Viewing New Hampshire from Space

A Bird's-eye View of the Granite State!

Introduction

Environmental changes are a major concern for researchers and policy makers today since these changes have both human and ecological impacts (Dodge and Congalton 2013). Locating and studying these changes has, until recently, been a challenge; requiring a significant amount of effort, time, and money. Remote sensing has made this process much more efficient and cost effective by utilizing imagery collected from aircraft and satellites to monitor and study both natural and human induced changes. Imagery collected by aircraft has been extensively used and still is today, but remotely sensed satellite imagery is becoming very popular. Satellites can collect images frequently and systematically, which means it can be used to monitor short term or long term changes (Dodge and Congalton 2013). Furthermore, we can view information about features on the ground that we may not otherwise have been able to see if looking at it in person. Today's sensors can capture multiple discrete wavelengths of light outside of the visible range our eyes can see in allowing us to observe phenomena that we may otherwise have not been able to see with our eyes alone.

For these reasons and more, public and private groups are beginning to understand the potential of this technology in a number of fields and thus geospatial sciences are becoming one of the most rapidly growing fields (Landengerger et al., 2011). In order to utilize all this information, the observer needs to understand how to interpret what he or she is seeing on the imagery since features within the imagery may not always look the way we see them in real life. The ability to interpret different ground features comes with a bit of training, but once learned can be utilized in a number of applications.

This document provides background and practice with remotely sensed satellite imagery. It is broken up into three parts. The first section covers the basics of remote sensing: what remote sensing is, what is being sensed, and how satellites work. The second section is a guided practice where readers will be shown various satellite images of common features with corresponding background information to help them understand the imagery. The final section is a self-test using the skills and information acquired. Throughout all three sections, the reader will be asked questions related to the material that they just read in order to test their understanding as well as encourage them to apply their own experiences and knowledge.

For additional information about satellite remote sensing, example applications, and case studies, please refer to *Meeting Environmental Challenges with Remote Sensing Imagery*. A PDF version of the book can be downloaded at the link provided below.

Suggested Publication:

Dodge, Rebecca L., and Russell G. Congalton. 2013. *Meeting Environmental Challenges with Remote Sensing Imagery*. American Geosciences Institute, Alexandria, VA. 82p. Download at: http://www.americangeosciences.org/sites/default/files/RemoteSensing.pdf

Reference:

Landengerger, Rick, Mark W. Patterson, Ramesh Sivanpillai, and Rick Lawrence. 2011. "America View: Promoting Remote Sensing Science and Technology Through Cooperative Partnerships." *Photogrammetric Engineering & Remote Sensing* 77 (10): 969–74.

This document was produced by NewHampshireView (Heather Grybas and Russell Congalton). For further information please email Russ Congalton at russ.congalton@unh.edu or visit http://www.nhview.unh.edu/. Funding for this work provided by Grant #G14AP00002 from the Department of Interior, United States Geological Survey to AmericaView. Contents of this work are the sole responsibility of the authors.

What is remote sensing?

Important Vocabulary!

Remote Sending – Learning something about an object without touching it

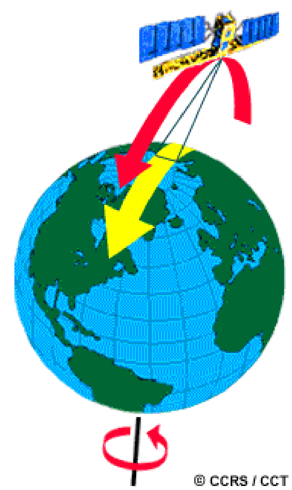
Sensor- a device that detects or measures a physical property and records, indicates, or otherwise responds to it.

Radiate- to give off energy from a specific source ex. The sun

Remote sensing is learning something about an object without touching it. We can use remote sensing to gather information about a number of things and we have different tools to help us. For example, many people are concerned about the environment and how humans are changing it because these changes can have negative impacts like polluted water or a decrease in the amount of wildlife because their habitats have been cut down or removed. Studying these changes is important but it would take a long time for you or me to go outside and find them all. This is where remote sensing can help. We can attach sensors to airplanes or satellites that take images of the earth from above so we can study the environmental changes that have occurred over a large area rather quickly.

a. Humans have five senses. Three of them could be considered a form of remote sensing. What are they?

Attaching **sensors** to airplanes has been done for many years, but airplanes can only fly when the weather is good and can also be expensive. Satellites orbiting the earth in space can continuously collect images of the Earth's surface regardless of the weather. As the satellite orbits around the earth from north to south, the Earth is rotating from east to west. This allows the satellite to take an image of a new area on the Earth with each rotation around the planet. Eventually, the entire planet will be covered and the satellite will start again. This process will continue for weeks, months, or even years! Over time we can collect hundreds of images of the Earth's surface from different times. We can look at a satellite image from a single day or we can compare images from different dates to see what has changed, much like you will do in these exercises. But before you can start you need some practice because satellite imagery has some special properties that you should understand so you know how to use it effectively.

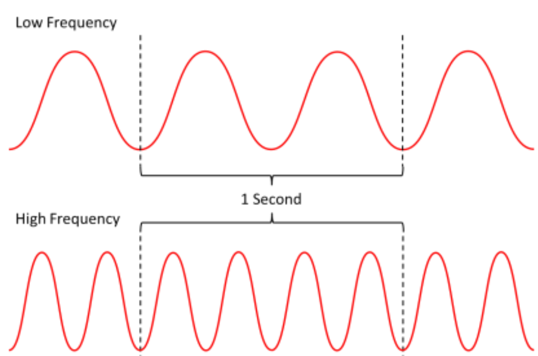


Source: Canada Center for Remote Sensing

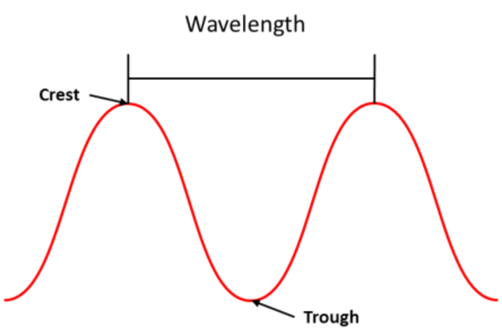
What is Being Sensed?

This may seem like an obvious statement, but we can only see an object because of light. Light is energy that **radiates** from a source, for example a light bulb or the sun. This energy is called electromagnetic energy and it is more important than you may realize. For example, when you watch TV, listen to the radio, or send a text message, you are using electromagnetic energy.

We do not tend to think about light as something that moves, but it travels from one place to another. It just moves so fast we cannot see this motion with our eyes. Electromagnetic energy is made up of charged particles and when they move, they move like a wave with high points called crests and low points called troughs. We can describe these waves using two important properties: frequency and wavelength.



Imagine for a second that you can see light as it moved. You would see each individual crest and trough as it passed by. If you had a stop watch



and counted the number of times a crest passed by you in a second, you would be calculating the frequency. **Frequency** is the number of crests that pass by a given point in one second; the more crests per second, the higher the frequency of that wave. **Wavelength** is the distance from the top of one crest to the top of the next crest. Wavelength and frequency are important properties of electromagnetic energy because it allows us to decide what type of energy it is.

Important Vocabulary!

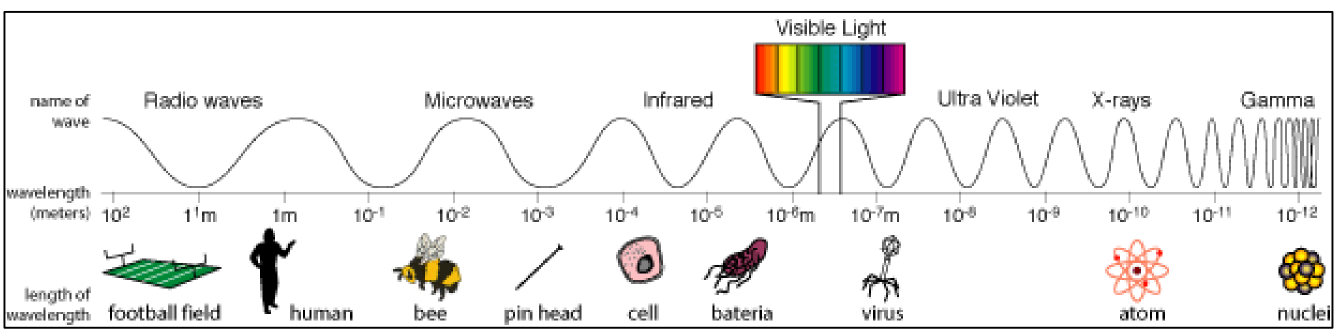
Frequency- The number of crests that pass by a given point in one second

Wavelength- The distance between the top of one crest and the top of the next

Electromagnetic Spectrum- The range of wavelengths and frequencies that electromagnetic energy exists within

