STEM Digital   STEM Education Institute

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ABC's of DEW (ADI) Software

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DIGITAL EARTH WATCH SOFTWARE

By John Pickle, Jacqueline Kirtley, and Alan Gould

LHS*

2009 Edition
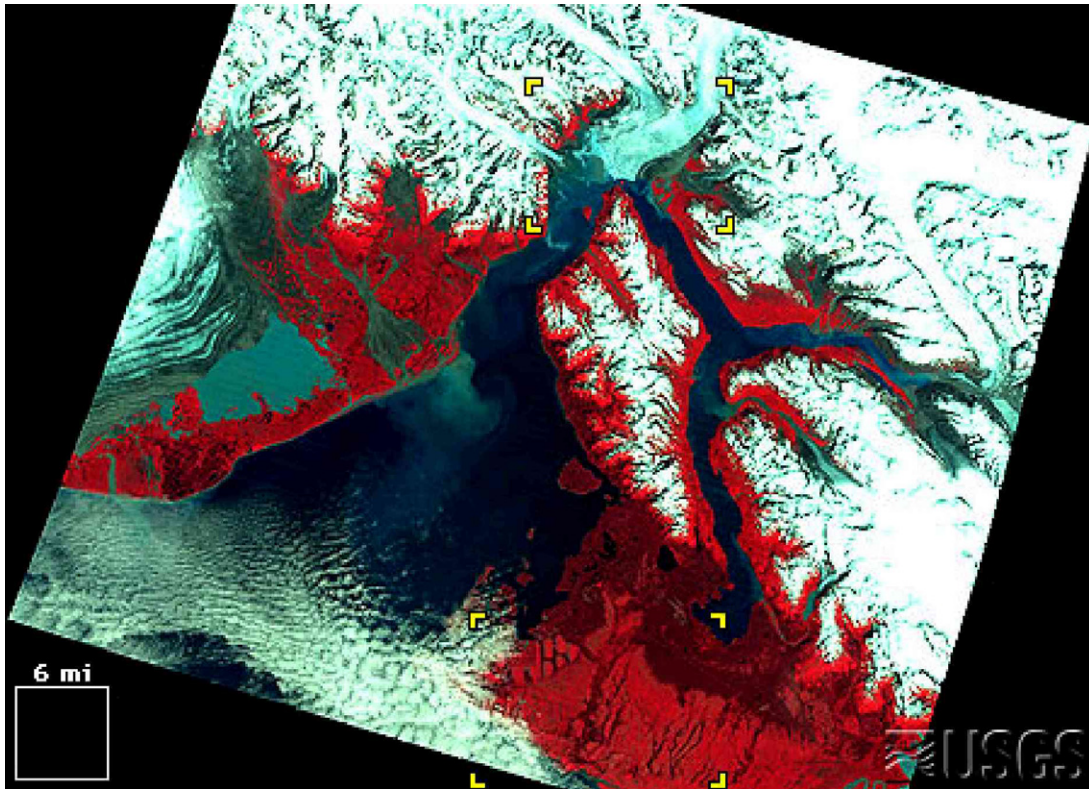
Satellite image courtesy of the United States Geological Society (USGS) from their web site:
http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents

Digital Earth Watch (DEW) software is based on Interpreting Digital Images
(IDI) software created by John Pickle as a part of Global Systems Science
(GSS) curriculum materials.
http://lhs.berkeley.edu/GSS/

DEW and IDI are a joint projects of the
Museum of Science, Boston and Lawrence Hall of Science

Digital Earth Watch Software

Contents

1. Three-Color Light

Introduction to Three-Color Light

Many of us were taught at a young age that the primary colors are red, yellow, and blue. Our early experiences with color mixing were blending together paints where yellow and blue make green and the three colors stirred together make colors ranging from brown, gray, or black. From this we have two errors in our understanding of color. First, primary colors can be mixed together to create all other colors. Second, that red, yellow, and blue are *the* primary colors.

When we talk about primary colors, we generally think about three colors which can be mixed together to create all of the colors of the rainbow. Have you ever tried to make black out of your red, yellow, and blue? Even more difficult—try to make fluorescent pink, silver, or gold. Primary colors cannot make all other colors, but they can make the most colors from the fewest starting resources.


Adding Color Pigments
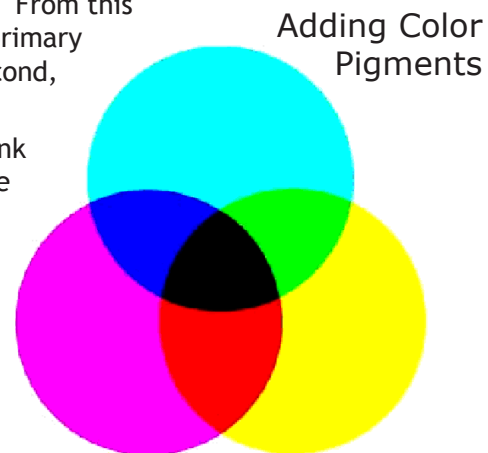
Difference Between Pigments and Light

There are two sets of primary colors: one for pigment (dyes and paints) and another for light. Look at the printing process for the color pages of your local newspaper or a color printer, and you will see that the rainbow of colors is created from four colors of ink: cyan, magenta, yellow, and black. Modern printing has found that combinations of cyan, magenta, and yellow (which are very specific shades of blue, red, and yellow) can create the maximum number of colors. When mixed together in equal parts, the three create black (or gray). In printing, the black ink has been added as a fourth color to use less ink. To see how this works, take a microscope or magnifying glass to a color picture in the morning paper or a magazine.

What you see up close is a series of overlapping dots of various sizes and transparency in those four colors. You may even see a newspaper once in a while where the color layers were not properly lined up so the images appear to be double and the picture colors are not right.

In light, the primary colors are red, green, and blue. Despite what you learned in paint, when you mix yellow and blue light the result is white. Likewise, magenta + green makes white; and cyan + red makes white. Color television and computer monitors use the three primary colors of light to display thousands or millions of

Adding Color Light
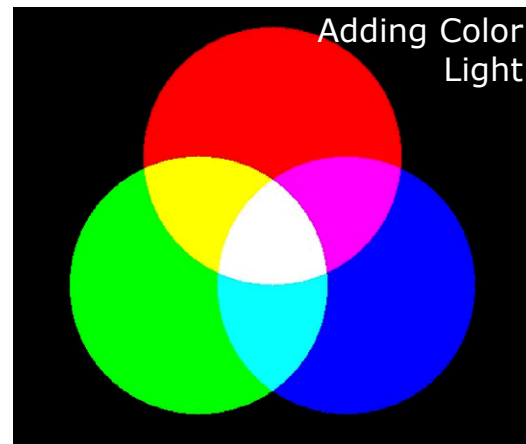
different colors. If you take a magnifying glass to your computer monitor or television, you will see a regular pattern of red, green, and blue lines or dots. Each of these glows at varying intensities, just as a color printer drops varying amounts of ink. In both cases, what you perceive is the mixing of the primary colors and up to 16.8 million different colors on the screen.

Newsprint and Video Displays

With a microscope or magnifying glass examine a color picture in the morning paper or a magazine. Look for the overlapping dots of various sizes and transparency in four colors of ink: cyan, magenta, yellow, and black.

With a magnifying glass, examine your computer monitor or television. Look for the regular pattern of red, green, and blue lines or dots.

How does the paper print dots compare with what you see on the computer monitor or TV?

The difference between mixed pigments and mixed light rests on how light gets reflected and absorbed. Pigment and paint are substances that absorb specific wavelengths of light, **subtracting** them from the light energy reflected by the surface. A blue painted surface will absorb all colors of light except the blue, which it reflects back. The reflected light reaches your eyes and you perceive the color blue. A colored light bulb or a computer monitor is a light source which shines or adds light energy of specific wavelengths. A red light bulb shines red light directly to your eyes and you perceive the color red.

Computer Monitors

A number of different technologies are used at present for computer displays or monitors. The two most common are the cathode ray tube (CRT) and the liquid crystal display (LCD; common in laptop computers). Here is a brief introduction to the CRT, although this is only the tip of the iceberg.

A CRT consists of a negatively charged heated metal filament, called a *cathode*, inside a glass vacuum tube. Coming out from the cathode is a ray of electrons. A positively charged metal piece, called the *anode*, attracts the electron beam and focuses it onto the screen at the front of the glass vacuum tube, which is the front of the monitor. When excited by the beam, a coating of phosphors on the screen glows. A color CRT has three electron beams and the screen is coated with phosphors that glow in three different colors: red, green, and blue (RGB). Each electron beam will excite only the dots or lines on the screen that have been coated for its color (i.e. the beam for red excites the dots coated in a red phosphor).

Naming Colors

People have given many names to the colors they see. When Isaac Newton wrote down the colors he saw in the rainbow, he chose to break them out into seven names. We still use that list of names today, although you may find it difficult to pick out the color indigo or the color violet somewhere in the room.

There are a number of basic color names that people refer to: red, orange, yellow, green, blue, purple, brown, white, and black. But individual people may not agree on what to call a specific block of color. Is it red, orange-red, salmon, burnt-sienna, or watermelon? Naming or distinguishing between colors is a very subjective process. As you study light and color throughout this course, you may find that what you think is pure red has more blue in it than the computer's pure red. Don't let that confuse you; when it comes to studying color it is not the name of the color that matters most.

Creating Colors

Part I: Create Colors

In the Tri-Color Creation Chart, guess the combination of red, green, and blue intensity values that would create the color in the left column. Enter your guess in the **ColorBasics** program (using the *Make Colors* tab) and see what color is created. Write what you would call that color in the 5th column. If it doesn't match, use the extra columns to guess again.

Tri-Color Creation Chart

Guess the color intensity combination to create the following colors:

	Red Intensity	**Green** Intensity	**Blue** Intensity	**What color is your 1st guess?**	Extra guesses Red	Green	Blue
Pure Red							
Pure Green							
Pure Blue							
White							
Black							
Yellow							
Violet							
Orange							
Pink							
Your favorite colors:*							
Your least favorite colors:*							

*Write the name of your color in the left column, and then make your guesses.

