Lecture 13: Remotely Sensed Geospatial Data

A. The Electromagnetic Spectrum:

The electromagnetic spectrum (Figure 1) indicates the different forms of radiation (or simply stated light) emitted by nature. Of main interest in terms of remote sensing are the microwave, infrared (IR), and visible light components of the spectrum. Different types of light have different wavelengths. Microwaves have relatively long wavelengths on the order of millimeters versus the short sub micrometer (400 to 700 nanometer, nm) associated with visible light.

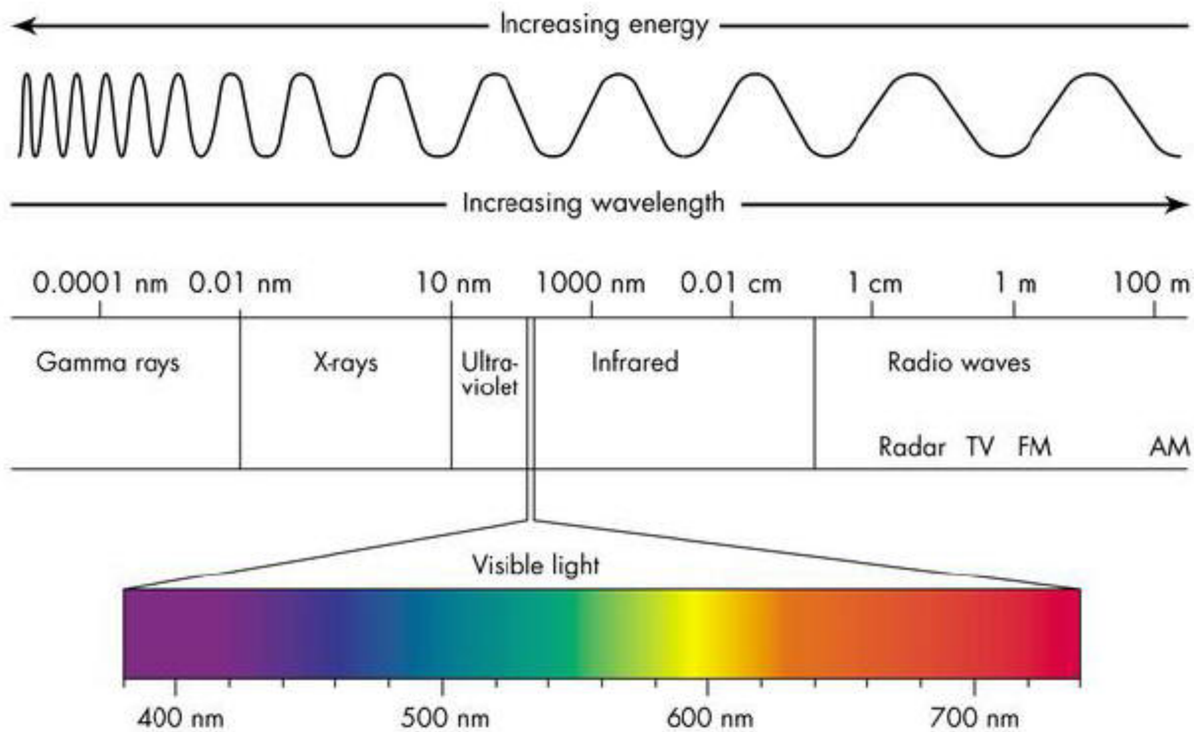

Figure 1. The electromagnetic spectrum.

The quantity of energy carried by light is inversely proportional to wavelength (λ). Microwaves are less energetic than either IR or visible light. This statement seems odd. After all, we commonly heat up water in a microwave oven. Microwaves themselves do not carry abundant energy but it is the interaction of the microwaves with the water molecules that can become energetic. Microwaves are at the right frequency to cause water molecules to move, vibrate, and bounce off of each other, which produces the friction and heat that warms your water.