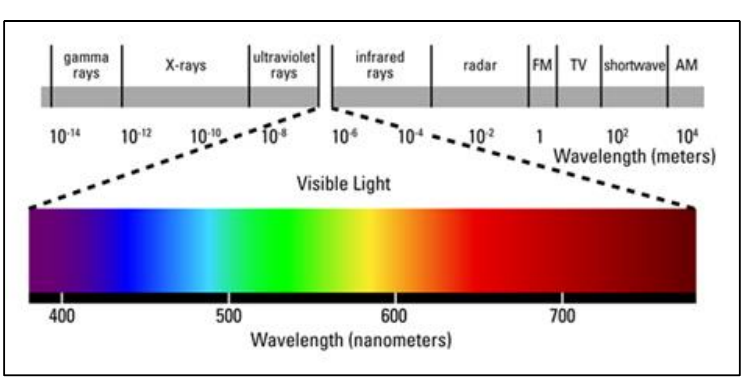
Visible Light – The range of the electromagnetic spectrum that contains wavelengths our eyes can see

Not all electromagnetic energy is the same. It can move with different frequencies and have different wavelengths. Scientists use the wavelength and frequency of the energy to group them like shown in the diagram below. This diagram represents the **electromagnetic spectrum**, or the range of wavelengths and frequencies over which electromagnetic energy extends. The objects under the wavelengths in the diagram below give us an idea of how long the distance between crests would be if we could see them. The spectrum ranges from the longest wavelengths (radio waves) to the shortest (gamma rays). We can use the wavelength to decide what group the energy should fall into. For example, if a particle of energy has a wavelength of 10^{-5} meters, it would be classified as infrared light. Now there are many types of electromagnetic energy that we can use for remote sensing, but for the satellite remote sensing we will be doing, we will focus on the visible and infrared light.



Source: http://science.hq.nasa.gov/kids/imagers/ems/

b. Do you recognize any of these types of electromagnetic energy? How might they be used in your daily life?
c. What is the relationship between frequency and wavelength?



Source: http://science.hq.nasa.gov/kids/imagers/ems/

We know radio waves exist because we can listen to our favorite music through our radios, but we do not see radio waves. When we turn on a lamp, however, we can see the light that comes out of the bulb. Despite this difference, these are both types of electromagnetic energy, so you may be asking yourself, “Why don’t I see all this energy around me?” That’s because our eyes can only see the light or electromagnetic energy from a very small portion of the electromagnetic spectrum known as **visible light** (see the figure to the left). Everything else

Important Vocabulary!

Refraction - Change in the direction a wavelength of light is moving after passing through an object

Reflect- to move in one direction, hit a surface, and then quickly move in a different direction

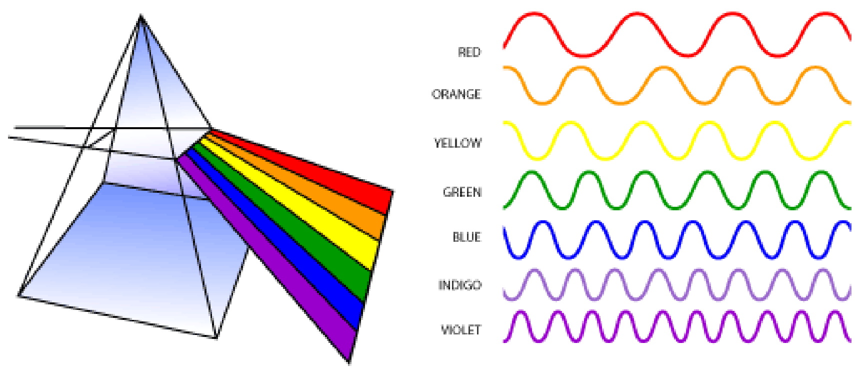
Primary colors – a set of colors that, when combined in different amounts, can produce all other colors.

falls outside of that range so we do not see them but they do exist and are around us every day. Visible light has wavelengths that range between 400-700 nanometers (1 nanometer = 0.000000001 meters). Our brain interprets the different kinds of wavelengths within this range as different colors. For example, if electromagnetic energy with a wavelength of 700 nanometers entered a completely dark room, we would see it as red light. If the energy had a wavelength of 400 nanometers, we would see it as violet.

d. What color would the light be if the wavelength was 450 nanometers? What would happen if the wavelength of the light coming into the dark room was 300 nanometers?

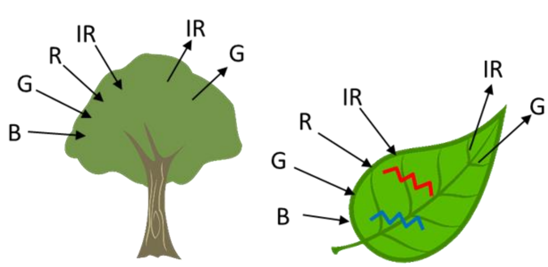
We see sunlight as one uniform color, white, but it is actually made up of various wavelengths of energy including all the wavelengths within the visible range. We can prove this to ourselves if we look at light through a prism.

As light enters the prism, the different wavelengths of light are bent (this is known as **refraction**) by differing amounts depending upon the wavelength. This splits up the light into the individual wavelengths that make it up. As the light leaves the prism, our brains interpret each wavelength as a particular color. We see rainbows after a rainstorm because the water in the sky acts like tiny prisms, splitting the light shining through it.



Source: http://science.hq.nasa.gov/kids/imagers/ems/

So the colors we see around us are a result of the different kinds of electromagnetic energy (light) within the visible range that is **reflecting** off of the object we're looking at. A leaf looks green to us because we see the light within the green portion of the visible range reflecting off the surface of the leaf. So what about the rest of the visible light? Why do we only see the green light reflected off the leaf and not any other colors? To understand, we need to learn how electromagnetic energy (light) interacts with an object.



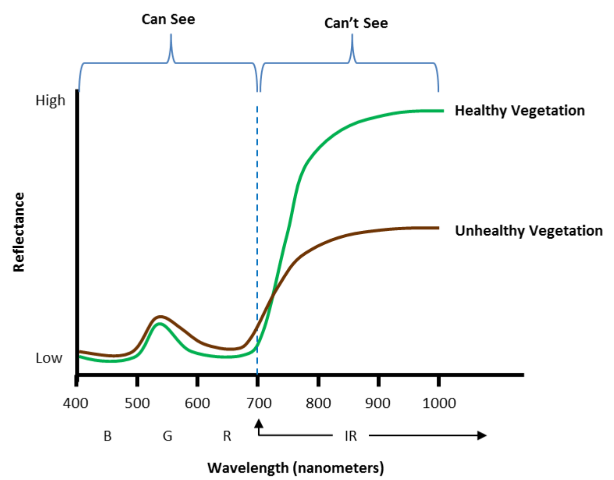
When any light, or electromagnetic energy, travels through space and strikes an object, it interacts with that object. The energy can be either absorbed by the object or reflected off the surface of the object. We will stick with the leaf as an example of this. You will also see that visible light is represented by blue (B), green (G), and red (R) light instead of all the colors. These are the **primary colors** or wavelengths in the spectrum. No other wavelength can make blue, green, or red, but all the other colors can be created by combining these three in different proportions. Infrared light (IR) is also shown in the diagram, but we will discuss that later.

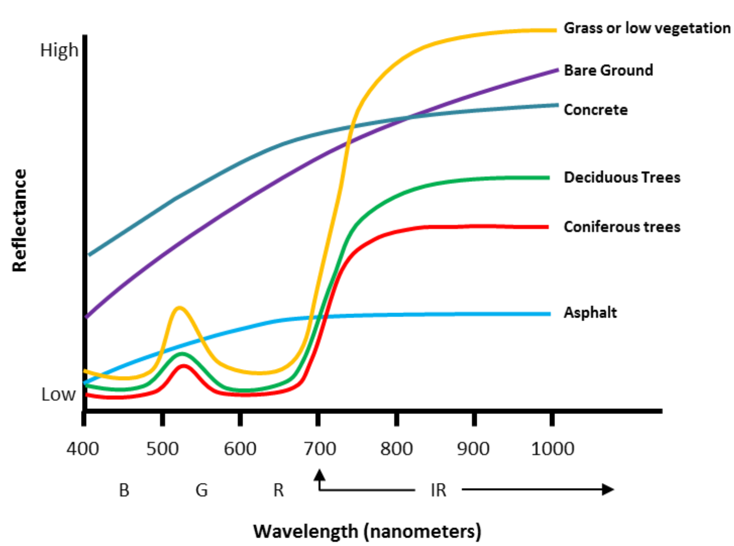
Remember that light from the sun is made up of many different wavelengths, including the visible light and infrared. It passes through our atmosphere and strikes the leaves of the trees. The blue light and the red light are absorbed by the leaves because leaves contain chlorophyll that absorbs most of the red and blue light for photosynthesis, which is how a plant produces food. The plant does not need the green light so it is not absorbed; instead the green light is reflected back. When we look at an object, we see the energy being reflected off the object towards our eyes. Since green light is the only visible light being reflected, the leaves appear green to us. As we've already learned though, there is more than just visible light out there. There are wavelengths that are invisible to our eyes but are still being absorbed or reflected off of objects. In the diagram of the tree, you can see that it is not just green light that is reflected from the leaf, but infrared light was well. We just do not see the infrared light with our eyes. The most useful of the invisible energy to us is in the infrared region of the spectrum, however. As we will see, there is a lot we can learn just by looking at how much infrared energy is being reflected by an object.

e. What color would an object be if it reflected all visible light?
f. What color would an object be if it reflected no visible light?