Roses are red,

Violets are blue,

How can I express them

In saturation, value, and hue?

Part II. Predictions

Now that you have started to see how the computer creates different colors from the primary colors of light—red, green, and blue—try to translate the colors from the computer's point of view.

With the Tri-Color Prediction Chart, you are given a set of intensity values for several "mystery" colors. Using what you learned from the Tri-Color Creation chart, predict what color is produced by these color intensity values. After you have written your guess in the chart, enter the intensities into the **Make Color** tab of **ColorBasics** and write the color you see in the column on the right. Use the last few lines of the chart to try some colors of your own design.

Tri-Color Prediction Chart

Red Intensity Value	Green Intensity Value	Blue Intensity Value	What color do you guess this is?	What color do you see with ColorBasics?
100	100	0		
0	100	100		
100	0	100		
75	75	75		
50	50	50		
25	25	25		
100	50	50		
100	50	0		
100	0	50		
50	100	50		
0	100	50		
0	50	100		
75	50	25		

Part III. Tri-Color Game

Test your understanding of how a computer creates color from intensities of red, green, and blue with a little competition. Using the *Play With Colors* tab of *ColorBasics*, play the game against another student or against the computer. Try to match the red, green, and blue intensities of the "secret" color. The software will keep track of the number of guesses each player uses to match the secret color.

Here is how you play:

1. **Select the level of difficulty for your game.** There are three levels of difficulty that determine how close the guess color must be to the secret color in order for the colors to 'match'. On Easy, the guess must match the secret color to within 15% of each of the 3 color intensities; Medium is to within 10%; and Hard is to within 5% of the secret color.

2. **Select your opponent** from the menu button next to 'Opponent': "Play a Person" or "Play the Computer."

3. **Click "Set Secret Color."** If you are playing a person, Player 1 enters 3 color intensity values in the boxes on the secret color window that pops up. Player 2 should cover his/her eyes or look away while Player 1 enters the numbers. If you are playing the computer, a color is randomly set.

4. **Try to reproduce the color:** make the right box color the same color as the left box color.

5. **Once the color is matched, you can explore** the colors that match for the level selected by clicking on "Explore Matched Colors", then you can switch roles and Player 2 will set a secret color.

6. **Play as many rounds as time permits.** Your scores appear at the bottom right corner of the screen.

The winner is the player who took the LEAST number of tries to match the colors.

Note: The game can be played with more than 2 players by dividing players into team 1 and team 2.

Fill in the Tri-Color Reference Chart as you wish to summarize the "formulae" for common colors in terms of intensity values of the three primary colors. Keep it handy—it will help you in interpreting color digital images.

Tri-Color Reference Chart

Use data that you've already collected as well as both software programs (**TriColor** and **Game_TriColor**) to fill the color intensity values on this chart.

Color	Red Intensity Value	Green Intensity Value	Blue Intensity Value
Black			
White			
Red			
Yellow			
Green			
Cyan			
Blue			
Magenta			
Orange			
Purple			
Brown			
Pink			
Light Gray			
Medium Gray			
Dark Gray			

Color in Computer Images

Computers use intensities of the colors red, green, and blue to create a myriad of different colors on our monitors. Throughout this activity you have used percentages to create over a million colors—primary color intensities ranged on a scale of 0 to 100 percent. Most digital images use a binary scale with 2^8 levels. Instead of 101 possible intensity values, there are 2^8, or 256, possible intensity values for each color. These images can display over 16.8 million different colors.

2. *Pixels and Colors*

Introduction to Pixels

The term pixel is a truncation of the phrase "picture element" which is exactly what a pixel is. A pixel is the smallest block of color in a digital picture. The term is also used for the smallest block of color on your computer monitor. In fact, to run these activities we recommend that you have the display setting for screen area on your monitor set to at least 1024x768 pixels. What that means is that your monitor has 786,432 blocks of colors arranged in rectangle with 1024 columns and 768 rows.

The resolution of an image refers to the number of pixels used to display an image. A higher resolution image uses more pixels and allows for more detail to be seen in the picture. Scanners and printers will often advertise their resolution in *dots per inch (dpi)*, which is the number of pixels per inch that they are capable of recording or depositing. A document printed at low resolution (fewer dpi) has jagged steps of dots that make up a curve like the letter "O". From a high resolution printer (more dpi), that same letter looks like a smooth circle.
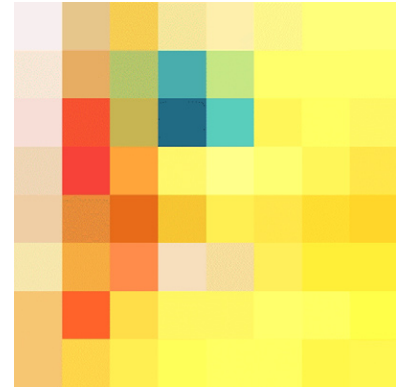
Images of a rubber duck with large pixels and with very small pixels.

Pixels and Digital Images

The number of pixels in an image tells you the picture's resolution. More pixels means a higher resolution, allowing you to distinguish more details in the picture.

The **Pixels** button of the software **DigitalImageBasics** can increase and decrease the resolution of the image, so that you can see how many pixels are necessary to recognize the picture's subject. When you open an image, it will be at the lowest resolution: 2x2=4 pixels. Increase the number of pixels until you can make out what the picture is. Record the resolution needed to recognize the mystery pictures.

Software to use: **DigitalImageBasics** with the **Pixels** button active.

Use the program **DigitalImageBasics** with the **Pixels** button activated to fill out the chart on the next page and answer these questions:

Question 2.1. How does the resolution of an image affect what you can see? Why would you need more pixels to identify an image?

Question 2.2. When could you identify an image with large pixels? How does resolution affect interpreting satellite images?

Pixel Count Chart

Mystery Picture #	At what resolution can you recognize the subject of the picture?	What is the subject of this picture?

Color Within a Digital Picture

You see color on things around you because light shines into your eye, is received by the cones and rods of your retina, and is converted to electrochemical signals that are then processed through your brain. A digital camera detects color because light shines on sensors in your camera which are sensitive to red, green, and blue. The number of sensors in the camera will define the highest resolution possible for that camera.

A traditional film-based camera records an image onto a chemically treated plastic. *Digital* cameras record the red, green, and blue intensities for each pixel into a numerical file – the values of color and position of the pixel are defined with numbers. A number of different file types are used to compress the data so the file takes up a minimal amount of computer memory. To display the image on the computer screen, the computer takes the red intensity value for a particular pixel from the file and shines the red component of the pixel at that amount at that place on the computer screen. It does the same thing for the other two primary colors (green and blue) for every pixel in the image.

Seeing Only One Color of Light

When we talk about seeing only one color we are not referring to the condition known as color blindness. People who are colorblind have difficulty distinguishing between certain colors, for example red and green, but they are still capable of perceiving light of both colors. What we are talking about is if you could only see the small range of light wavelengths that is called "red". You would be unable to perceive the spectrum of light including orange, yellow, green, blue, and violet.

Seeing only two colors of light:
the image at left of a rubber duck
has the complete set of red, green,
and blue colors, while the one on the
*right has only red and blue colors.*
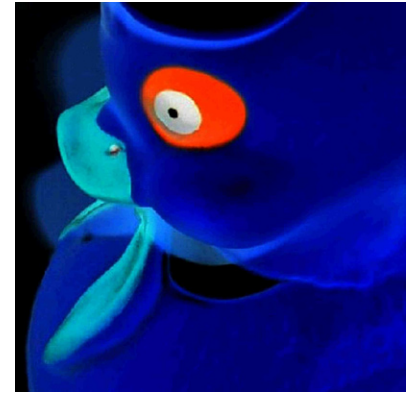
In satellite images, each color is data of the image that provides specific information. By turning off all of the light that is not red, we can look solely at the information that red light provides. If we were physically only able to see the range of light that is red, it would appear more like a black and white image than a red and black image. The use of black and white to view such information allows us to make out details and differences in shade and intensity more easily.

Why is the Sky Blue?

The Sun produces white light. White is the combination of all of the colors of the rainbow. When we view sunlight through a prism, we bend the colors so that they are separated. When sunlight shines through our atmosphere, it is bent and scattered by particles. Our atmosphere, because it is largely made up of nitrogen and oxygen, is most efficient at scattering blue wavelengths of light. If you look back at your data from Chapter 1, you will see that if we remove blue from our white light, the color that we are left seeing is yellow. The scattered blue light leaves the sun looking yellow.

But we all know that the sky is not always blue. At sunset and sunrise, the sky includes many more colors from throughout the spectrum. You may have picked up on the use of the word "efficient" above. Other colors of light are scattered by our atmosphere, but not as efficiently as the blue. When the Sun is high in the sky, its light has a shorter distance to travel through the atmosphere and the blue light is scattered. When the sun is low in the sky, the path is much longer and more colors of light are scattered.
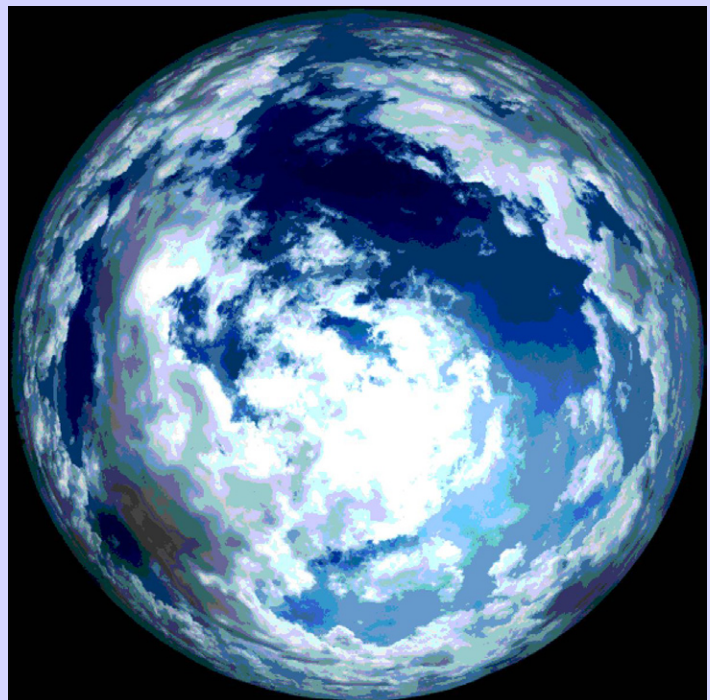
While the question "why is the sky blue?" is one of general interest, the reason we are discussing it here is to start thinking about the effect that our atmosphere has on the light that travels through it. If we are going to take an image from space of light that shines from the Sun through the atmosphere and is reflected back up to space, then we must pay attention to what the atmosphere does to that light on its travels.