The fundamental premise of remote sensing is that all objects emit electromagnetic energy based on their temperature. In physics, a theoretical construct known as a blackbody can be used to relate temperature with wavelength (λ). A blackbody, which does not need to be black, is an ideal object that absorbs and re-emits all radiation striking the body. Natural objects like the earth and sun are not true blackbodies but close enough so that we can use this concept for examining how electromagnetic radiation is emitted from these objects

The longer the wavelength of the electromagnetic energy, the less energetic the radiation, and the cooler the object is that is emitting the radiation. For example, the earth has average temperature 288 K, emits in the infrared (IR) part of the spectrum. Conversely, the sun has a temperature of 5000 K and mainly emits in the visible band of the electromagnetic spectrum.

Space based remote sensing of the earth is possible because the earth's atmosphere has wavelength bands that allow light to pass through; indicated by white areas on Figure 2. Additionally, there are wavelengths that the atmosphere is opaque to, especially in the IR part of the spectrum as is illustrated in Figure 2.

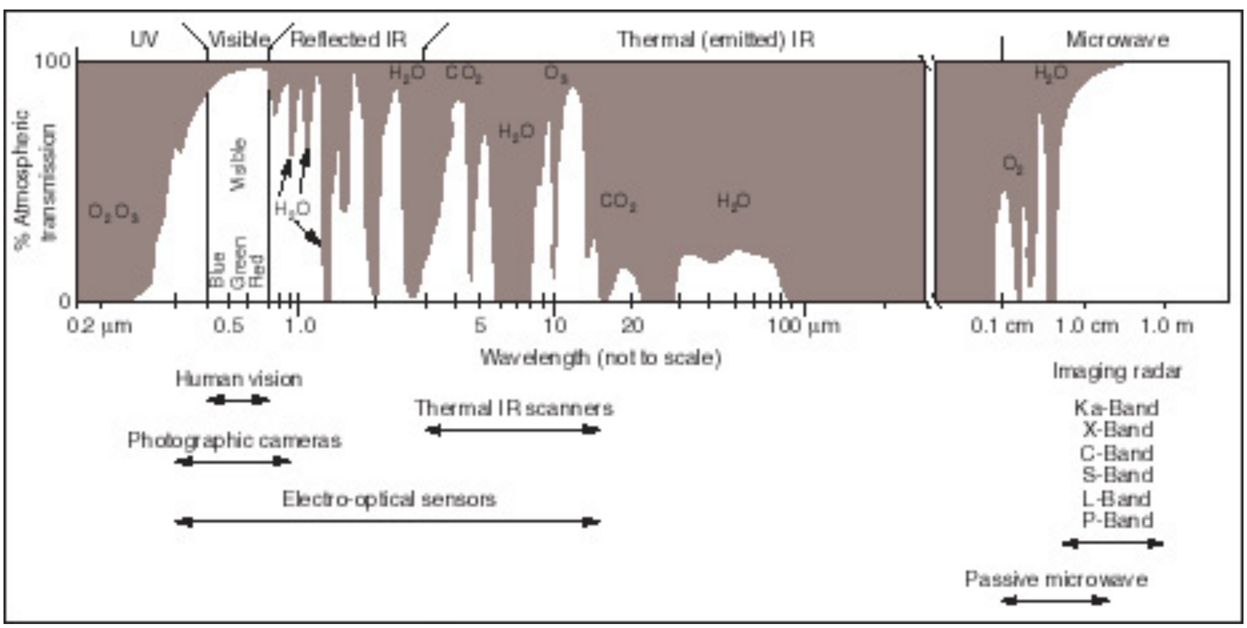

Figure 2. Wavelengths in the electromagnetic spectrum that are opaque (brown) and transparent (white). Wavelength windows that are transparent of greatest utility in remote sensing.

B. The Nature of Remotely Sensed Data:

All objects on earth emit a characteristic spectrum of IR radiation - known as a spectral response pattern or spectral signature (Figure 3). This spectra can be determined for each type of landscape allowing for the rapid detection of changes on the earth's surface.