If everything on Earth interacted the same way with electrometric energy, everything would be the same color; thankfully this does not happen. Every surface interacts with electromagnetic energy differently. Different surfaces will absorb and/or reflect energy weakly or strongly in different wavelengths. We can use this knowledge to our advantage. If we measure the amount of energy reflected off a surface at different wavelengths, we can use that information to figure out what it is. We can create a graph called a spectral reflectance curve (below) that lets us see the amount of reflected energy across a range of wavelengths for a particular object or surface.

Lets say the green line on the graph to the right is the spectral reflectance curve for the tree we just looked at. As pointed out before, there is almost no reflectance in the blue and red wavelengths because that energy is absorbed for photosynthesis, but there is peak in the green which is why leaves look green. If you go beyond the visible light into the infrared, you will see that the amount of reflected energy suddenly spikes. A structure within the leaf known as the mesophyll is very effective at reflecting Infrared energy so healthy vegetation exhibits a very high peak in infrared reflectance on the graph. If we could see that energy, then vegetation would look very bright to us, but because we do not see IR wavelengths we only see the green light.

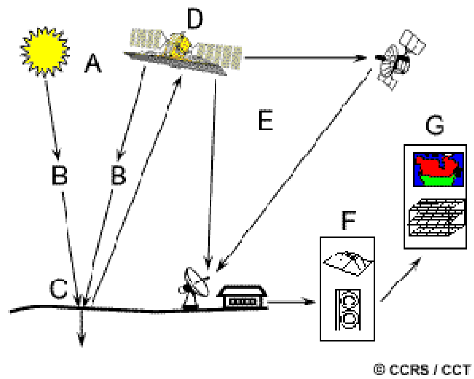




Different types of objects or surfaces tend to have characteristic spectral reflectance curves that we can use to distinguish one object from another or to assess the condition of something on the ground. Like in the example to the left, we can see that in the visible light, vegetation is very different from bare ground or concrete. Deciduous and coniferous trees would look very, similar, however because there is not a big difference in the amount of reflected energy in the visible wavelengths. When objects look similar in the visible range, the energy in the invisible portions of the spectrum can come in handy. To our eyes there would be almost no difference between deciduous and coniferous trees, but in the infrared there is a big difference. A very common use of remote sensing is to assess the health of vegetation. We can detect damage to trees before we can see it visibly with our eyes. Look at the spectral reflectance curves above for healthy and unhealthy vegetation. When plants are stressed, for example during a drought or infestation, they exhibit a significant drop in the amount of infrared reflectance well before there is enough of a change in visible light for us to visually see the damage. We can use remote sensing to detect this stress early by looking for the sudden drop in infrared reflectance and acting as soon as we see it.

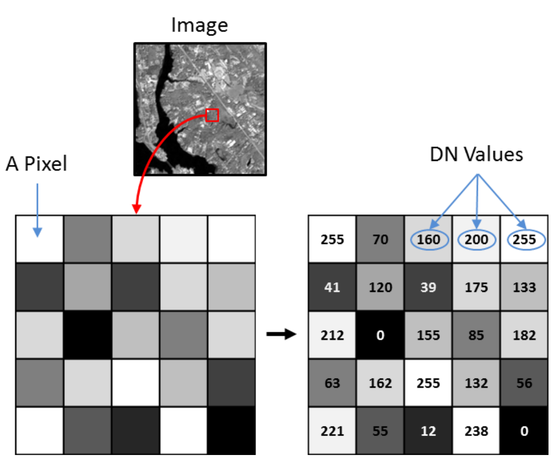
How Do Satellites Work?

Satellites are a very important tool we can use to help us understand the environment. There are currently satellites orbiting the earth with sensors that, like our eyes, can "see" the energy being reflected by different objects on the Earth's surface. These sensors do not act exactly like our eyes though because they can detect the wavelengths beyond visible light that our eyes cannot see!



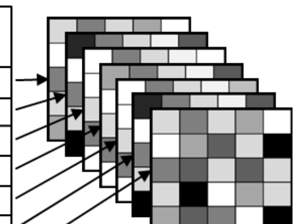
Source: Canada Center for Remote Sensing

Electromagnetic energy from the sun (A) travels through space and the Earth's atmosphere (B) where it interacts with the objects on the Earth's surface (C). As we now know, some of that energy is absorbed, but some of it is also reflected. The sensor (D) on the satellite flying overhead collects and measures the type and amount of electromagnetic energy reflected by the surface. The information collected by the sensor needs to transmitted to a processing station on Earth where it is turned into a digital image (E). We can then extract information from the satellite image that we are interested in (F). We apply this information to answer a question, solve a problem, or simply learn something more about a feature of interest (G). So let's take a look at a digital image.



A digital image is a grid of equal-sized squares called pixels. Each pixel covers a certain area on the ground and has a digital number (DN) that represents the amount of electromagnetic energy being reflected in that area. A higher DN means there is more energy being reflected by the features within the area covered by that pixel. You'll see that black pixels have a DN of 0 (no reflectance) while white pixels have a DN of 255 (maximum reflectance). Satellites record the amount of reflected energy in different portions of the electromagnetic spectrum. Each portion is called a spectral band or band, for short. For example, the information shown in the table below represents the types of electromagnetic energy measured by the Landsat 8 satellite. It records the energy reflected in the visible lights (B, G, and R) as well as 3 types of infrared. So when measuring the amount of blue light being reflected, the sensor on the satellite is measuring the reflected energy between 450-510 nanometers. That band is then turned into an image like shown to the right of the table. A digital image is generated for each spectral band the sensor collects. So for this satellite we have 7 digital images, each one representing the amount of reflected energy in that portion of the electromagnetic spectrum. We can

Bands	Wavelength (nanometers)	Color
Band1	430 - 450	Coastal Blue
Band 2	450 - 510	Blue
Band 3	530 - 590	Green
Band 4	640 - 670	Red
Band 5	850 - 880	Near Infrared
Band 6	1570 - 1650	Shortwave Infrared 1
Band 7	2110 - 2290	Shortwave Infrared 2



then use a computer to view these images together in color.

It’s important to mention that not all pixels have the same size (spatial resolution); they can vary from sensor to sensor. For example, Landsat is a very popular collection of satellites. Landsat images have a 30m pixel size. This does not mean that the pixel is 30m on your computer screen, but that a single pixel represents a 30 meter by 30 meter area on the ground. Pretend that you went outside and marked a 30 meter by 30 meter square on the ground. One Landsat pixel represents the same area. The DN in that pixel represents the averaged reflectance of all the objects in that 30mx30m box. Other satellites can collect images with a pixel size of 10 meters, 5 meters, and even less than 1 meter. You could fit a lot of those pixels in one Landsat pixel.

g. What is the area covered by a single Landsat pixel? If another satellite image has 5 meter pixels, how many of those would fit in a single Landsat pixel? What might be an advantage of having smaller pixels?

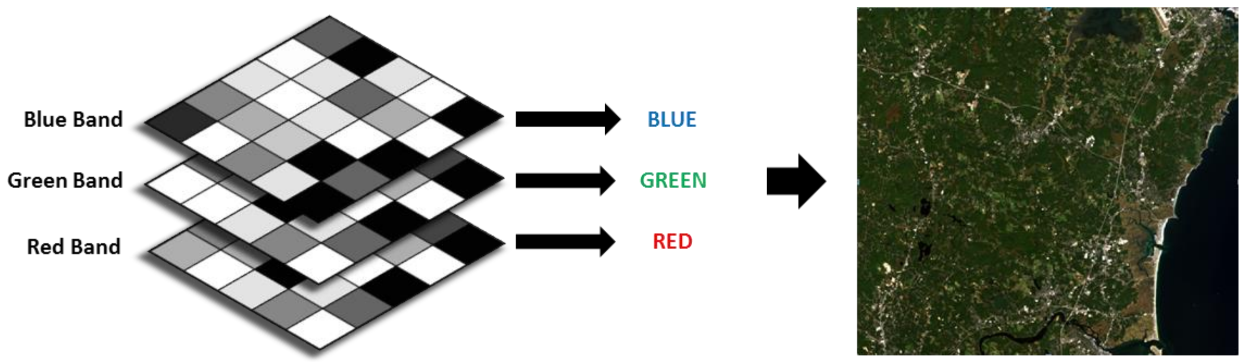
Satellites can measure the amount of electromagnetic energy being reflected in the visible range (B, G, and R) as well as outside of what our eyes can see. As we just learned, the infrared range is very useful for scientists because it can tell us a lot about an object. In the spectral curve example, deciduous and conifer trees would look very similar in the visible range of the spectrum, but we could tell them apart if we could see in the infrared portion of the spectrum. We cannot see the infrared energy that could help us, but this is where satellite imagery and computers can help us! The satellites measure the amount of energy reflected in the visible and invisible portions of the spectrum and the computer gives us a way to see the energy we could not see before.