Color of a Pixel

The word *pixel* comes from the phrase "picture element." Each pixel displays the color of a tiny region of the image, and that color is the average color for the entire region. In the following tables you will look at the red, green, and blue intensities of a large pixel and the smaller pixels that define the same region.

Software to use:
DigitalImageBasics with the *Pixels* button active.

2x2 pixel resolution

UL	UR
LL	LR

Pixel	Red Intensity Value	Green Intensity Value	Blue Intensity Value
Upper Left (UL)			
Upper Right (UR)			
Lower Left (LL)			
Lower Right (LR)			

4x4 pixel resolution

1	2	UR
3	4	
LL		LR

Pixel	Red Intensity Value	Green Intensity Value	Blue Intensity Value
UL – 1			
UL – 2			
UL – 3			
UL – 4			
Average for each:			

A. Open a mystery picture of your choice in *DigitalImageBasics* with the *Pixels* button active. With the resolution at the minimum, 2x2=4, show the pixel borders for 2x2. Move the cursor over each pixel and write down the color intensity values (%) shown in the lower, left area of *DigitalImageBasics* window.

B. Increase the resolution of the picture to 4x4=16. This time write down the color intensity values for the four pixels that cover the same region as the Upper Left pixel from the 2x2 resolution. In the last row, write the average value of the column.

Question 2.3. Compare the averages from the second chart to the values for the Upper Left pixel from the first chart. How are they alike? What do you expect would be average intensity values for the pixels in this same region if the resolution is 8x8?

Switching Colors

Have you ever looked really closely at a television or computer monitor? If you haven't, take a magnifying glass or a small droplet of water and look at your computer monitor. Up close, you will see that your monitor screen is actually a series of red, green, and blue dots shining light at different intensities. When your computer displays an image, it takes the red intensity values from the image file and makes the red dots shine by those amounts. The **ColorPicture** program allows you to change which set of colors in the image file shine as which colors on the computer display—in other words change it so the red intensity values from the image file make the green dots or blue dots on the screen shine instead.

Part 1: Color Circles

Software to use: *DigitalImageBasics* with the *Colors* button active.

Open the picture *Color Circles 1*. Notice that the initial settings of the program have the same colors for "Color Measured by Camera" and "Displayed Color" (which is the color display on the computer monitor).

Question 2.4. Describe the colors you see in this picture. What color is the circle at the top? On the left? On the right? What other colors do you see in the picture?

Question 2.5. Change the combinations of "Color Measured by Camera" and "Displayed Color." What happens to the circle at the top? Can you make the picture have only one yellow circle?

Part 2: Seeing One Color

Open the picture *Sample: RGB Color Space*. This is a picture where the edges of a cube span all the values of RGB colors. Notice how the colors in this picture are arranged. Imagine what things would look like if your eyes could only see one color.

Question 2.6. What would this picture look like if we were blind to ALL colors except red—that is if we could see ONLY red light? How would the image look different in red than with all colors? Move your mouse over the picture to see the red intensity values of pixels throughout the image.

Question 2.7. Change the view of this picture so that you can only see the red intensity values of the image file. To do this, set all three "Color Measured by Camera" choices to 'Red'. What areas look bright in red light? Which areas look dark? You can also try settng the Blue and Green values to "None".

Question 2.8. Now view the picture with only the blue light. How does the picture look different? What details can you see better in the blue light? What is visible in the red light?

Question 2.9. When all of the computer display colors show the red picture color, why does the image appear black and white? If your eyes were only able to see red, do you think that is what the world would look like?

Part 3: Colors of the Sky

Open the picture _AllSky.jpg_. This is a picture of the sky using a camera with a fish-eye lens, which allows most of the sky to be seen at once. This picture is courtesy of Chuck Wilcox at the Museum of Science, Boston, Massachusetts.

Now that you have learned so much about color and light, get to know the colors in this picture. Move your mouse around the image and notice the color intensity values throughout the picture. Change which picture colors are seen in the computer display colors.

Question 2.10. Which of the three-color components (red, green, or blue) is dominant in the sky? Which color contributes the least intensity to the sky? See the contribution of a color by setting all of the computer display colors to a single picture color.

Question 2.11. If the sky is blue because of tiny atmospheric particles scattering blue light, why is the Sun yellow? Hint: this is a good time to take a look back at the Tri-Color Reference Chart that you created in Part 1.

Question 2.12. If the Sun appears to be yellow, why do clouds appear so white in the image? If you were riding on a satellite thousands of miles above the Earth, what would be the color of the "sky" (or outer space) and what would be the color of sunlight?

Open the picture _sunset.jpg_. This is a picture of the Sun setting over the ocean. Here the sky is yellow and orange while the clouds are dark. Use the **ColorPicture** program to get to know the colors in this picture.

Question 2.13. Why is the color of the sky different at sunset from the middle of the day? What about the clouds and the Sun?

Question 2.14. What color is the dominant color of the water? Where is the blue in this picture?

3. *Measuring Length in Digital Images*

The *AnalyzingDigitalImages* software allows you to measure distances, areas, and color in a wide variety of digital images, including those taken with a digital camera, color-coded maps, aerial photographs, and satellite images.

Investigation

Spatial Analysis: Length

Materials

- *AnalyzingDigitalImages* software

- Plant Leaf image (or any image including an object of known size, such as a ruler to determine scale.

Getting Started

Start the *AnalyzingDigitalImages* software and open a picture by clicking on one of two options: "Open Picture" in the File menu, or use the "Open a Picture" button at the bottom of the screen.

AnalyzingDigitalImage **File** Utilities Measurements Save C

Click

Open Picture	⌘O
Calibrate Pixel Size	⌘C
Save Picture	⌘S
Show/Hide Original	⌘H
Draw Color Histogram	⌘D
Draw Color along Line	⇧⌘L
Page Setup	
Print Picture	⌘P

Intro   Spatial Analysis

These tools are designed so you may visualize ar measure the spatial and spectral (color) information and relationships in digital images.

There are three sets of tools, and images created with one set may be used with the other tools.

Use the spatial tools to measure the size and colors of features in the original image, a color enhanced image, or a masked image.

Spatial measurements may be saved to a text file and analyzed with spreadsheet software.

The color enhancement tools let you change how the image is displayed.

The masking tool lets you count the number of pixels within a range of colors within the original or a color enhanced image.

Modified images may be saved or printed.

There are two utilities available in the File Menu:
1) Trim images to speed up processing time, and
2) Combine two or more images into one for comparison.

Other useful tools available in the File Menu:
1) Color histogram of the displayed image and selected sreas of the image, and
2) Color along Selected Line.

Although these tools were not designed to create artistic images, you may make some beautiful and exotic looking images.

Measure a Feature's Size and Color with Spatial Tools

Measure the Length of the Leaf

Quickly

Flow diagr with

or Click

Open a Picture

Calibration

1. Before making any measurements, calibrate the size of a pixel* to the size of an object of known length that is visible in the image. This procedure automatically starts after you select an image. To run the calibration method again, use the "Calibrate Pixel Size" in the File Menu.

A pixel is the smallest portion of a digital image with uniform color. For most digital photos, the pixels are so small you won't be able to see them.

2. Click and drag the cursor across the length of the scale. To adjust the ends of the line, either click and drag the blue or red end of the line or click the small arrows that appear below the image.

   TIP: Use the longest length possible since this minimizes small errors of drawing the calibration line.

   TIP: To make measurements with a centimeter scale, rather than enter "4" and "in" in the above boxes, type "10.16" and "cm" instead. Note: 4 inches x 2.54 cm/in = 10.16 cm.

Selec: Method of Pixel Size Calibration

Select Method to Calibrate the Pixel Size

Known Pixel Size — Click if you know the size of the pixels, which is common for orthophotographs from aerial reconnaissance and satellite imagery.

Scale Present in Image — Click if there is a linear scale located in the image. This includes photographed objects of known length (ruler, penny, clipboard, etc.) or a distance scale on digital maps or satellite imagery.

Click

None — Click if there is no way to know the size of the pixels in the image.

Picture 4.png is 612 by 514 pixels

	X	Y	
Start of Line	69	471	
End of Line	533	474	

Length of Drawn Line: 4

Unit of Length: in

Zoom In   Magnification: 0.93%   Zoom Out

When zoomed in, pan around the image by using the arrow keys or hold the SHIFT key and click and drag the image.

Done

3. TEST YOUR CALIBRATION: After completing the calibration, use the "line" analysis tool in the Spatial Analysis window to measure the length of the scale. If possible, measure a visible scale perpendicular to the direction of the first test. For example, if you used the length of a ruler to calibrate the pixel size, use the width of the ruler as the second test, if it is visible.

If the calibration is incorrect, recalibrate before moving on—in the *File* Menu, choose *Calibrate Pixel Size*.

Measure Length

1. Make length measurements by clicking and dragging on features in the image. To adjust the ends of the line, either click and drag the blue or red end of the line or click the small *Adjust* arrows that appear to the left of the image.

