in resolution

1. Have students draw any multicolored picture they like on the graph paper that has the smaller squares (1 cm x 1cm).

2. Then have students lightly draw lines on the graph paper that mark off squares the size of the next larger graph paper's grids (2cm x 2 cm). Thus each larger square should have four smaller squares contained within it.

3. Students then determine the average color represented in each larger square. Have them draw that color on a new piece of graph paper with the larger squares. Is the new drawing recognizable? What is the resolution of each pixel in the drawing (A: 2 cm)? Repeat for the largest grid graph paper (4 cm x 4 cm, image resolution 4 cm).

4. Using the original artwork, the students then determine the average color represented in each of the smaller squares. Have them draw that color on a new piece of graph paper with the smaller squares. Now are the drawings recognizable? What is the resolution of each pixel in the drawing (1 cm)? What features are still not represented in the pixel drawing?

Discussion:
Compare the 1 cm grid graph paper to a 1 km resolution HRPT (High Resolution Picture Transmission) satellite image. The largest graph paper then demonstrates the relative detail in a 4 kilometer-resolution APT (Automatic Picture Transmission) image. This should give students a sense of the kind of detail that can be lost in satellite imagery.

More About Resolution in Satellite Imagery
To compare resolutions, take a photograph of the same person or object at a distance of 2 feet, 10 feet, 20 feet, and 100 feet (optional- if you have access to a digital camera). Then look at archival satellite images of the same view of Earth at different resolutions.