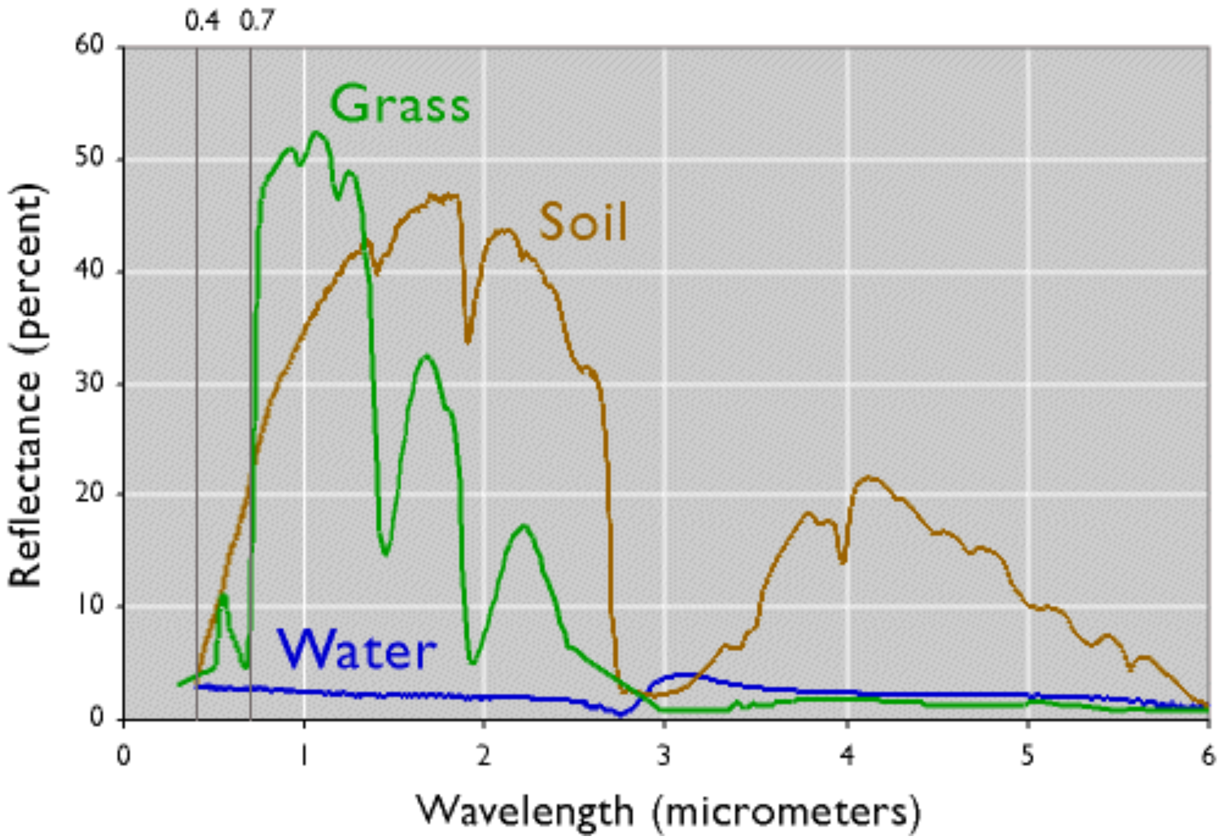

Figure 3. Spectral response of grass, bare soil, and water for visible and near (reflected) IR wavelengths.

Most remotely sensed data is raster data in nature. Color in raster images commonly are collected in RGB format (red, green, blue) where millions of colors can be shown by 0 to 255 (8 bit) intensities of red (R), green (G), and blue (B).

Satellite sensors basically scan the earth at multiple wavelengths. Therefore, remote sensing products will consist of a pixel by pixel map that will document the nature of the landscape. For example, water has a different spectral signature than grass or bare ground (Figure 3). Even different types of vegetation have different spectral signatures, for example grassland will have differing spectral characteristics compared with forest.

Remotely sensing has the potential to allow geospatial professionals to continuously and quickly update land use maps. In order to make effective use of remotely sensed data the user needs to understand its limitations (resolution). With remotely sensed data there are four types of resolution.

Spatial Resolution - We have talked about this already several times in this course and is the physical width of the pixel that makes up the product.