2. If desired, *Save* values to a text file for use later with Excel or other spreadsheet/graphing software. To save measurements, use "Save Measurements" in the Measurements Menu. Besides the measurement, additional data are saved automatically to help check the quality of your measurements later.

3. Open a variety of images and see if you can make length/distance measurements in those images.

Most current versions of the Digital Earthwatch (DEW) software programs, including *AnalyzingDigitalImages*, are available through the GSS Staying Up To Date web pages http://lhs.berkeley.edu/gss or the Digital Earth Watch/Measuring Vegetation Health website (http://mvh.sr.unh.edu/software/software.htm).

4. Measuring Area in Digital Images

There are three ways to measure the area of objects in digital images using tools in the *AnalyzingDigitalImages* software: Rectangle tool, Polygon tool, and Masking.

Investigation

Spatial Analysis: Area

Materials

• *AnalyzingDigitalImages* software
• Plant Leaf image

A very simple example of area analyis is in the GSS book *A New World View*, Chapter 3, pages 25–27 in the investigation *Measuring Old Growth Forest Loss*. Measure how much old growth forest we lost in the past few hundred years. It uses the specialized software ForestAnalysis that was created specially for that investigation.

Method 1: Rectangle Tool

Click and drag to draw a rectangle around the object of interest. To adjust the size of the box, either click and drag the blue or red corner of the box or click the small arrows that appear to the left of the image.

As one would expect, this would not yield very accurate area measurement for objects that aren't rectangles.

Spatial tools measure the color and size of features in digital images. Measure features observed in three versions of the image: the original image, a color enhanced image, or a masked image (a range of color are highlighted in black).

Select Image to View and Analyze

◉ Original   ○ Enhanced   ○ Masked

Rectangle Tool

Pixel Position	X	Y	Adjust
Start Point	8	5	
Stop Point	572	449	

Number of Pixels 251,108

Area of Rectangle 18.6 in*in

Color	Intensity [%]
Average Red	58
Average Green	63
Average Blue	53

Picture 4.png is 612 by 514 pixels

Method 2: Polygon Tool

1. Draw a polygon around the object using the Polygon tool. Click on the image to place each corner of the polygon. Note: you may draw up to 20 corners to define a polygon. A warning appears after the 19th corner is drawn.

2. To adjust the size or shape of the polygon, click near a corner and drag.

Spatial tools measure the color and size of features in digital images. Measure features observed in three versions of the image: the original image, a color enhanced image, or a masked image (a range of color are highlighted in black).
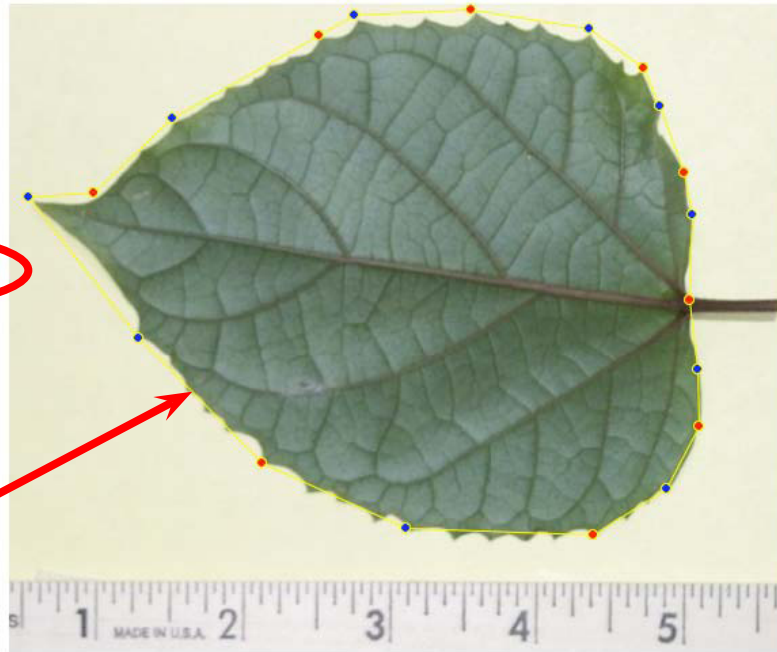
Select Image to View and Analyze
◉ Original   ○ Enhanced   ○ Masked

Polygon Tool

Number of Pixels   155,339

Area of Polygon   11.49 in*in

Color	Intensity [%]
Average Red	37
Average Green	45
Average Blue	37

Picture 4.png is 612 by 514 pixels

If this method provides a sufficient precision for your needs, save your measurements and process your next picture.

Method 3: Masking Colors

This method provides the most precise area measurement provided the color of the feature is sufficiently uniform and different from the surrounding features.

Selecting a color range or relationship to isolate specific features is called "masking".

1. To set a color range, go to the "Mask Colors" window and draw a rectangle inside the feature of interest. To adjust the size of the box, click and drag the blue or red corner of the box. The range of colors inside the rectangle is automatically selected.

Use only two colors, black and white, to show which pixels passed your color tests. Black pixels passed the color tests, white did not.

The resulting black and white image, or mask, may be used with the "area" spatial tools (rectangle and polygon) to calculate the area of specific features that have been isolated from its surroundings.

There are two types of masking tests:
1) Test the magnitude of colors. Select the range of color intensities, and pixels with colors within these ranges are turned black.
2) Test the relationships between colors. For example, highlight pixels that have blue intensities at least twice as great as red values.

TIP: To adjust the selected range of colors, click and drag the minimum (min)

or maximum (max)

lines for red, green, or blue intensities.

Select Image to Mask

( ) Original   ( ) Enhanced

☑ Red   Min 19   Max 57

☑ Green   Min 21   Max 64

☑ Blue   Min 11   Max 59

Apply Mask

Drag max/min values on graphs above or drag area on digital image.

Picture 4.png is 612 by 514 pixels

When zoomed in, pan around

TIP: Using the histograms of colors, which represent the frequency of color intensities for the complete image, you may decide only one or two colors are best to use to mask the image.

To ignore a color during masking, toggle the check box to off by clicking on it.

2. Click "Apply Mask" to blacken all pixels with colors within the selected range of colors. Pixels with colors outside this range will turn white.

TIP: To see if the desired feature has been accurately masked, click on the radiobutton labeled "Original". To see the mask again, click the "Show Mask" button. Compare boundaries of the feature in both images.

Use only two colors, black and white, to show which pixels passed your color tests. Black pixels passed the color tests, white did not.

The resulting black and white image, or mask, may be used with the "area" spatial tools (rectangle and polygon) to calculate the area of specific features that have been isolated from its surroundings.

There are two types of masking tests:
1) Test the magnitude of colors. Select the range of color intensities, and pixels with colors within these ranges are turned black.
2) Test the relationships between colors. For example, highlight pixels that have blue intensities at least twice as great as red values.

Select Image to Mask

(•) Original   ( ) Enhanced

☑ Red   Min 6   Max 57

☑ Green   Min 11   Max 64

☑ Blue   Min 4   Max 58

Show Mask

Drag max/min values on graphs above or drag area on digital image.

2) Create Relationship Mask

Picture 4.png is 612 by 514 pixels

Zoom In   Magnification: 0.93%   Zoom Out

When zoomed in, pan around the image by using the arrow keys or hold the SHIFT key and click and drag the image.

3. Another way to mask colors is to create a mathematical relationship between red, green, and/or blue at each pixel. Use this feature if the range of colors cannot isolate the desired feature. Note that this option takes much longer to process the image than the first masking option, so be patient when applying.

Create a Mask based on Relationships between Colors of a Digital Image

Create color relationships to identify spatial and spectral relationships in digital images.

This is a slow process, and for large digital images, it can be dramatically slow. Consider trimming the size of the digital image to identify the best relationship before applying to the original, full-size image.

Example: Show the pixels with more than twice as much red as blue:

1 x Red + 0 x None >= 2 x Blue OR 1 x Red * 0.5 x Blue >= 1 x None

Example: Show the pixels where the red values are within 5 of green:

1 x Red +/- 5 x None = 1 x Green

[1] x [Red] [+] [0] x [Choose C...] [<] [1.5] x [Green]

NOTE: To increase the flexibility for this tool, pixel values range from 0-255 rather than the previous 0-100%, respectively.

[Apply Relationship Mask]   [Close Window]

4. When satisfied that the mask isolates the feature you want to measure, return to the "Spatial Analysis" window and use either the Rectangle or Polygon tool to draw around just the highlighted feature. Notice that the blackened pixels of the ruler are not inside the rectangle drawn below – these will not be counted in the area calculation.

Note that when using the Masked Image (see highlighted below), the area of the masked pixels inside the box or polygon is calculated (the white pixels are ignored). Using the other images, Original and Enhanced, the area tools calculate the area of the total pixels inside the drawn shape.

Spatial tools measure the color and size of features in digital images. Measure features observed in three versions of the image: the original image, a color enhanced image, or a masked image (a range of color are highlighted in black).