The two images below are actually acquired by a single satellite. The imagery is being displayed two different ways. On the left is what we call a natural color composite, meaning that this is how our eyes would see this area if we were looking at it from above. Everything makes sense to us. For example, we know that the green is vegetation and the sand on the beaches is white. The right hand image is called a false color composite. It looks nothing like the image on the left and the colors do not make much sense to us anymore. Why is that?

The computer monitors we use are known as RGB moniors. RGB is the same R,G,B we have been talking about; red, blue, and green. You will also remember that red, blue, and green are primary colors and when combined together in different amounts, can produce all the other colors we see. So a computer monitor uses the three primary colors to produce all the different colors we see on the screen. Using special software, we can assign one of the primary colors to a particular band that was collected by the sensor. The computer then displays each pixel in the image as a particular color based on the amount of reflected energy that recorded at that pixel in the bands that were chosen.

h. What is the maximum number of bands we can choose to display on the computer monitor? Why?

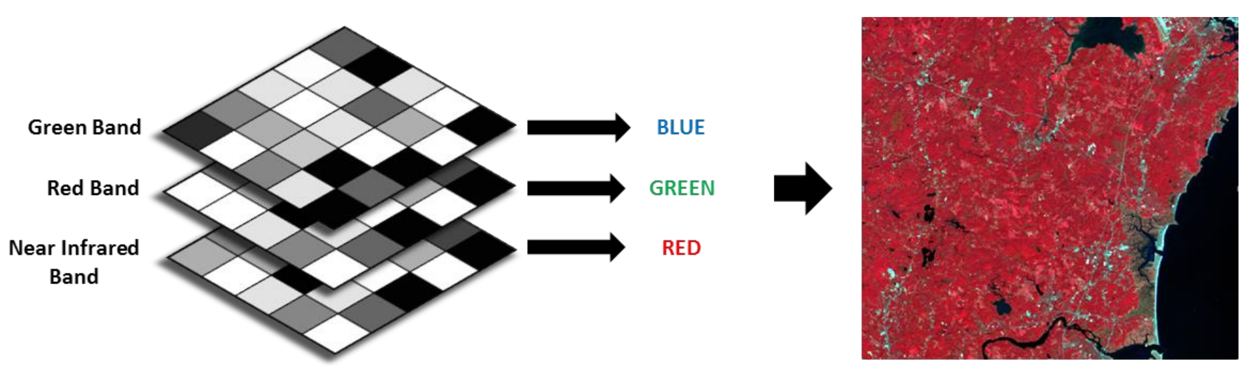
So now lets look at a natural color composite in more detail. To create this composite, we assigned the color blue to the blue band, green to the green band, and red to the red band. You will see the primary color we assigned each band matches the type of energy that was recorded by that band and the bands chosen are all the visible portion of the spectrum.



This display shows the imagery exactly as we would see it if we were looking at the Earth from above with our eyes. We know that in the visible portion of the spectrum, vegetation has very little blue and red reflectance and much more green. Lets say a single pixel recorded the amount of reflected energy in the middle of a forest. The DN values of that pixel in the blue and red band would be very low, but higher in the green band. When the computer looks at the proportion of red, blue, and green reflectance (represented by the DN values) at that pixel, there is really only green reflectance (the other DN values are very low) and since we assigned the green band the color green, vegetation appears on the screen as green exactly as we would expect it.

i. While trying to make a natural color composite to show you, someone assigned the color blue to the green band, red to the blue band, and green to the red band. What's wrong? What color would the vegetation be on the computer screen? Why? How should the bands really be displayed?

Satellites record the amount of energy in multiple different bands, not just the visible. Therefore, we can make a false color composite, which allows us to utilize the infrared energy that we know is very useful. How do we make a false color composite? Well, we would do exactly what we did for the natural color composite with a few modifications.



In the diagram above you will see that we removed the blue band and added in the near infrared band. Now the green band has been assigned the color blue, the red band is assigned green, and the near infrared band is assigned the color red. The computer was told to display the amount of near infrared (a type of infrared) energy being reflected as one of the primary colors we can see, in this case red. Remember in the spectral reflectance curves above that vegetation reflects a lot of of this kind of energy, much more so than the green that our eyes see. Because the infrared reflectance is so high, we see the vegetation as red in the image. A false color composite is a very common way to display satellite imagery on a computer and as you continue with this exercise, you will learn how being able to see the amount of infrared reflectance can be very helpful. Next you will see how different features on the ground appear in satellite imagery.

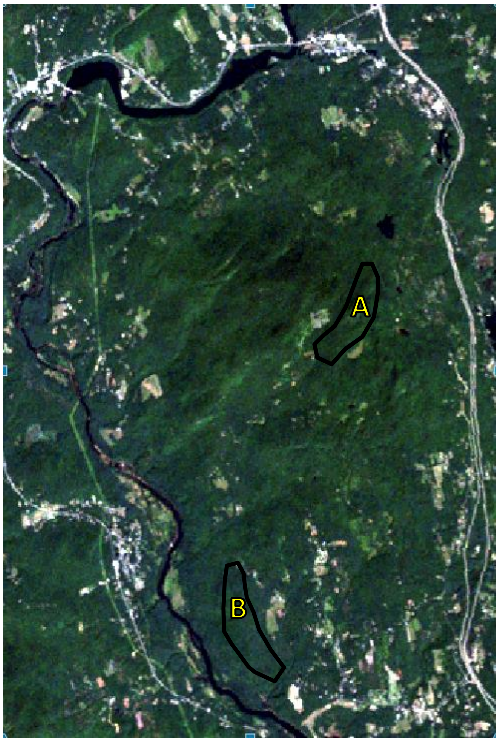
Before You Move On….

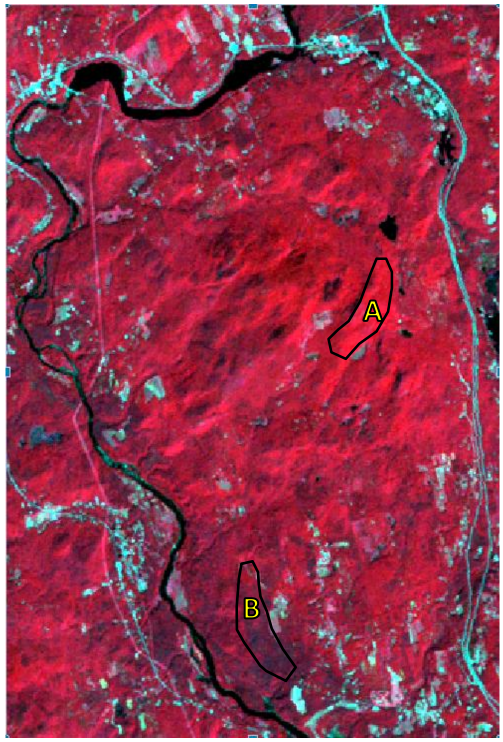
Now that you have the background information you need, you are ready for some hands on practice. The next two sections will present you with several example images and ask questions to test your knowledge and understanding of remote sensing. The first section, “Image Interpretation”, is a guided practice. You will be provided with some example images of common landscapes in New Hampshire (forests, mountains, cities, etc.) and some additional background information that will help you to interpret the image and answer some questions related to what you just saw and read. In this section you will be given the answers to those questions. In the last section, “Test Yourself”, you will be given images and questions for you to answer on your own without additional guidance. The last section is a way to test your understanding of everything you have read in this exercise. Remember to think outside of the box, beyond what you have read here. When interpreting satellite images, it is very common for us to utilize knowledge and experiences we already have to help us answer questions, it is what makes us good problem solvers.

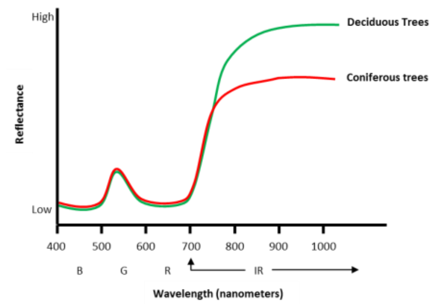
Good Luck!

Image Interpretation

Forest: Sanbornton Mountain located between Franklin and New Hampton, west of Laconia, NH.