High resolution (sub meter to meter)

- CIA type satellite photography; IKONOS

Medium resolution (10's m)

- Landsat

Low resolution (km's)

- TRMM, GPM, SMAP, AVHHR, AMSR-E

Temporal Resolution - Depends on how often a satellite will fly over an area of interest. Can range from hours to weeks in length.

Radiometric Resolution - Provides an indication of how accurately can the magnitude of energy emitted from the earth be measured as is illustrated in Figure 4.

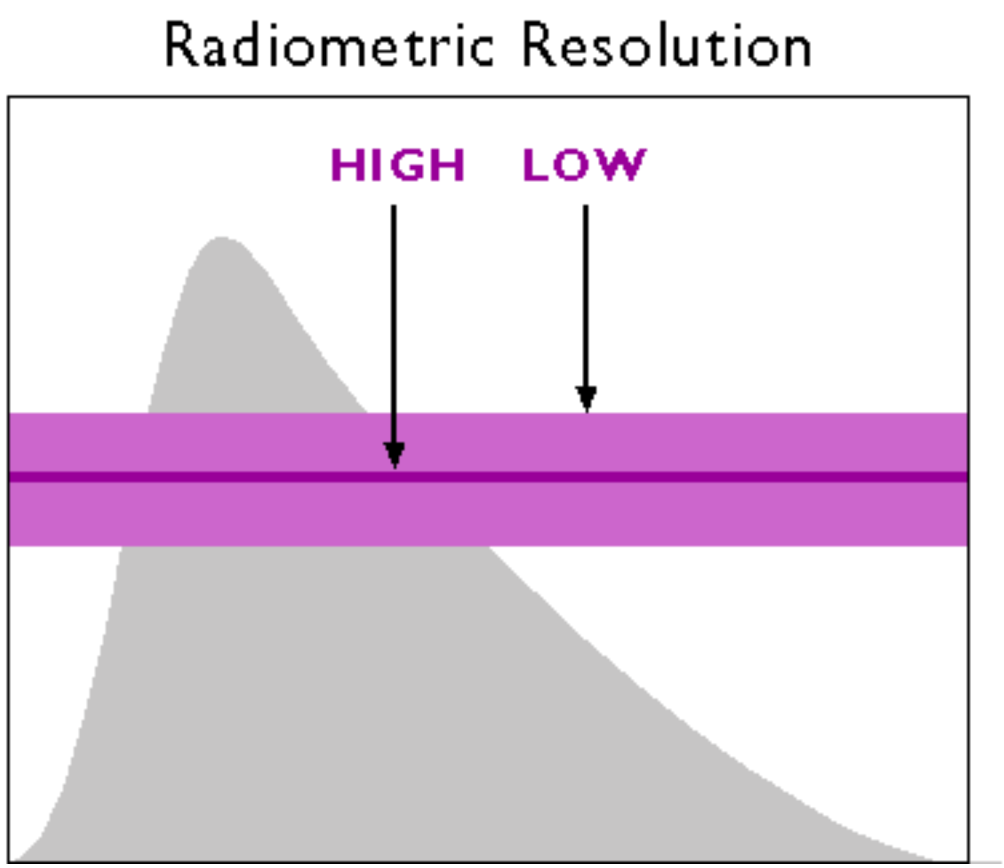

Figure 4. On previous page - Illustration of radiometric resolution (previous page).

Spectral Resolution - Provides an indication of how accurately can a specific wavelength of radiation be discerned as is illustrated in Figure 5.