Select Image to View and Analyze
○ Original   ○ Enhanced   ● Masked

[Rectangle Tool]

	Pixel Position		Adjust
	X	Y	
Start Point	14	6	
Stop Point	556	435	

Number Masked Pixels   150,121

Area of Masked Pixels   11.11 in*in

Color	Intensity [%]
Ave Red of Mask	35
Ave Green of Mask	44
Ave Blue of Mask	35
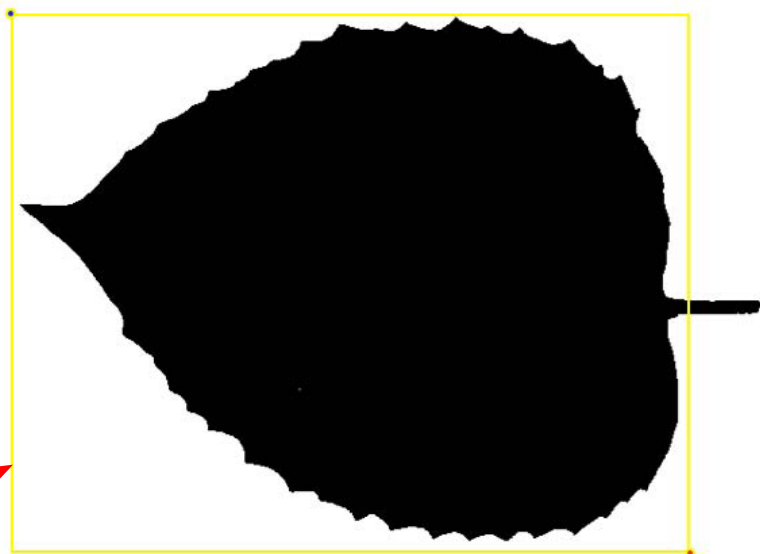
5 1 2   3   4 . 5

Picture 4.png is 612 by 514 pixels

Comparing the area using the polygon (11.49 in^2) and the masking tool (11.11 in^2), one would use the masking tool to study daily growth of leaves during the springtime.

Augmenting the Masking Colors by Enhancing Colors First

If it is difficult to isolate the feature from the surrounding colors using the mask tools, use the tools on the "Enhance Colors" window to change the colors of the image prior to using the mask tools. There are two sets of color enhancement options: first are the pre-defined options and the second are to create your own color alterations.

Picture 4.png is 612 by 514 pixels

1. Preset Enhancements

There are 7 preset enhancements to view the digital image, and these are very useful to survey the colors of an image: RGB, Red (gray), Green (gray), Blue (gray), Red v Green (normalized), Red v Blue (normalized), and Green v Blue (normalized)

Red-Green-Blue (RGB): Standard color composite of digital imagery in which the color intensities of red, green, and blue are displayed in the computer display's red, green, and blue, respectively.

The image should look the same as the object you photographed.

Red, Green, or Blue as shades of gray: Gray shade images allow you to examine the intensities of values without biasing your sensitivity to red, green, or blue. If blue is being displayed as gray (shown in image on right) then high intensities appear white, and low intensities appear black.
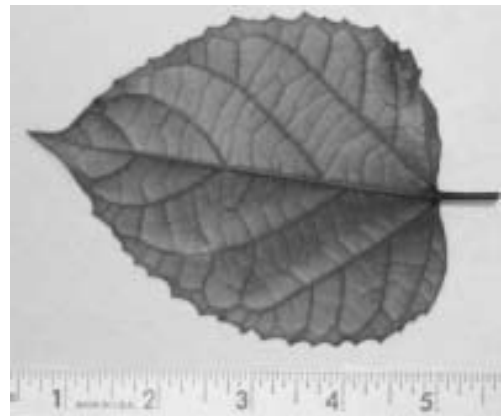
Red versus Green, Red vs. Blue, or Green vs. Blue (normalized): Provides a comparison of two color intensities. The difference of the color intensities is divided by the sum of the color intensities. The displayed color is the greater of the two intensities. Equal intensities are displayed as black. This enhancement minimizes the effects of shadows and uneven lighting across the image.

For example, suppose Red vs. Green (normalized) is selected (shown above). If a pixel has red, green, and blue (RGB) values of 40%, 80%, and 60%, respectively, the difference between red and green is 40% in the green, and the sum of the red and green intensities is 120%. The normalized value will be 40% / 120% or 0.33, which is converted back to percent values of 33% for display purposes. The displayed color for that pixel will be a dark shade of green (RGB values of 0%, 33%, 0%). Compare this value to another pixel with a difference between red and green of 40%, but in this case the pixel has RGB values of 0%, 40%, 20%. The normalized difference is 40% / (0% + 40%) which equals 1. This value is converted back to a percentage of 100%. The pixel will be displayed as a very bright green (RGB value of 0%, 100%, 0%).

2. Custom Enhancements

The second option to enhance the colors of an image is to select a range of colors and either *limit* or *stretch* this range of intensities.

Limiting

Limiting to only that range of selected intensities turns off that color for pixels outside this threshold.
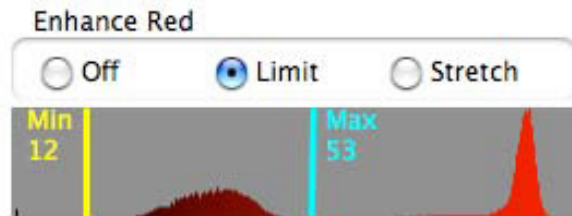
Clicking and dragging the yellow and cyan lines selected the red intensities between 12 and 53. The reds within this range represent the leaf.

By displaying only those red colors within this range (the limit option), the leaf remains the same but the background turns a cyan color because the more intense red values of the background have been turned off.

Stretching
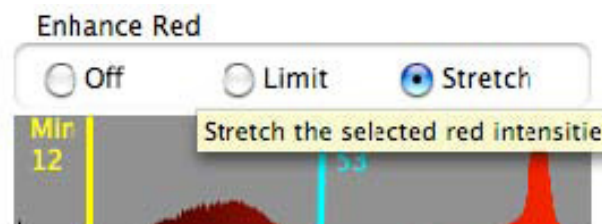
Stretching a range of color produces a similar effect for colors outside the selected range – those colors are turned off, but the selected colors are linearly expanded from 0% for the minimum intensity to 100% for the maximum intensity.

When the same values are stretched, the selected reds in the leaf become exaggerated, changing just the color of the leaf to redder hues.

Turning "off" a color for enhancement speeds up the processing time since it will be ignored.

Regardless of which enhancement method is used, the color enhanced image may be manipulated in the masking tool by selecting the Enhanced image button.

Use only two colors, black and white, to show which pixels passed your color tests. Black pixels passed the color tests, white did not.

The resulting black and white image, or mask, may be used with the "area" spatial tools (rectangle and polygon) to calculate the area of specific features that have been isolated from its surroundings.

There are two types of masking tests:
1) Test the magnitude of colors. Select the range of color intensities, and pixels with colors within these ranges are turned black.
2) Test the relationships between colors. For example, highlight pixels that have blue intensities at least twice as great as red values.

Select Image to Mask
○ Original   ● Enhanced

☐ Red

☑ Green   Min Max
          7   13

☐ Blue
Uncheck to ignore blue intensities during masking (saves time)

Apply Mask   Drag max/min values on graphs above or drag area on digital image.
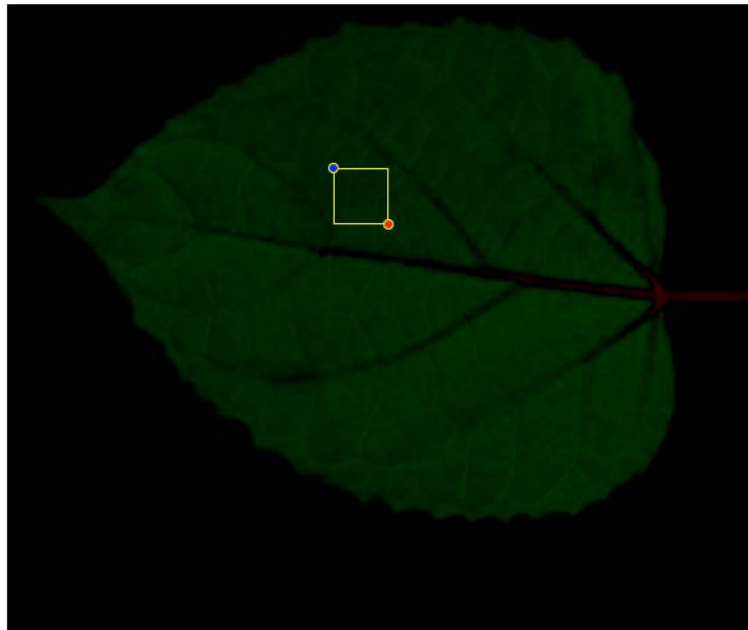
Picture 4.png is 612 by 514 pixels

When zoomed in, pan around

Quick Reference Guide for Length and Area Measurements with Digital Images

1. Calibrate pixel size when opening the image.
   - Scale present in image: click and drag to draw a line along scale and enter length.
   - Test you calibration by measuring object of known length in image.

2. To measure lengths, go to the Spatial Analysis window, select the Line Tool, and measure lengths by clicking and dragging a line along a desire feature.
   - Save measurements to a text file for later analysis with Excel or another spreadsheet program.

3. To measure areas, there are 3 options.
   a) In the Spatial Analysis window, use the Rectangle tool for very rough estimates or for objects that have a rectangular shape that are oriented parallel to the edges of the photograph.

   b) In the Spatial Analysis window, use the Polygon tool to draw a polygon around the object.

   c) Use the Mask Colors window to isolate the colors of the desired feature from its surroundings. Use the masked image in the Spatial Analysis window with either the rectangle or polygon tool to convert the masked pixels to an area measurement.

   When the colors of the desired feature are similar to the colors of the surroundings, use the tools on the Enhance Colors window to alter color relationships. The enhanced image may be used with the Mask Colors window, allowing for a greater chance the feature may be highlighted for an area measurement.

5. Exploring & Measuring Light

Introduction

It is now possible with inexpensive technology to measure the intensity of specific wavelengths of light. Light Emitting Diodes (LEDs) were invented in the 1960s. An LED is a device in which electrical energy is converted into light in a very narrow range of wavelengths. They have been refined over the years, becoming smaller, more intense, and emitting light at a greater variety of wavelengths than ever thought possible.

An LED can also operate in reverse: it can convert light energy of a particular wavelength into electric current. The amount of current is proportional to the intensity of light shining on the LED. The wavelength of light needed to produce this effect is approximately the same as the wavelength of light that the LED normally produces when operating in the electricity-to-light mode, but not identical. An LED that emits red light can actually generate electricity from light in orange wavelengths.