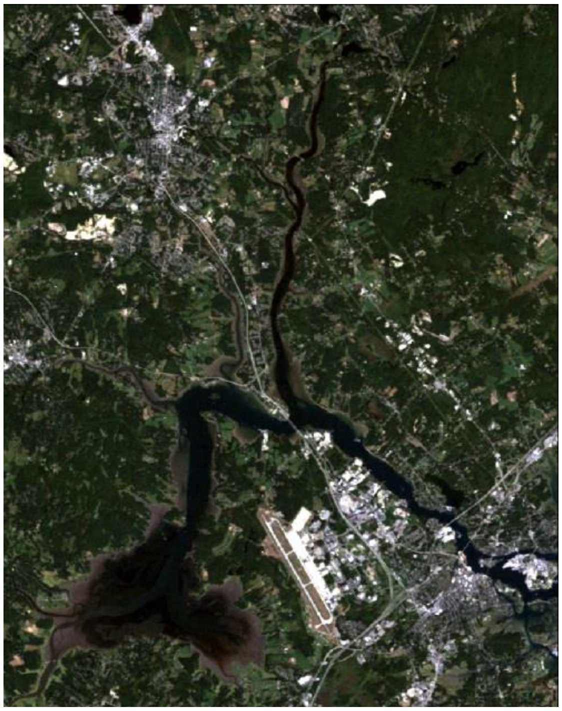
Here we have an example of a forested area in a Landsat 8 image. This forest is a mix of deciduous trees and coniferous trees. On the natural color composite (left) it is difficult to see the difference between different tones of green, but if you look at the same area on a false color composite (right) you'll see far more shades of red. This allows us to see the difference between the deciduous and coniferous areas. The spectral reflectance curves for deciduous and coniferous trees are shown above. You will notice that the deciduous trees reflect more infrared energy than the conifers. So if we are looking at a false color composite that lets us see infrared reflectance, the deciduous forests should look much brighter.

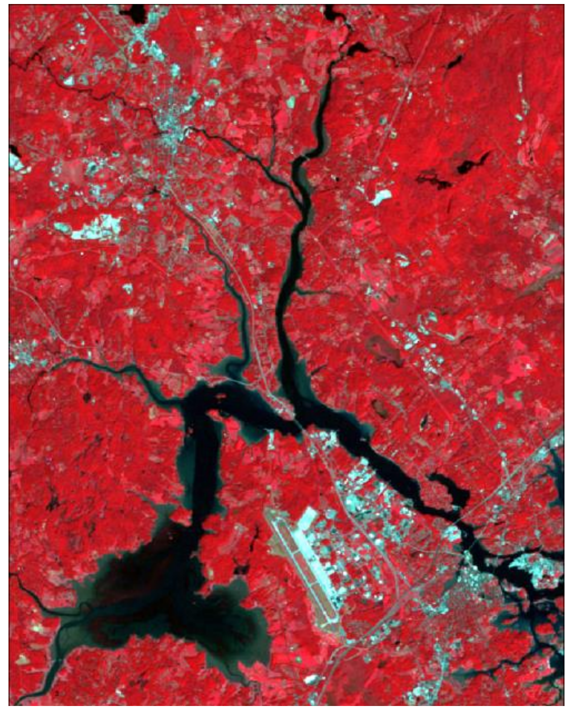
a) Look at area A and B on the images above. Which one is deciduous and which one is coniferous? How do you know this? Which type of image was more helpful?
b) How do you tell the difference between deciduous and conifer trees with your eyes?
c) When can you most easily tell the difference between area A and B?

Answer:

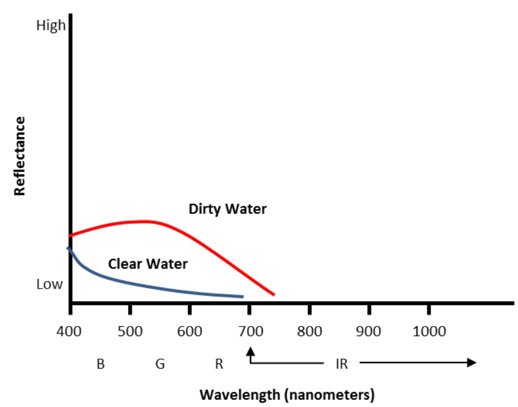
a) Area A is a patch of deciduous forest and area B is coniferous forest. We can tell this because deciduous trees have more infrared reflectance than conifer trees and area A is much brighter than area B. The false color composite image was more helpful.
b) Deciduous trees have leaves while coniferous trees have needles
c) The best time to tell area A from area B would be during the fall or winter because deciduous trees would not have any leaves but the coniferous trees would still have needles.

Water: Great Bay surrounded by Newington, Newmarket, Durham, Dover, and Elliot, NH





Here we have an example of water. The spectral reflectance curve for clean water is to the left. You will notice that clear water has very low reflectance in the visible portion of the spectrum and almost none in the infrared. Water is an excellent absorber of energy and will absorb a lot of the electromagnetic energy that hits it. Because it absorbs a lot of energy, it reflects very little and will appears very dark (dark Blue to black) in both the natural and false color composites, however, if there is a lot of sediment in the water from erosion or algae, the reflectance characteristics of water, especially in the visible range, will change significantly. The water itself will absorb most of the energy that hits it but the materials floating in the water or at the bottom (if the water is shallow enough) will reflect some energy. The materials in the water creates higher reflectance than we would expect if the water was clean or deep and lets us assess water quality in rivers, lakes or bays.

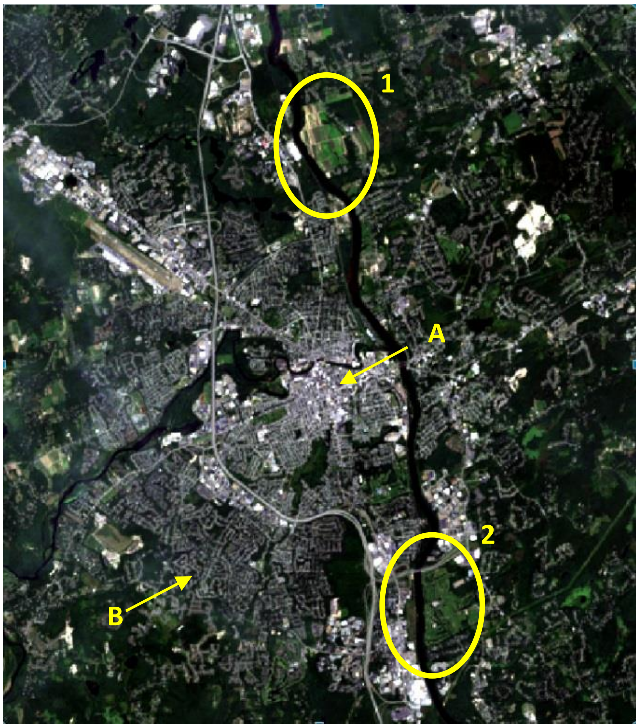


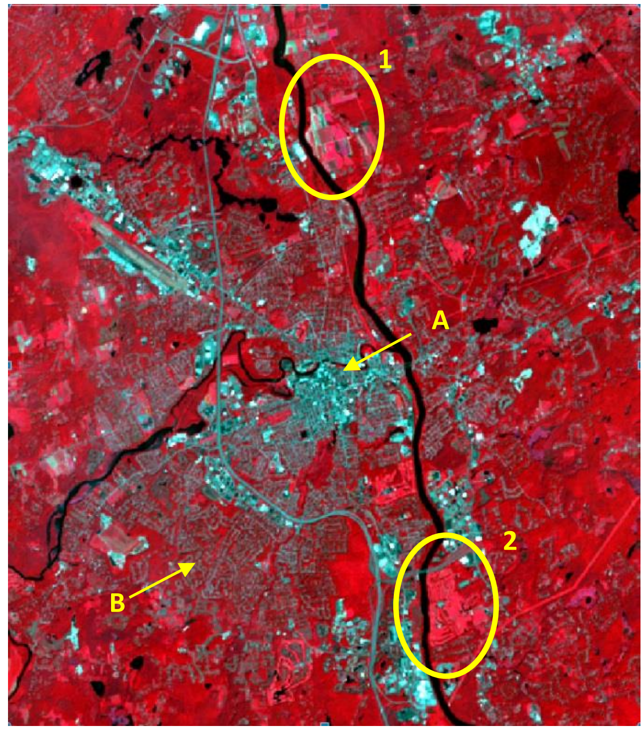
a) Look closely at the water in the two images. Do you see any difference in the water?
b) Pretend that you had to describe what water looks like in the imagery to someone who can't see the pictures. Besides what color it is, how else would you describe it?

Answer:

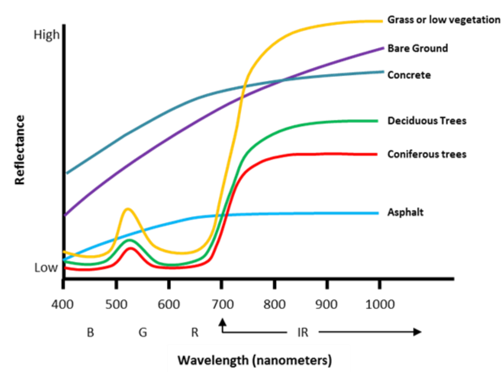
a) In both images you can see the difference between deep water and shallow water. The vegetation and sediment in the shallow edges of the bay cause greater reflectance in the visible portion of the spectrum. Since the water is not deep, the sensor can detect the reflectance from these materials.
b) The water is smooth, glassy, uniform, and flat,

Development: Nashua, NH





Above is an example of a developed area. Development is interesting because it has a variety of land cover types like bare pavement, grassy field/lawns, water, and forested areas. The spectral reflectance curve for a number of these land cover types is shown to the right. You should be able to spot the forested areas and the water in the image, but there are some other features you might not be familiar with. The circles are centered on non-woody vegetation like grass or agricultural field. They tend to be pale or bright pink in color because of the high near infrared reflectance of the vegetation, but they are a not deep red like the forests to the right of them.