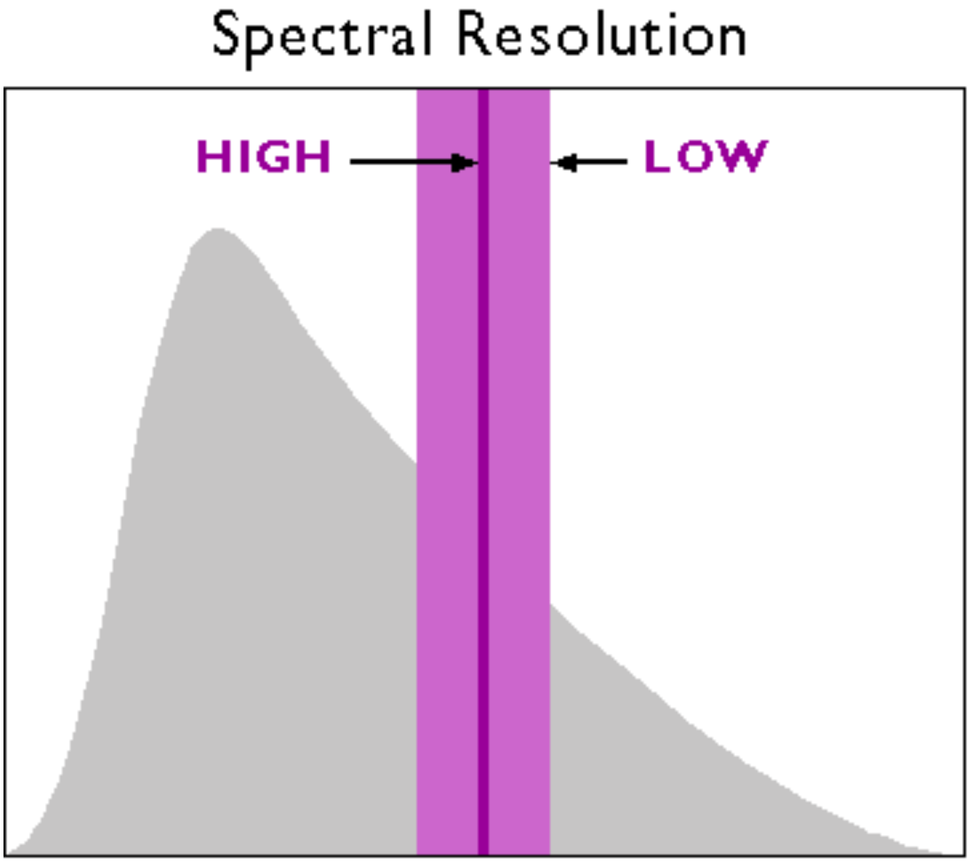

Figure 5. Illustration of spatial resolution.

C. Remotely Sensed Data Products

The following is a list of some common remote sensing products, that you should explore and consider utilizing in the final project.

KVR-1000 / SPIN-2

This product consists of Russian satellite photos, which is in the visible part of the spectrum and has 2 m spatial resolution.

SPOT

SPOT was one of the first commercial satellites to provide imagery and the first SPOT satellite was launched in 1986. Spatial resolution can vary depending upon the application but typically ranges from 2.5 to 20 m.

DMSP http://en.wikipedia.org/wiki/Defense_Meteorological_Satellite_Program

The Defense Meteorological Satellite Program has imagery available in both the visible and near IR parts of the spectrum. Near IR imagery extends the utility of this product allowing for reconnaissance during the night. An application of DMSP product is determining the extent of nighttime lights as a means of tracking global population growth.

IKONOS http://www.satimagingcorp.com/gallery-ikonos.html

IKONOS is a private US firm, which started to launch satellites back in 1998. Imagery is based on visible light and has a 0.5 to 1 m resolution. IKONOS is most noted for its famous photo of Area 51 (Goggle it). Other private satellite platforms include QuickBird and WorldView-1 each with a spatial resolution of less than 1 m.

AVHRR http://en.wikipedia.org/wiki/Advanced_Very_High_Resolution_Radiometer

AVHRR stands for the Advanced Very High Resolution Radiometer. This satellite has low spatial resolution (2.4 km) but has very high Radiometric Resolution. The AVHRR platform has a number of applications including land use, agricultural yields, fire susceptibility, and snow cover.