Investigation

LEDs as Light Sensors

Part 1: Parts of the LEDs

Make sketches of each LED from the top and two views from the side (perpendicular to each other). What are the differences and similarities between the two LEDs?

Materials:
- Digital multimeter with alligator clips
- 2 LEDs: IR and Red

IR LED Top	Side 1	Side 2

Red LED Top	Side 1	Side 2

The wavelength of light generated by the LED is controlled by the width of the slot in the metal plate (visible from the side views). Light is emitted from the cup at the top of the LED.

Part 2: Testing the LEDs

- Start with the red LED.
    - Connect **one** 1.5 volt battery to the LED.
    - Battery's _positive_ end connects to the LED's _longest_ wire.
    - Battery's _negative_ end connects to the LED's _shortest_ wire.

        NOTE: LEDs may be damaged or destroyed by using more than one battery in series or by connecting them in reverse with the positive charge going to the shortest wire of the LED. It is customary to use a red wire to connect to the positive end of a battery and a black wire to the negative end.

    When properly connected, red light will be emitted from the LED's top. See photo.

- Now the IR LED.

Repeat the procedure above.

    Do you see anything emitted? Does the LED get warm when hooked up? Did the Red LED?

    How can we see if it works? Interestingly, a digital camera can detect IR. Use a digital camera with an LCD screen to detect IR. Turn the camera on, point it toward the top of the IR LED after the battery is connected. What do you see?

    If you have a TV remote control handy, try pointing it toward the camera, press a button on the remote control. TV remotes work by sending out pulses of IR.
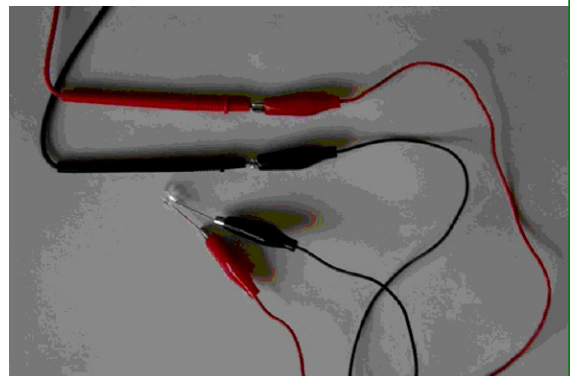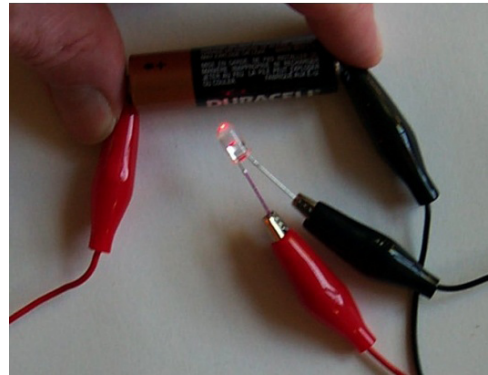
Part 3: Measuring Light with LEDs

- Connect the red alligator clip from the positive (long) wire of the LED to the red wire of the multimeter. Connect the black clip to other end of the LED and to the black wire of the multimeter. Connect the clip in the same way as the photo in order to minimize the chances of wires touching when using the instrument.

- Turn on the multimeter to the voltmeter that measures up to 2 volts.

- Point top of LED toward a bright light and observe how much voltage the LED creates.
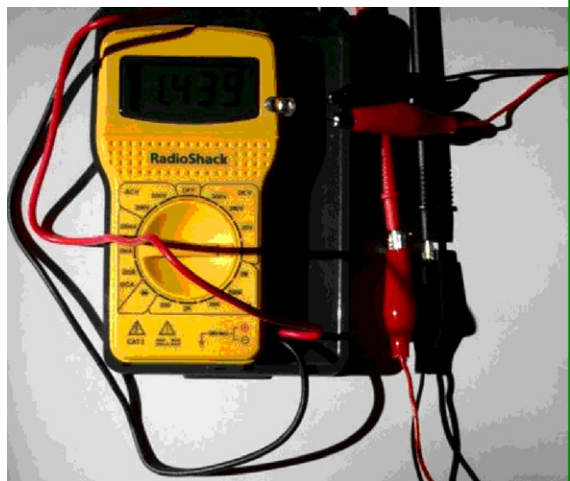
Part 4: Angle of Sensitivity

Using either a light bulb or a red laser, point the top of the LED toward the light source. Slowly rotate the LED to see at what point the voltage on the multimeter drops significantly. Measure this angle for the red LED. If using a red laser, does the IR LED generate any electrical current? Use an incandescent light to test the IR LED.

LED	Angle of Sensitivity
Red	
IR	

If you have straws that fit over the LEDs, create a sleeve to let only light hit the top of the LED. Test with the LEDs you just used. Does this affect the angle of sensitivity?

Part 5: Measure Light Sources in the Classroom

Locate several different types of light sources in the room, for example, regular light bulbs (incandescent), fluorescent light bulbs, halogen bulbs, the source of light for an optical scanner, LEDs on various electronic equipment. Using either tape measures or the tile on the floor (typically 1 foot squares), systematically record the current generated by several of these light sources from various distances away.

Measuring Light Sources in the Classroom

Light Source	Distance	Voltage from Red LED	Voltage from IR LED

Although these instruments cannot measure the magnitude of red and IR light being emitted from these light sources, are you surprised at how much IR is given off by light bulbs? IR is heat energy and does not contribute the visible light of a light source. In that sense, IR is wasted energy for a visible light source.

Part 6: Measure Warm and Cold Things

How much IR and red does your hand emit? How about a hot pad? Ice?

Using a box, place a warm or cold source in the box and place the LED into the box with the LED still connected to the multimeter outside the box. Make sure the top of the LED is pointing toward the object being measured. You may need to use tape, string, or wire to hold the LED in place. You could also use a dark closet and have a student hold the LED and another record the observation while standing outside the closet.

Warm and Cold Things

Object	Voltage from Red LED	Voltage from IR LED

Although our bodies do emit IR, the wavelengths are in the *far* or *thermal* IR region. The IR being detected with these LEDs is in the *near* IR region, which is generated from very hot light sources. All objects emit light, but cooler objects emit light of longer wavelengths. Hotter bodies emit light of shorter wavelengths. For example, blue stars are hotter than red stars (blue is a shorter wavelength than red).

Part 7: Measuring Reflection, Transmission, Absorption

Although these instruments cannot measure actual light magnitudes, they can be used to measure the *percentage* of reflectance, transmittance, and absorption of light from an object.

• First, determine that the object does not emit light (test in dark room).

• Second, measure the voltage generated by incoming light (use sunlight).

• Third, measure the voltage being reflected off the object. The percent of light reflected is the voltage from reflected light / voltage from incoming light.

• Fourth, if you can get behind the object, say it is a leaf or a piece of paper or fabric, measure the voltage of light traveling through the object. The percent of light being transmitted through the object is voltage from transmitted light / voltage from incoming light

• Finally, the light being absorbed from the object is

Light absorbed = 100% - %reflected - %transmitted.

Part 8: Measuring Reflection of Land Covers

Go outside with your instruments, preferably on a sunny to partly cloudy day.

First, measure the intensity of the sunlight by pointing the LED toward the Sun.

    Do not look directly at the Sun while doing this.

    Estimate your pointing by either:

    (a) watching the voltage and moving the LED to find the maximum value, or

    (b) looking at the shadow of the LED on the ground—the smallest shadow of LED will mean it's pointing directly at Sun.

Second, point your LED at the ground and record the voltage and the surface type. If you have a partly cloudy sky, continue to measure the intensity of sun light before each measurement.

Measure a variety of surfaces. Record your observations and measurements.

Reflection of Land Covers						
Surface Cover	Voltage of Red LED from sunlight	Voltage of Red LED from reflected light	Reflected Red Light [%]	Voltage of IR LED from sunlight	Voltage of IR LED from reflected light	Reflected IR Light [%]

1973

1985

1990

1997

Muskingum mines, Ohio
1973, 1985, 1990, 1997

These images show coal mining in eastern Ohio. In these images vegetation is red, water is black to dark blue, and the mines are bright gray. Federal Law requires the restoration of mined lands to their approximate original contours and that reclaimed land support either the same or better land uses than it supported before mining. To meet this requirement the Muskingum mines, as well as other mines, are replanted to grassland, for agricultural use. The mining company replaces the topsoil, grades the soil, and applies grass seed and mulch.

Satellite images
LM1019032007324690 (Landsat 1 MSS, 3 September 1973)
LM5018032008519990 (Landsat 5 MSS, 18 July 1985)
LM5018032009022990 (Landsat 5 MSS, 17 August 1990)
LT5018032009718410 (Landsat 5 TM, 3 July 1997)
*024009220810 (Landsat 4 TM, 26 July 1992)*

6. Spectral Analysis

Introduction

The word *spectral* can mean "ghostly," but we are using its other meaning which relates to the rainbow of color formed when all the energies of white light are spread out and arranged in order. Similarly, the electromagnetic spectrum is an ordered arrangement of invisible radiation with energies ranging from high energy gamma rays to the longest low energy radio waves and including visible light (see diagram at right). Electromagnetic energy is colorless—we see colors in visible light only because of functions going on in the eyes and brain.

Space satellites have cameras/sensors to detect energies invisible to our eyes, but to analyze them it's helpful to display those energies as visible light computer monitors. For just one value of electromagnetic energy we could use shades of gray that give brightness information ranging from black representing no brightness to white representing very bright. Color monitors display all colors as combinations of three colors: red, green, and blue (RGB), so with a color monitor, each of those three colors can represent a different invisible electromagnetic energy. The displayed colors can help us identify physical properties of objects, Earth's surface, gas components of the atmosphere, even the Earth's magnetic field, depending on what type of camera/sensor is used.

