Intro to spectral remote sensing

Learning Objectives

After completing this tutorial, you will be able to:

- Define spectral and spatial resolution. Explain how the two types of resolution are different.
- Describe *atleast* 3 differences between NAIP imagery, Landsat 8 and MODIS in terms of how the data are collected, how frequently they are collected and the spatial & spectral resolution.
- Describe the spatial and temporal tradeoffs between data collected from a satellite vs. an airplane.

What you need

You will need a computer with internet access to complete this lesson and the data for week 6 of the course.

{% include/data_subsets/course_earth_analytics/_data-week6-7.md %}

About Spectral Remote Sensing

In the previous weeks of this course, we talked about lidar remote sensing. If you recall, a lidar instrument is an active remote sensing instrument. This means that the instrument emits energy actively rather than collecting information about light energy from another source (the sun). This week we will work with spectral remote sensing. Spectral remote sensing is a passive remote sensing type. This means the the sensor is measuring light energy from an existing source - in this case the sun.

LEFT: Remote sensing systems which measure energy that is naturally available are called passive sensors. RIGHT: Active sensors emit their own energy from a source on the instrument itself. Source: Natural Resources Canada.

Electromagnetic spectrum

To better understand spectral remote sensing we need to review some basic principles of the electromagnetic spectrum.

The electromagnetic spectrum is composed of a range of different wavelengths or "colors / types" of light energy. A spectral remote sensing instrument collects light energy within specific regions of the electromagnetic spectrum. We call each region in the spectrum a band.

Above: a video overview of spectral remote sensing.

Above: Watch the first 8 minutes for a nice overview of spectral remote sensing.

Key Attributes of spectral remote sensing data

Space vs. airborne data

First, it is important to understand how the data are collected. Data can be collected from the ground, the air (using airplanes or helicopters) or from space. You can imagine that data that are collected from space are often of a lower spatial resolution compared to data collected from an airplane. The tradeoff however is that data collected from an satellite often offer better (even global) coverage.

For example the landsat 8 satellite has a 16 day repeat cycle for the entire globe. This means that you can find a new image for an area, every 16 days. It takes a lot of time and financial resources collect airborne data. Thus data are often only available for smaller geographic areas. Also, you may not find the data are available for multiple time periods OR, in the case of NAIP, you may have a new dataset ever 2-4 years.

Space-born vs airborne remote sensing. Notice that space-born data are often of lower resolution however because a satellite rotates continuously around the earth, the spatial coverage may be better than airborne data. Source:

Bands and Wavelengths

When talking about spectral data, we need to understand both the electromagnetic spectrum and image bands. Spectral remote sensing data are collected by powerful camera like instruments known as imaging spectrometers. Imaging spectrometers collect reflected light energy in “bands”.

A *band* represents a segment of the electromagnetic spectrum. You can think of it as a bin of one “type” of light. For example, the wavelength values between 800nm and 850nm might be one band captured by an imaging spectrometer. The imaging spectrometer collects reflected light energy within a pixel area on the ground. Because an imaging spectrometer collects many different types of light - for each pixel, the amount of light energy for each type of light or band, will be recorded. So for example a camera records the amount of red, green and blue light for each pixel.

Often when you work with a multispectral dataset, the band information is reported as the center wavelength value. This value represents the center point value of the wavelengths represented in that band. Thus in a band spanning 800-850 nm, the center would be 825).

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<img src="~/Documents/Github/earthlab.github.io/images/course-materials/earth-analytics/week-6/spectrum
<figcaption>Imaging spectrometers collect reflected light information within defined bands or regions o
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Spectral Resolution

The spectral resolution of a dataset that has more than one band, refers to the spectral width of each band in the dataset. In the image above, a band was defined as spanning 800-810nm. The spectral width or spectral resolution of the band is thus 10 nanometers. To see an example of this, check out the band widths for the Landsat sensors.

While a general spectral resolution of the sensor is often provided, not all sensors collect information within bands of uniform widths.