Landsat

Landsat is a series of satellites launched by NASA from the 1970 to 1990's (http://en.wikipedia.org/wiki/Landsat_program). MSS stands for multi-spectral scanner (MSS). Landsat MSS imaged each point on the earth was imaged at a minimum once every two weeks. Therefore, the Landsat mission was to detect changes in land use. The most significant finding of the Landsat missions was documenting the deforestation of the Amazon (Google it). The earlier Landsat satellites had only four spectral bands (green, red, and two bands in the near IR). More recently, Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) has a better spatial (30 m) and spectral resolution and remotely sensed the earth with more spectral bands. For example, Landsat TM had seven and ETM+ had eight spectral bands. Finally, in 2013 Landsat 8 was launched that has two sensors, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). Both of these platforms expanded the capacities of the Landsat mission to support specific applications such as: vegetation health; soil moisture; and soil and geology type. I recommend that you browser the USGS Earth Explorer website and examine some Landsat Data, which you may want to incorporate into your final project.

MODIS

The Moderate Resolution Imaging sensor (MODIS) was developed to monitor the health the planets vegetation through examination of visible and infrared bands that are sensitive to vegetation. Spatial resolution of MODIS data varies from 0.25 to 1 km.

D. Multi-spectral Image Processing:

Remote sensing products are rarely useful without extensive corrections. Why? Remember that with aerial photography the only point that lacks distortion is the principal point directly under the camera. Now you can imagine that the problem of distortions will be greatly compounded with satellites in orbit that are imaging a point of the earth's surface as the satellite passes overhead at a velocity of 18,000 mph. There are several types of corrections applied to remotely sensed imagery.

<u>Geometric Correction</u> - accounts for relief displacement (like with aerial photos), satellite movement, and random geometric errors caused by the orientation of the satellite with the earth's surface. Geometric correction is analogous to the rectification process associated with aerial photography.

<u>Radiometric Correction</u> - corrects for differences in radiation associated with changes of seasons, time or day, atmospheric conditions, etc. There are two approaches to radiometric correction. To correct for changes of seasons or time or day a remote sensing specialist compiles a table of expected radiation for each location on the planet based on the position of the earth and sun at the moment of remote sensing. To adjust for atmospheric conditions such as haze, data can be collected during a period of clear atmospheric conditions and this can be used as the standard to correct for data collection under non-ideal conditions.

<u>Image Enhancement</u> - A common type of image enhancement that even an individual with Photoshop Elements can apply is **contrast stretching**. Contrast stretching involves expanding the pixel scale of the raw image. For example, a raster image has a pixel intensity that ranges from 30 to 80 but the image is 8-bit and can potentially have an overall range of 256. Contrast Stretching can artificially increase the intensity range so that it covers the full 256 intensity range to allow features to stand out better.

Contrast stretching must be applied in a consistent manner to facilitate inter-comparison. Realize that remote sensing products can be used to develop new derived data sets that can be calculated by differences, ratios, or other quantities from reflectance's values in two or more wavelengths. For example, comparing visible (red) and near infrared reflectance is the basis for the NDVI index (http://en.wikipedia.org/wiki/Normalized_Difference_Vegetation_Index), which is a commonly used metric that can quantify the health of vegetation. The NDVI can be calculated using the following equation:

$$NDVI = (NIR - R) / (NIR + R)$$

Where R represents the visible red band, while NIR represents the near-infrared band. NDVI values range from -1 to 1 where 1 represents a healthy vegetation cover. Lower values indicate less healthy vegetation.

Image Classification - As we have previously mentioned it is possible to generate vector entities from raster data. Raster to vector data conversion is the basis for many derived products that are generated from remote sensing platforms (Figure 6). A common application is the development of vector land use datasets from a remotely sensed raster platform. Through raster to vector data conversion geospatial professionals can quickly develop useful maps that can document changes on the earth's surface.

Critical to raster to vector data conversion is exactly how pixels are classified into specific categories that can be used to define vector geographic entities. There are two types of classification (supervised and automated).

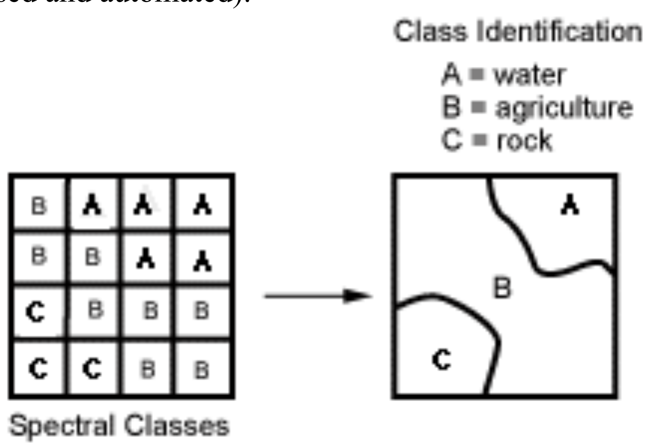

Figure 6. Raster-to-vector data conversion. In this case involving using the spectral response of three surface types to derive vector based geographic entities.

