Intro to spectral remote sensing

Learning Objectives

After completing this tutorial, you will be able to:

- Define spectral vs spatial resolution.
- Describe 2-3 differences between NAIP imagery, Landsat 8 and MODIS.
- Describe the tradeoffs between collected data 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 5 of the course.

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 - http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/images/resource/tutor/fundam/images/passiv.gif.

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 (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 costs a lot of money to collect airborne data so you may not have repeated data OR, in the case of NAIP, you may have a new dataset ever 2-4 years.

Spaceborn vs airborne remote sensing. Source:http://www.cartospace.com/?page_id=22

Bands and Wavelengths

A *band* represents a segment of the electromagnetic spectrum. You can think of it as a bin. For example, the wavelength values between 800nm and 850nm might be one band as captured by an imaging spectrometer. The imaging spectrometer collects reflected light energy in a pixel for light in that band. 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 800-805 nm, the center would be 825).

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<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 example above, a band was defined as spanning 800-805nm. The spectral width or spectral resolution of the band is thus 5 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 the data are better, why wouldn't we always just collect high resolution data (smaller pixels?)

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The spatial resolution of a raster represents the area on the ground that each pixel covers. Source: Colin Williams, NEON.

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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.

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 band that is a near-infrared band available. NAIP imagery is typically has a 1m spatial resolution. This means that each pixel represents 1 meter on the earth's surface. NAIP is typically 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 - http://landsat.usgs.gov

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<img src="~/Documents/Github/earthlab.github.io/images/course-materials/earth-analytics/week-6/Landsat8
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<figcaption>The bands for Landsat 7 (bottom) vs Landsat 8 (top).  Source: Penn State:  https://www.e-edu
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MODIS imagery

The Moderate Resolution Imaging Spectrometer (MODIS) instrument is also a 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.

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