Electromagnetic Spectrum

Longer wavelengths correspond to lower energies.
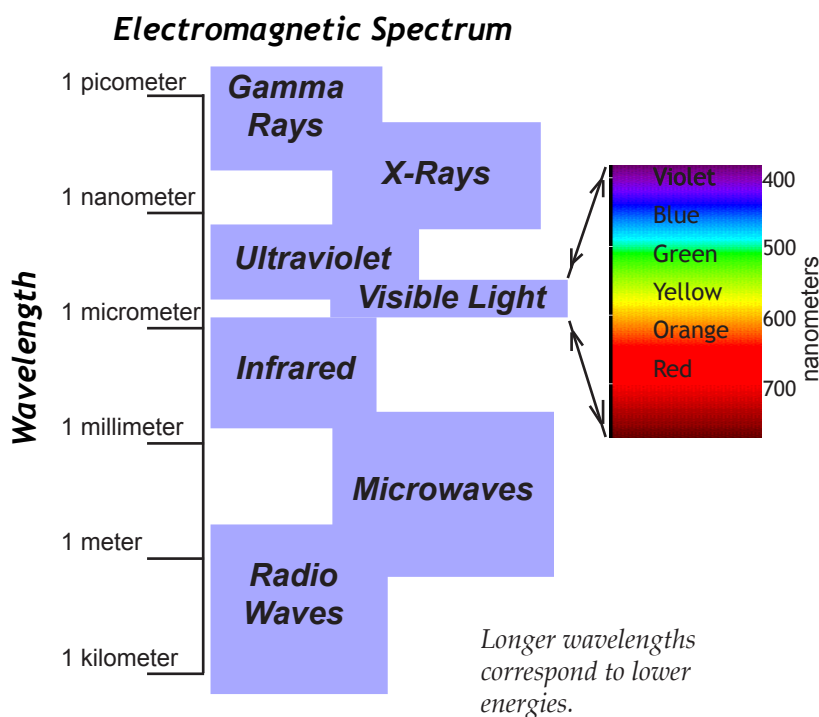
The investigation False Color Surface Features is also a portion of the investigation **Satellite Views of Rondonia, Brazil,** *in the GSS book* **A New World View**, *Chapter 5.*

Investigation
False Color Surface Features

Part 1: False Color

Start the *DigitalImageBasics* program, click the *False Color* button, and open Satellite image 4. This was a 1973 picture of Mt. St. Helens in southwestern Washington recorded by sensors on Landsat, the first satellite to measure and monitor land resources. The sensors could measure a number of narrow bands of electromagnetic radiation, but only three are available for this image: infrared, red and green light. The only visible energies though are red and green.

Start with the following settings for *Computer Color* and satellite *Measured Light*:

Computer Color: Red   set for Measured Light: Red
Computer Color: Green set for Measured Light: Green
Computer Color: Blue   set for Measured Light: none (off)

Question 4.1. In this "blue-less" world, what features can you see and how can you tell what they are?

Just for fun, make the satellite *Measured Light* red show up as *Computer Color* green and vice versa—satellite *Measured Light* green show as *Computer Color* red. You're starting to create "false colors!"

Now make the invisible energy, infrared, visible. Assign the invisible infrared energy *Measured Light* data to a *Computer Color* as a "false color" that we can see: red, blue, or green. Try different ones.

Question 4.2. How does the intensity of the infrared data compare to that of the visible red and green light?

Part 2: Reflectance of Surface Features

Use the following pictures to complete the table below. Change the way you display the satellite data to see how much each set of measurements is contributing to the combined intensities within the image.

Satellite image 4 - MtStHelens_1973: volcano in Washington State

Satellite image 5 - Rondonia_1975: tropical rain forest in Brazil

Satellite image 6 - GreatSaltLakeUtah_1987: city, lake, and desert in Utah

OrlandoDisney_1986.jpeg: city and large developed area in Florida

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Common way to view Landsat imagery

Although Landsat satellite measured many wavelengths of the electromagnetic spectrum, three energy bands are commonly used: infrared, red, and green. Most scientists use the following false color scheme that makes *ALL* the energies false color:

Computer Color: Red   set for   Measured Light: Infrared
Computer Color: Green set for   Measured Light: Red
Computer Color: Blue   set for   Measured Light: Green

Task: Using the *DigitalImageBasics* program, *False Color* button, rank the intensities of reflected infrared, red, and green light from the list of surfaces.

5 = maximum reflected values, 0 = no reflected light.

Surface Cover	Infrared	Visible Red	Visible Green	Color in Standard Landsat Imagery
Forest				
Lawns				
Crops				
Water				
Snow				
Cloud				
Rock / Soil				
Buildings				
Paved Roads				

Part 3: Analysis with Color Subtraction

1. Using the *AnalyzingDigitalImages* software, open *MtStHelens_1973.jpeg* with either *File: Open Picture* or by clicking the *Open a Picture* button. The volcano violently erupted in 1980, creating dramatic changes to the vegetation around the volcano.

2. Click the "Enhance Colors" button and try different selections in the dropdown menu "Show Original or Select Enhancement" to examine the relative intensities of infrared (IR), and Red (R) and Green (G) light reflected from the Earth's surface and displayed in the image on your screen.

   The first option (Original) is a standard color composite of Landsat imagery with infrared (IR) displayed as the computer display's Red color, visible Red displayed as the computer's Green, and visible Green displayed as the computer's Blue.

   The next 3 options show IR, Red, or Green as a gray shade and allow unbiased viewing of the intensities of each of these satellite measured light values individually.

   The next option, Gray Image of Average Intensities, is a composite gray scale image.

   The remaining options allow you to quickly see which surface features reflect greater amounts of IR (computer red), Red (computer green), or Green (computer blue) light. They display the difference between two colors, with the color of the *greater* value is displayed and ***brighter*** colors showing ***larger differences*** and ***darker*** colors indicating little difference. The term "*normalized*" indicates that the color value for each pixel is not simply one color subtracted from another, but a formula is used to minimize difference in illumination of the surface caused by shadows of clouds and slope of the land surface that cause uneven illumination of the surface by the Sun.

   Example: In "Red vs Green (Normalized)" the formula is

   $$\frac{\text{(Intensity Red - Intensity Green)}}{\text{(Intensity Red + Intensity Green)}}.$$

Keep in mind:

(a) the color of the greater value is displayed.

(b) the displayed colors are Computer colors and represent actual satellite data by the Landsat standard scheme:

   Computer Red = Satellite sensor IR.

   Computer Green = Satellite sensor Red.

   Computer Blue = Satellite sensor Green.

   In the example Red vs Green, if a pixel has 10% IR and 20% Red, the difference is 10% and will be displayed in the computer's Red, since the larger value is IR which corresponds to computer Red. The normalized difference is 10% divided by 30% = 0.33. This value is scaled to 33 and will be displayed in the computer's Red. Compare this to 10 displayed earlier.

Question 4.3. See if you can use the enhancement functions to better discern features in the Mt. St. Helens image. Explain what features are easier to see and what you think those features are.

Part 4: Back to Spatial Analysis

Click on the Spatial Analysis button. By way of review, see if you can use the Pixel, Line, Area, and Polygon tools to answer these questions:

Question 4.4. What are the maximum and minimum x and y values you can find on the satellite image?

Question 4.5. Using the small white square, which represents one mile along each edge, in the lower left of the image, what is the number of pixels that represents 1 mile? Assuming the edge of one pixel touches the edge of the neighboring pixel, what is the size of one pixel? How many pixels represent 10 miles?

Question 4.6. This image is oriented so that north is up and east is to the right. The east-to-west and north-to-south extents of the satellite image are how many miles? What is the distance from the upper-left corner to the lower-right corner of the image? Hint: you will need to use the Pythagorean Theorem if you are using the pixel analysis tool or you may use the line length in pixels output from the line analysis tool.
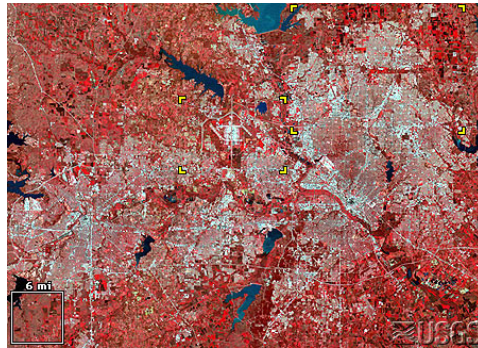
Question 4.7. What is the greatest distance across the snow cover observed on Mt. St. Helens in the lower left corner of the satellite image?

Question 4.8. What is the greatest width across the lake observed in the left center of the satellite image? What is the greatest length across the lake?

Dallas, Texas 1974
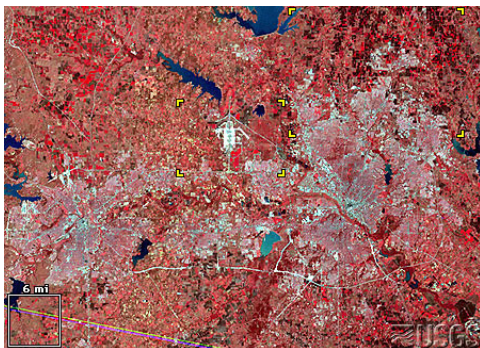
Dallas, Texas 1989

These images show the Dallas - Fort Worth metropolis, in northeast Texas. This city grew significantly, from 2,378,000 in 1970 to 3,776,000 by 1988. These images show the urban/suburban areas expanding into arable land in the countryside.

Satellite images
LM1029037007407190 (Landsat 1 MSS, 12 March 1974)
LM5027037008908190 (Landsat 5 MSS, 22 March 1989)

Special Challenge: Go to the EOS Webster Landsat "Click n Pic" page http://mvh.sr.unh.edu/Landsat/ and find a more recent image of the Dallas - Fort Worth area to compare with the images on this page. Also, can you find a series of images for your own city or town?

7. *Temporal Analysis of Satellite Images*

The word *temporal* means "of or relating to time." The images of Dallas at the end of the previous chapter show how satellite images captured at different times can reveal very important things to us.

Western Las Vegas in 1986 (above) and 1992 (below).