Supervised classification involves the interaction of a person with the image and determines the break points that form the basis of the classification. This process involves examining the spectrum of an image and determining natural break points in the spectrum and using these breaks as a method for classifying data.

Automated classification is done without human interaction by a geospatial program. What problems do you think may result from an automated classification? Remember computers are fundamental dumb and need human intelligence to derive a realistic depiction of the earth. Ask yourself this question - Would you completely trust a map produced without ground validation?

E. Remotely Sensed Data Products - Microwave Data:
Microwaves are longer wavelength radiation that can penetrate the atmosphere no matter atmospheric conditions (pass though clouds). This is unlike visible or IR radiation. Therefore, microwaves can be used to image the earth's surface on a continuous basis. Microwave imaging of the earth has been used applied for a number of applications.

As previously discussed microwaves have helped delineate the elevation of the earth's surface. An example of this is the Shuttle Radar Topography Mission, which mapped elevations on the planet at a spatial resolution of 30 m. The TOPEX-POSEIDEN mission has allowed earth scientists to measure the thermal expansion/contraction of the oceans to allow us to delineate El Nino/La Nina cycles that affect the weather over 1,000's of miles, including South Texas. Two other missions are TRMM and GPM, which is a space borne platform consisting of IR, passive microwave, and radar systems that remotely measure precipitation from orbit. Likewise, SMOS and SMAP use these same approaches remotely to detect soil moisture.

Readings
DiBiase, D., 2014, Nature of Geographic Information Systems. Sections 8.2 to 8.21.
Campbell, J and Shin, M., 2011, Essentials of Geographic Information Systems. Chp. 4.3.

Terms

EM Spectrum	Visible Light	Infrared	Microwaves
Blackbody	RGB	Spectral Response	Spatial Resolution
Spectral Resolution	Temporal Resolution	KVR-1000 / SPIN-2	SPOT
Radiometric Resolution	DMSP	DMSP	IKONOS
Landsat	MODIS	GPM	SMOS
Imagine Classification	TOPEX-POSEIDEN	SMAP	TRMM

Concepts
At which wavelengths is the earth's atmosphere transparent. These are the wavelengths that are most useful for remote sensing
Know how the spectral response can differ for different types of land covers
Know the difference between the different types of resolution that can be applied in remote sensing
Be familiar with some of the remote sensing products that exist. Know whether they image the visible, infrared, or ultraviolet parts of the spectrum
Know about the steps that are required to processes a multi-spectral satellite image

HOMEWORK

1. Describe in your own words the electromagnetic spectrum.

2. Contrast radiometric and spatial resolution.

3. What is the difference between supervised and unsupervised classification in converting raster in vector data layers.

4. What is the spectral response pattern?

A. The range of wavelengths that a sensing system is able to detect

B. The magnitudes of energy that an object reflects or emits across a range of wavelengths

C. The ability of a sensor to detect small differences in wavelength

D. The ability of a sensor to detect small differences in energy magnitude

5. What is the resolution of the SPIN-2 images

A. 2 mm

B. 2 cm

C. 2 meters

D. 2 km

6. What system has poor spatial resolution but excellent radiometric resolution.

A. Landsat ETM+

B. IKONOS

C. AVHRR

D. Aerial Photo

7. Visit the USGS Earthshots webpage and using it to explore how San Antonio has changed over the decades.

8. Calculate the NDVI for two Texas landscapes. Example 1 1has a heathy vegetation cover and example 2 does not. Use the data provided below. Show your work.

	Example 1	Example 2
NIR	31.2	24.6
R	2.9	4.6