Spatial Resolution

The spatial resolution of a raster represents the area on the ground that each pixel covers. If you have smaller pixels in a raster the data will appear more “detailed”. If you have large pixels in a raster, the data will appear more coarse or “fuzzy”.

If high resolution the data show us more about what is happening on the earth’s surface why wouldn’t we always just collect high resolution data (smaller pixels?)

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<img src="~/Documents/Github/earthlab.github.io/images/course-materials/earth-analytics/week-6/pixel-de
<figcaption>The spatial resolution of a raster represents the area on the
ground that each pixel covers. Source: Colin Williams, NEON.</figcaption>
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<img src="~/Documents/Github/earthlab.github.io/images/course-materials/earth-analytics/week-3/raster-re
<figcaption>Remote sensing data is collected at varying spatial resolutions.
Remember that the spatial resolution represents that area on the ground
that each pixel covers. Source: Colin Williams, NEON.</figcaption>

NAIP, Landsat & MODIS

In this week's class, we will look at 3 types of spectral remote sensing data.

1. NAIP
2. Landsat
3. MODIS

NAIP imagery

We will work with NAIP imagery in the next lesson. NAIP imagery typically has red, green and blue bands. However, sometimes, there is a 4th near-infrared band available. NAIP imagery typically is 1m spatial resolution. This means that each pixel represents 1 meter on the earth's surface. NAIP is often collected using a camera mounted on an airplane.

Landsat 8 imagery

Compared to NAIP, Landsat data are collected using an instrument mounted on a satellite which orbits the globe, continuously collecting images. The landsat instrument collects data at 30 meter spatial resolution but also has 11 bands distributed across the electromagnetic spectrum compared to the 3 or 4 that NAIP imagery has. Landsat also has one panchromatic band that collects information across the visible portion of the spectrum at 15 m spatial resolution.

Landsat 8 bands 1-9 are listed below:

Landsat 8 Bands

Band	Wavelength range (nanometers)	Spatial Resolution (m)	Spectral Width (nm)
Band 1 - Coastal aerosol	430 - 450	30	2.0
Band 2 - Blue	450 - 510	30	6.0
Band 3 - Green	530 - 590	30	6.0
Band 4 - Red	640 - 670	30	0.03
Band 5 - Near Infrared (NIR)	850 - 880	30	3.0
Band 6 - SWIR 1	1570 - 1650	30	8.0
Band 7 - SWIR 2	2110 - 2290	30	18
Band 8 - Panchromatic	500 - 680	15	18
Band 9 - Cirrus	1360 - 1380	30	2.0

Above: Source -

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<img src="~/Documents/Github/earthlab.github.io/images/course-materials/earth-analytics/week-6/Landsat8_

<figcaption>The bands for Landsat 7 (bottom) vs Landsat 8 (top).

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there are several other landsat instruments that provide data - the most
commonly used being Landsat 5 and 7. The specifications for each instrument are
different. Source: USGS Landsat.</figcaption>
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MODIS imagery

The Moderate Resolution Imaging Spectrometer (MODIS) instrument is another satellite based instrument that continuously collects data over the Earth's surface. MODIS collects spectral information at several spatial resolutions including 250m, 500m and 1000m. We will be working with the 500 m spatial resolution MODIS data in this class. MODIS has 36 bands to work with however in class we will focus on the first 7 bands.

First 7 MODIS Bands

Below, you can see the first 7 bands of the MODIS instrument

Band	Wavelength range (nm)	Spatial Resolution (m)	Spectral Width (nm)
Band 1 - red	620 - 670	250	2.0
Band 2 - near infrared	841 - 876	250	6.0
Band 3 - blue/green	459 - 479	500	6.0
Band 4 - green	545 - 565	500	3.0
Band 5 - near infrared	1230 – 1250	500	8.0
Band 6 - mid-infrared	1628 – 1652	500	18
Band 7 - mid-infrared	2105 - 2155	500	18

In the next lesson, we will dive further into multi-band imagery. We will begin to work with NAIP imagery in `R`.

Additional resources:

- Learn more about band combinations
- About multi spectral data - Penn State E-education