These images show the rapid growth of Las Vegas, Nevada. This is by far the fastest-growing metropolis in the United States. The population grew in the last century as follows:

1964:   127,000   1986:   608,000

1972:   273,000   1992:   863,000

1997:   1,124,000

These are the same kind of standard false-color images that appear throughout Earthshots (*http://edcwww.cr.usgs.gov/earthshots*), simulating color-infrared aerial photographs. Remember "R-G-B = IR-R-G": red, green, and blue in the image represent how much infrared, red, and green solar energy the ground reflects.

As the city expands you can see a sort of landcover succession through human construction.

• Pre-construction land appears medium gray-green indicating sparse desert vegetation, reddish soils, and stone.

• Construction land appears brighter. Bulldozed soil, bare of vegetation, is very reflective.

• A young neighborhood appears medium green (medium green) again, perhaps a bit brighter from all the reflective pavement and roofs. The trees are small, and some developments now conserve water by landscaping with rock and desert plants rather than grass.

• An old neighborhood appears dark, brownish red, from the mature trees and more grass.

• Golf courses appear bright red because they are the most intense vegetation.

• Water appears almost black because at this angle it scatters little light back to the Landsat sensor.

Satellite images

The 1972, 1986 and 1994 scenes are from the NALC dataset.

LM1042035007225790 (Landsat 1 MSS, 13 September 1972)

LM5039035008625390 (Landsat 5 MSS, 10 September 1986)

LM5039035009225490 (Landsat 5 MSS, 10 September 1992)

Chernobyl, Ukraine
1986 (above), 1992 (below)

A devastating nuclear accident happened at Chernobyl, Ukraine, on 26 April 1986. These images show the area around the nuclear power plant approximately <u>one month after</u> the accident, and <u>six years after</u> the accident. This area is near the common borders of <u>Ukraine, Belarus, and Russia</u>.

The images clearly show farm abandonment. Agriculture appears as a collage of bright red (growing crops) and white (highly reflective bare ground). Many of these areas appear a flat tan-green in 1992, indicating natural vegetation which has taken over the abandoned fields. While the reactor was still on fire, all settlements within 30 km were evacuated, including Pripyat (1986 population 45,000), Chernobyl (1986 population 12,000), and 94 other villages (estimated total population 40,000). As of 1992, this area remained almost completely abandoned.

The radiation also affected wild plants and animals around Chernobyl. Pine forests soon died, cattails grew three heads, and wild animals declined in number. But in the coming years, as the short-lived radionuclides decayed and the longer-lived contaminants settled deep into the soil, the wildlife rebounded. Human abandonment also made habitat available for birds, deer, rodents, wolves, boar and other animals. These populations appear to be increasing despite the extraordinarily high mutation rates caused by contamination in the food chain and by one of the highest background radiation levels in the world.

Satellite images

<u>LT5182024008615110</u> (Landsat 5 TM, 31 May 1986)
<u>LT4182024009220810</u> (Landsat 4 TM, 26 July 1992)

NDVI: A Measure of Vegetation

One way to identify different surface covers has been to compare the intensity of the infrared to the visible light being reflected from the Earth's surface. An early technique was to subtract the visible red from the infrared intensity. Since vegetation reflects more IR than visible light, the difference between IR and red is an indication of vegetation cover—a sort of "Difference Vegetation Index." This works well for ground without steep slopes, but for steep surfaces, there is a shadow effect: some areas reflect different intensities of light just because of their slope. But the *percent* of light reflected is the same, regardless of the intensity of light, so one way to eliminate the shadow/slope problem is express the Difference Vegetation Index as percent by dividing the difference between IR and red intensities by the total light being reflected. This technique is called *normalization*, and the scheme, which is commonly used to identify the amount of vegetation cover, is called the "Normalized Difference Vegetation Index" or **NDVI**.

Normalized Difference Vegetation Index

$$\text{NDVI} = \frac{\text{IR intensity - Red intensity}}{\text{Total light intensity}}$$

Changes in Mt. St. Helens

Use VegetationAnalysis software to observe and measure changes in Mt. St. Helens before and after the great eruption of 1980.
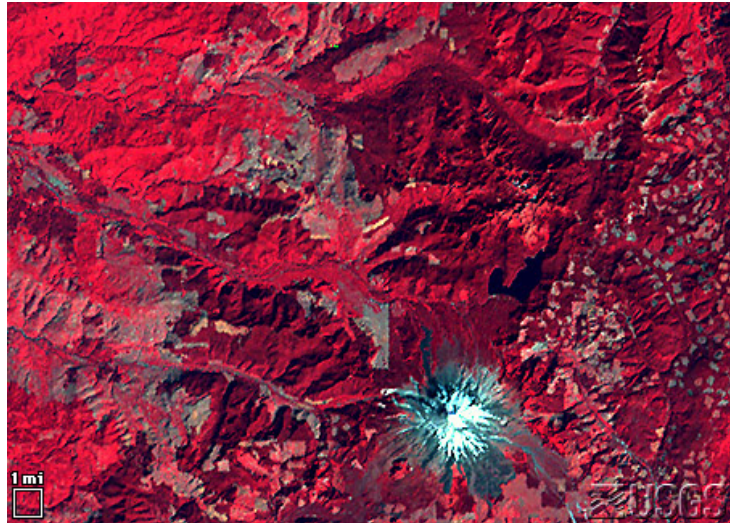
Materials

VegetationAnalysis software

3 images of Mt. St. Helens

MtStHelens_1973.jpeg

MtStHelens_1983.jpeg

MtStHelens_1996.jpeg

The Tools

1. Launch the VegetationAnalysis software and open the 3 images of Mt. St. Helens. Calibration procedure automatically looks for a white box in the lower right of the images. Just follow the Scale Calibration instructions that pop up automatically in the window on opening of the image files. Then familiarize yourself with the tools described in steps 2–6.

2. Use the menu to the right of 'Visualization' to toggle between an RGB picture and a NDVI enhancement. The following is a summary of NDVI values for common surface types:

NDVI	Surface Cover
+1	Vegetation
0	Exposed soil or rock
-1	Water, snow, clouds

3. With **Point Analysis Tool** in the menu button to the right of 'Analysis Tool', explore intensities of infrared, red, and green light and the vegetation index, NDVI, at the same pixel for each satellite image.

– Intensities are scaled from 0 to 100%

– Move the cross hair in three ways:

   (a) Click the mouse on an area of interest

   (b) Click and drag the mouse to an area of interest

   (c) Use the small up and down arrows along the upper-right edge

4. With the **Line Analysis Tool** in the menu button to the right of 'Analysis Tool',

• Click and drag the cursor to draw a line.

 – Move ends of line in similar way as the Point Tool.

• NDVI values for pixels along the line are graphed.

• The number of pixels along the line and length of line are automatically calculated.

• Average NDVI is calculated and color-coded by the year of each image.

 – Move cursor to each satellite image to see yearly data on the graph.

 – To see all data, move the cursor to the graph window.

5. With the Area Analysis Tool

- Click and drag the cursor to draw a rectangle.

   Move ends of line in similar way as the Point and Line Tools.

- A histogram (graph) is created of NDVI values for all pixels inside the rectangles.

  - The histogram shows the percentage of values within narrow ranges of NDVI values.

  – Data can be viewed year by year when cursor is moved to each satellite image.

  – Change the range of min/max NDVI values to calculate the percent of NDVI values between the selected range.

- The number of pixels within area and size of the area are automatically calculated.

5. Page Setup and Print—To print the images and graphs, first use 'PageSetup' in the File Menu (Mac users). Select 'landscape' printing and set scale to 75%.

Questions

Question 6.1. Using the line analysis tool, measure the diameter of caldera formed by the eruption. A caldera is the crater formed by a volcanic explosion or by the collapse of a volcanic cone. Find the location (x,y coordinates) of the center of the caldera and compare this to the location of the center of the volcano as seen in 1973. Does this explain the direction where most of the volcanic ash fell?

   Combine this measurement with an interesting measurement reported on the USGS Earthshots web site to estimate how large an area of solid rock was turned into volcanic debris: "Before the eruption, Mount St. Helens towered about a mile above its base, but on 18 May 1980 its top slid away in an avalanche of rock and other debris. When finally measured on 1 July 1980, the mountain's height had been reduced by 1,313 feet— from 9,677 feet to 8,364 feet."

[From Foxworthy and Hill, 1982, p. 11. Lipman, Peter, W., and Mullineaux, Donal, R., (ed.), 1981, The 1980 Eruptions of Mount St. Helens: Washington, U. S. Geological Survey Professional Paper 1250, Washington, D. C. (844 p.), p. 134.]

Using the 1973, 1983, and 1996 images of Mt. St. Helens, fill in the following table.

Location		Year	NDVI	Surface Feature
X	Y			
319	180	1973		
		1983		
		1996		
321	167	1973		
		1983		
		1996		
278	257	1973		
		1983		
		1996		
167	77	1973		
		1983		
		1996		
186	89	1973		
		1983		
		1996		
276	206	1973		
		1983		
		1996		

Question 6.2. Can you make any generalizations from your observations and measurements? Explain.

Now that you have studied these three satellite images of Mt. St. Helens, read the accompanying article provided by the United States Geological Survey for a discussion of the observed changes around Mt. St. Helens. The article and additional pictures and maps can be found on the Internet at

http://edcwww.cr.usgs.gov/earthshots/slow/MtStHelens/MtStHelens

More ideas for investigations concerning temporal changes

• For another investigation concerning temporal changes, see *Satellite Views of Rondonia, Brazil* in the GSS book *A New World View*, Chapter 5. It explores deforestation of tropical rain forest in the Amazon.

• Visit the EarthShots website (http://earthshots.usgs.gov) to find many examples of investigations in temporal change.

• Visit the EOS Webster Click n Pic web page (http://mvh.sr.unh.edu/Landsat) to order up time series of LandSat images from any location in the USA.

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