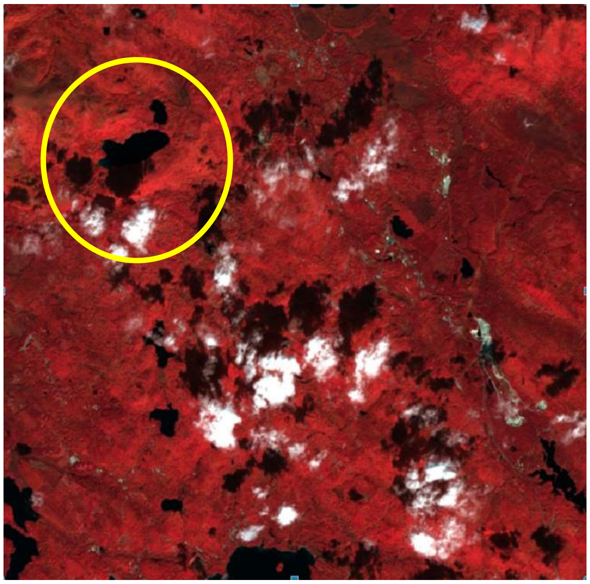
The second feature is the urban areas that appear bright blue in the false color composite. These are roads, buildings, or non-vegetated areas. They stand out significantly more from vegetation in that image. There are also areas of bare ground (no vegetation or pavement) that look blue-grey.

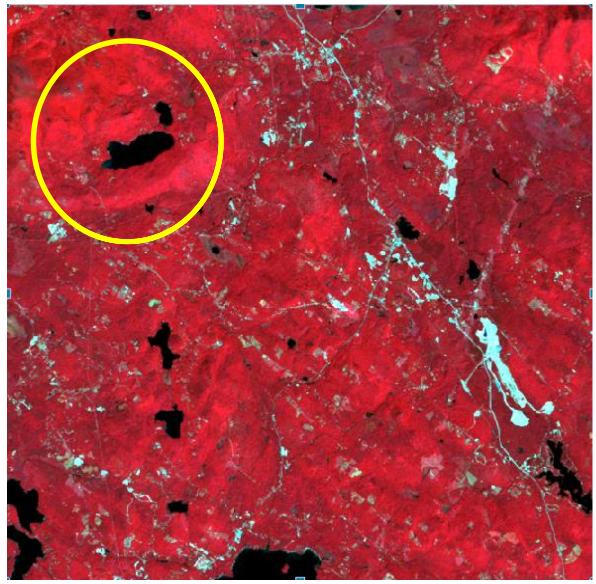
a) Areas 1 and 2 are both areas with non-woody vegetation. Area 1 is a farm and area 2 is a golf course. The colors of these areas are similar in both images. What other characteristics about these locations can you use to tell one from the other?
b) A and B are both pointing to developed areas. Area A is a heavily developed area and Area B is moderately developed. What difference do you notice that could help you tell one from the other? Do you notice any patterns that could help you tell developed areas from bare ground?

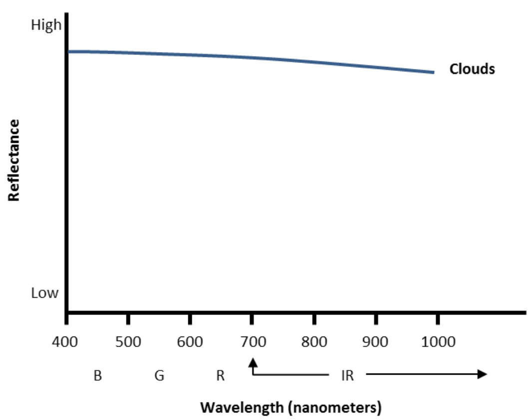
Answer:

a) The shape of the patches is helpful. The farmland is made up of rectangular patches of low vegetation where farmers have plowed fields.
b) Area A is more dark blue while Area B is made of some blue and some red indicating that there is more vegetation in area B and less bare ground or pavement. Developed areas also have long narrow strips of bare ground that cross over each other. These would be roads.

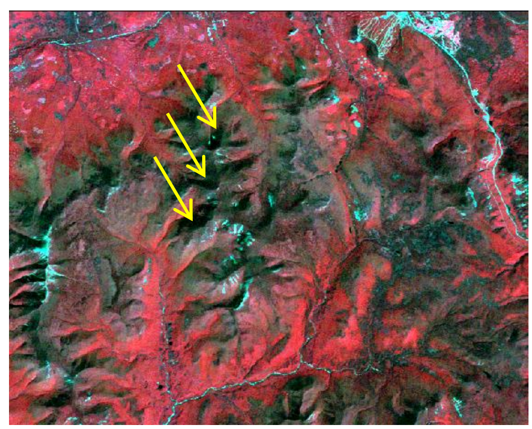
Clouds and Shadows







Clouds are an uncontrollable aspect of remote sensing. With satellite sensors flying so high above the Earth's surface they are going to capture the reflectance of features on the ground as well as the reflectance from the clouds. As you can see in the images above, clouds can hide the features on the ground underneath them making it hard to interpret those areas. The shadow from the clouds over head makes the lake look bigger than it actually is. Researchers usually try and use images with as few clouds as possible but sometimes it is hard to avoid. The spectral reflectance curve for a cloud is to the left. They are easy to tell from other features because they reflect a lot of energy across the visible and infrared portions of the spectrum making them bright white. You usually have to decide if their shadows are water or not though.



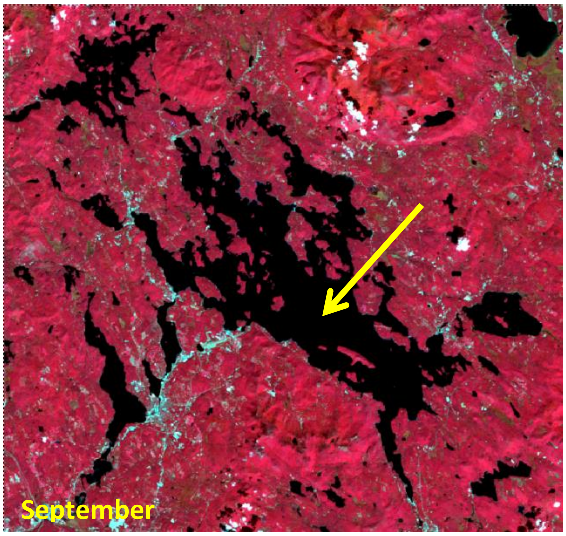
Other objects cast shadows too. For example, tall mountains like the one to the right can cast shadows because they block the sun from reaching one side. These shadows are useful because they let us know whether the feature we are looking at has height or not. The arrows on the image to the right point to locations where the mountain is casting a shadow. They look almost black on the image, but they are definitely not water.

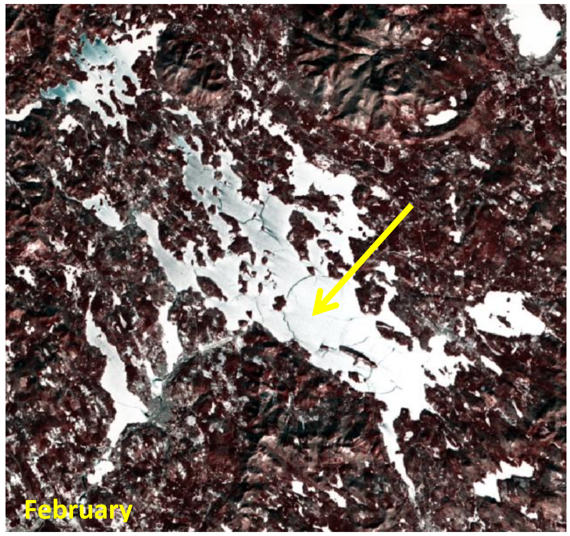
a) What is something you can do to tell the difference between cloud shadows and water in an image?
b) Clouds are not always bad. When might you want clouds in your images?

Answers:

a) Look at cloud free images from a previous date
b) If we were interested in weather on a particular day then we would like to see clouds in the imagery.

Test Yourself

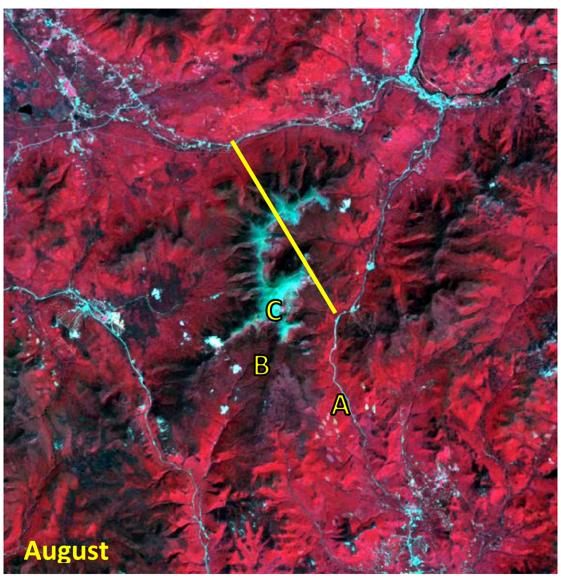


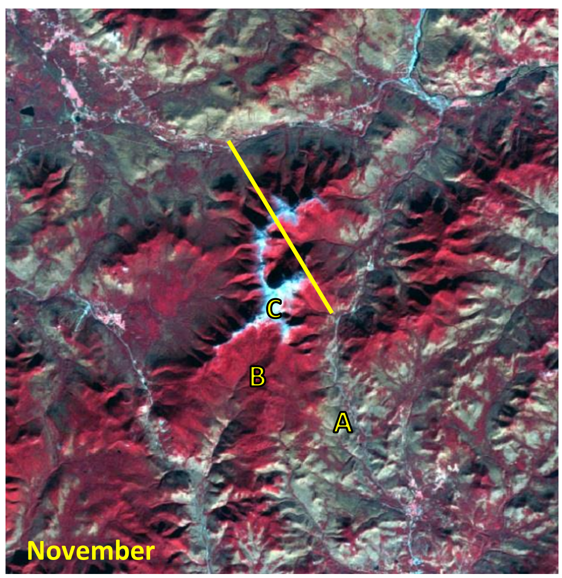


Note: Both images are false color composites

1. What is this yellow arrow pointing to in the image on the left?
2. Are both arrows pointing to the same thing? Why do they look different?
3. What does the color of the object in the image to the right tell you about the type and amount of energy being reflected there? Be general with your answer.

BONUS: What is the name of this location?

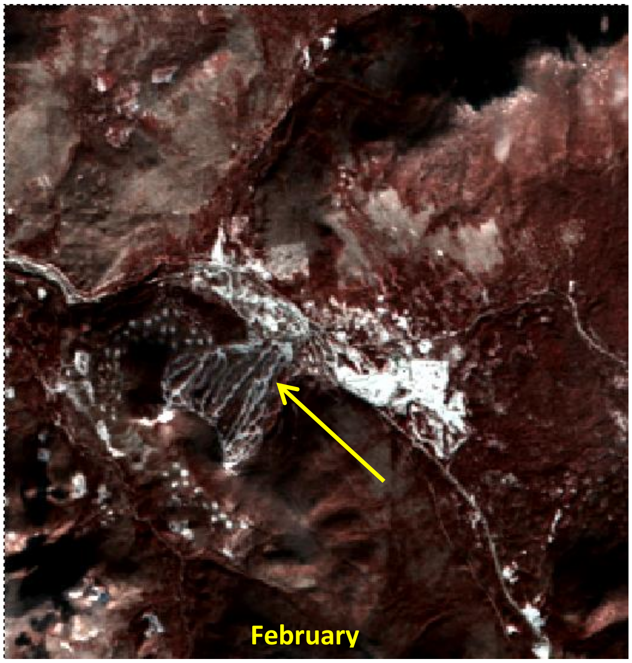




Note: Both images are false color composites

1. The image on the left was taken in August and the Image on the right was taken in November. What kind of vegetation is at points A and B on both images?
2. Why does the vegetation in area B still have a high infrared reflectance between August and November while there is no infrared reflectance in area A in November but a lot of reflectance in August?
3. Why is point C blue while the surrounding areas are red to red-purple in color?
4. The yellow lines represent a proposed new road. Would it be a good idea to build it here? Why? What clue helped you answer the question?

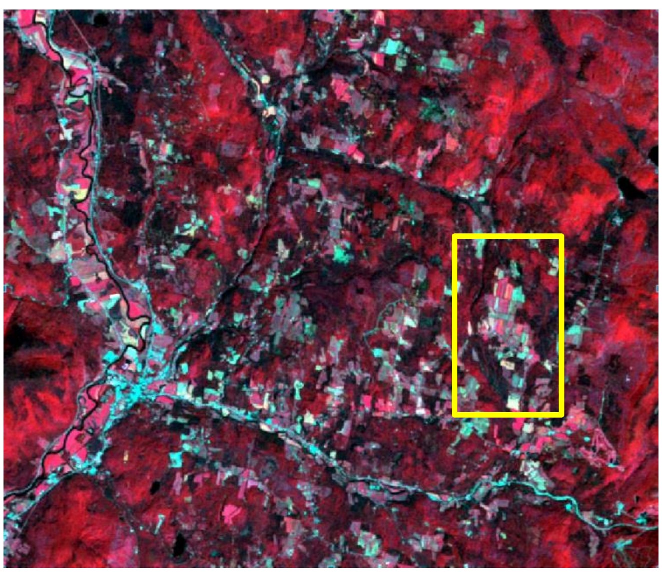
BONUS: What is the Name of this location?



Note: Image is a false color composite

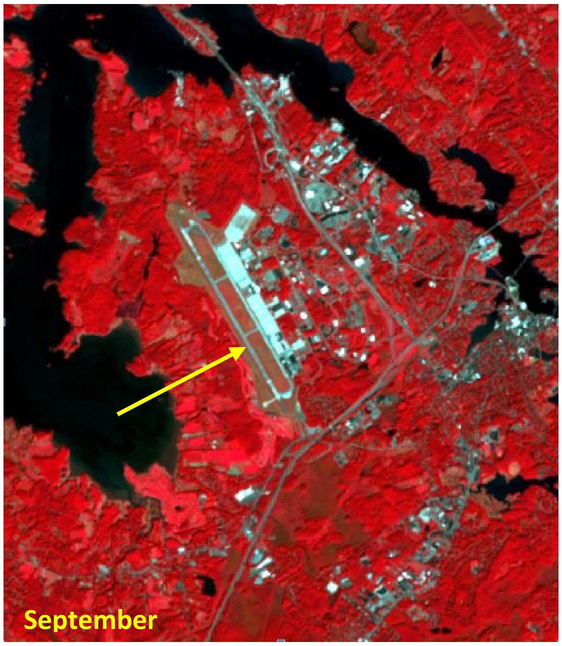
1. Is the feature the arrow is pointing to natural or manmade?
2. Based on your previous answer, what do you think this is?
3. Notice how the area the arrow is pointing to has lots of white pixels but the surrounding landscape has very few. Why might this be? Use your answer to the previous question to help you.

   BONUS: What is the name of this location?



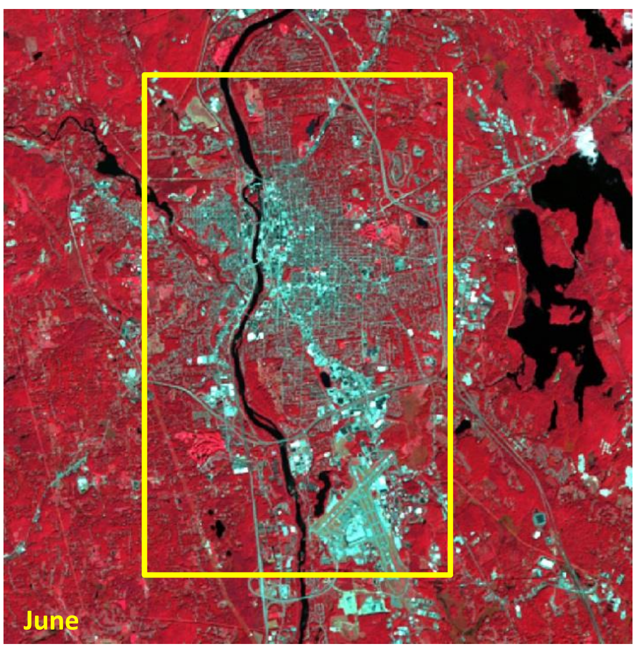
Both images were taken on the same day. The image on the left is a false color composite and the image on the right is a natural color composite.

1. What kind of land use is occurring within the yellow box?
2. What characteristics of this area helped you to answer question 1?
3. What seems to be the relationship between this land use and water (Hint: Look at the whole scene, not just the box)? Why do you think this is happening?
4. Why might this relationship be a problem environmentally?
5. Based on the whole image, should we be concerned about the water here



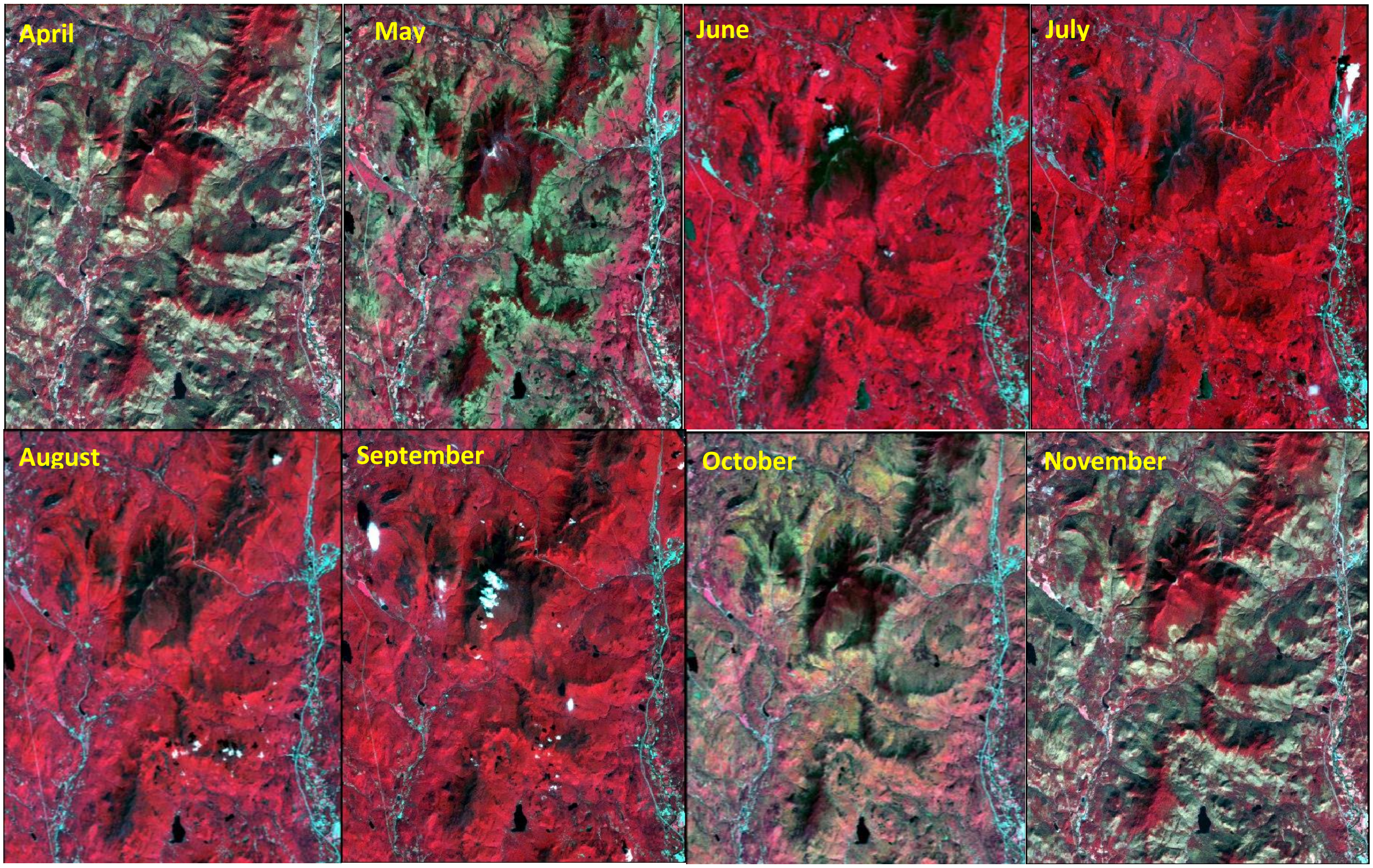
1. What is the arrow pointing to?
2. What characteristics about this object helped you to answer question 1?

   BONUS: What is the name of this location?



1. What is occurring in the yellow box?
2. What characteristics about this area helped you to answer question 1?

   BONUS: What is the name of this location?


April
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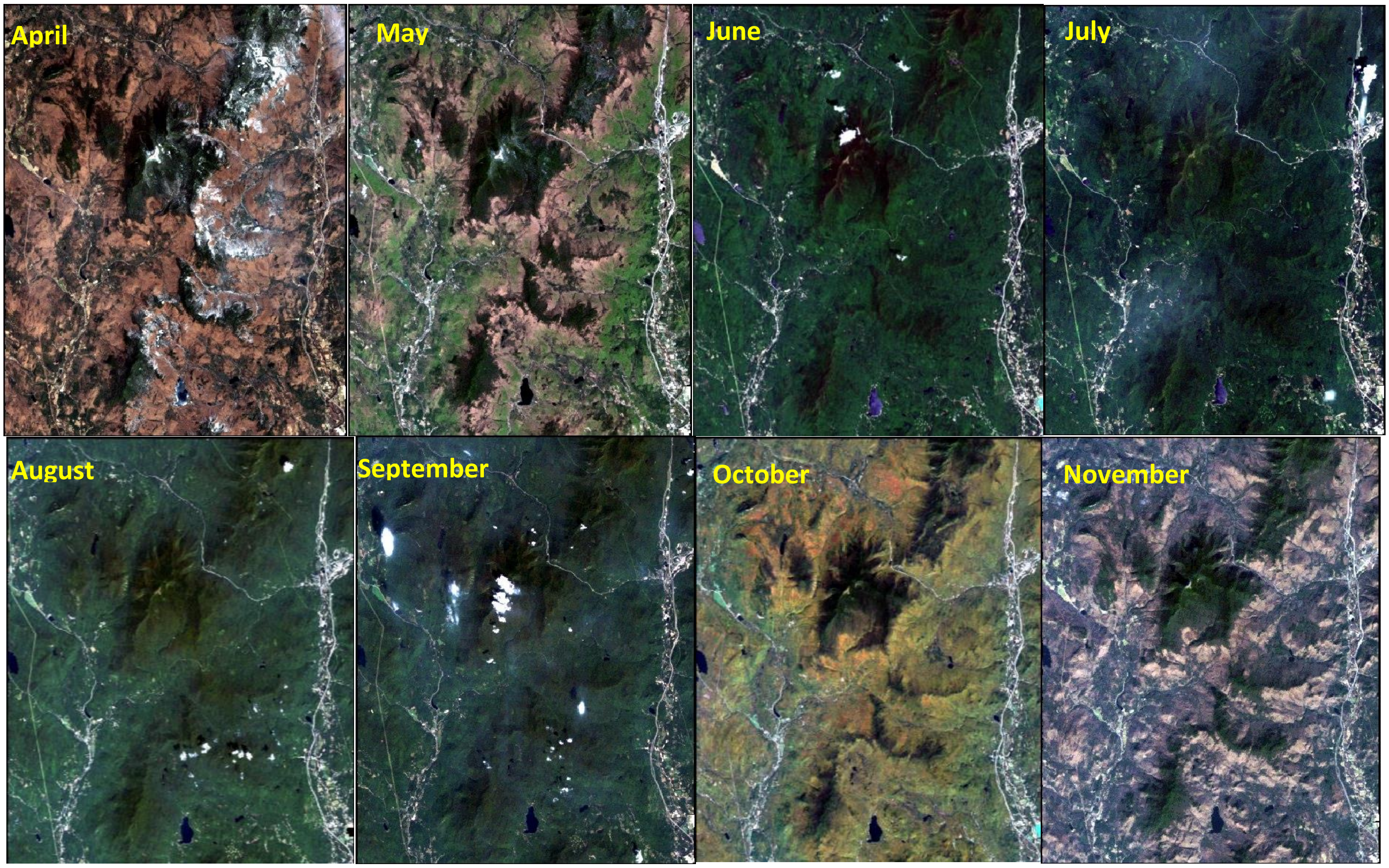
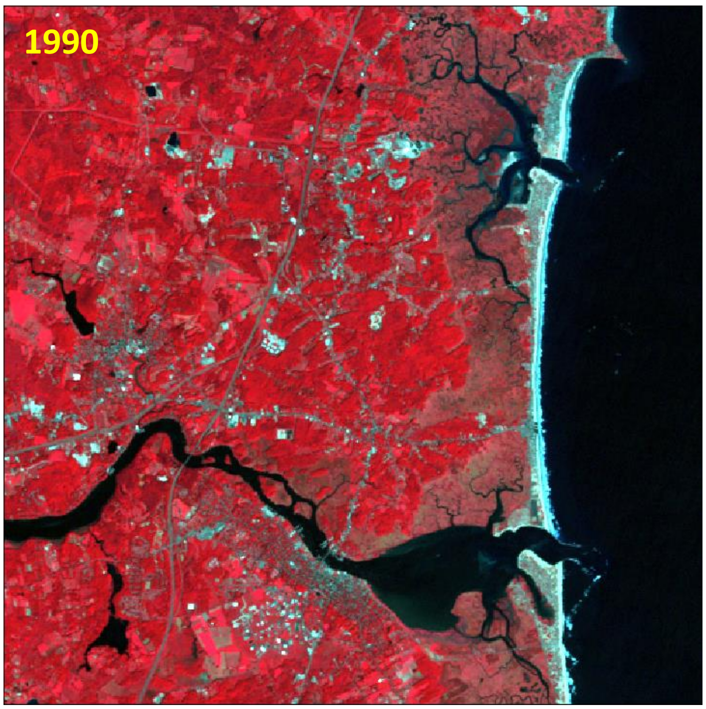

April
May
June
July
August
September
October
November

Above are a series of images from the same location collected between April and November. The first sets of images are false color composites and the second sets are natural color composites.

1. What natural process is happening in these photos?
2. If you wanted to study the health of the trees in a forest, what would be the best months to do so?
3. Is there a relationship between elevation and the type of trees we would see (Hint: is there an object in this image that has height)? If so, what is it? The second set of images in this practice section may be helpful to look at too.

BONUS: What is the name of this location?



1. Identify several areas that have changed between 1990 and 2010.
2. What types of changes have happened?
3. What might some of the environmental impacts be from these changes?