FOR375

INTRODUCTION TO REMOTE SENSING

SPRING 2016

Lecture 7 – Introduction & Remote Sensing

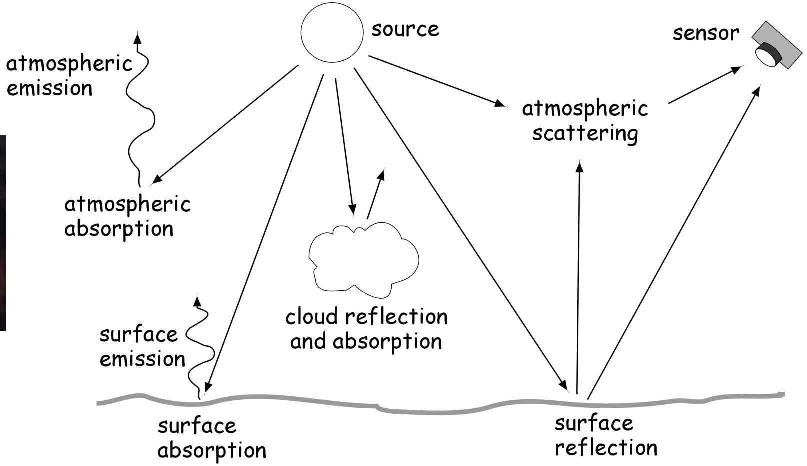
University of Idaho
College of Natural Resources

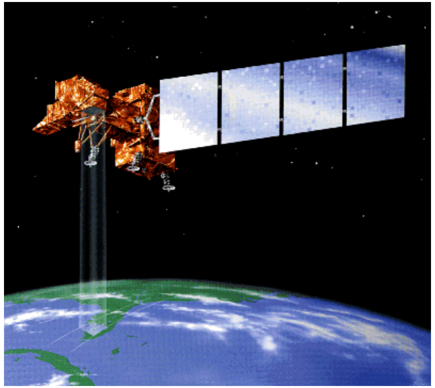
INTRODUCTION TO REMOTE SENSING

Learning Objectives:

- what remote sensing is and how it can be used for obtaining primary data
- value of the overhead perspective – context, patterns, adjacencies
- basic concepts of spatial, spectral, temporal and radiometric resolution
- converting raw spectral images into information outputs or maps – image classification using statistical classifiers

Remote sensing is the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth's surface. Campbell, 1996





TYPES OF REMOTE SENSING

- **Ground based platforms**
- Airborne based platforms
- Space based platforms

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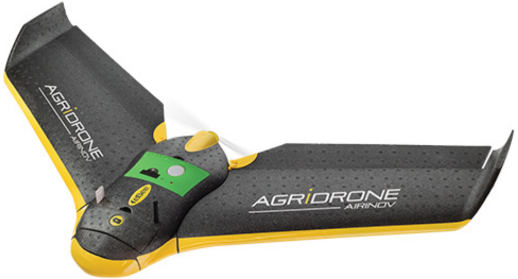
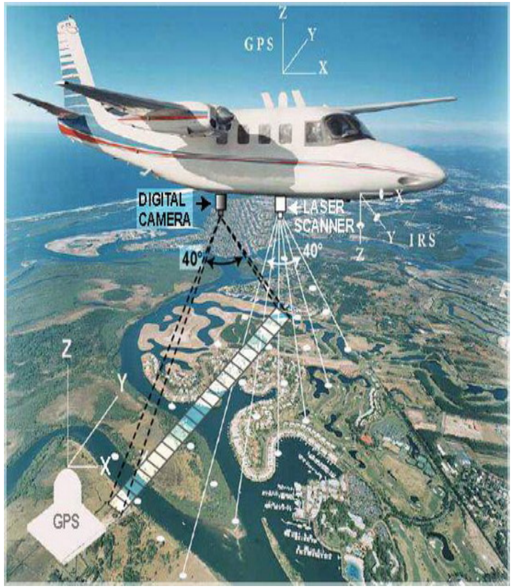
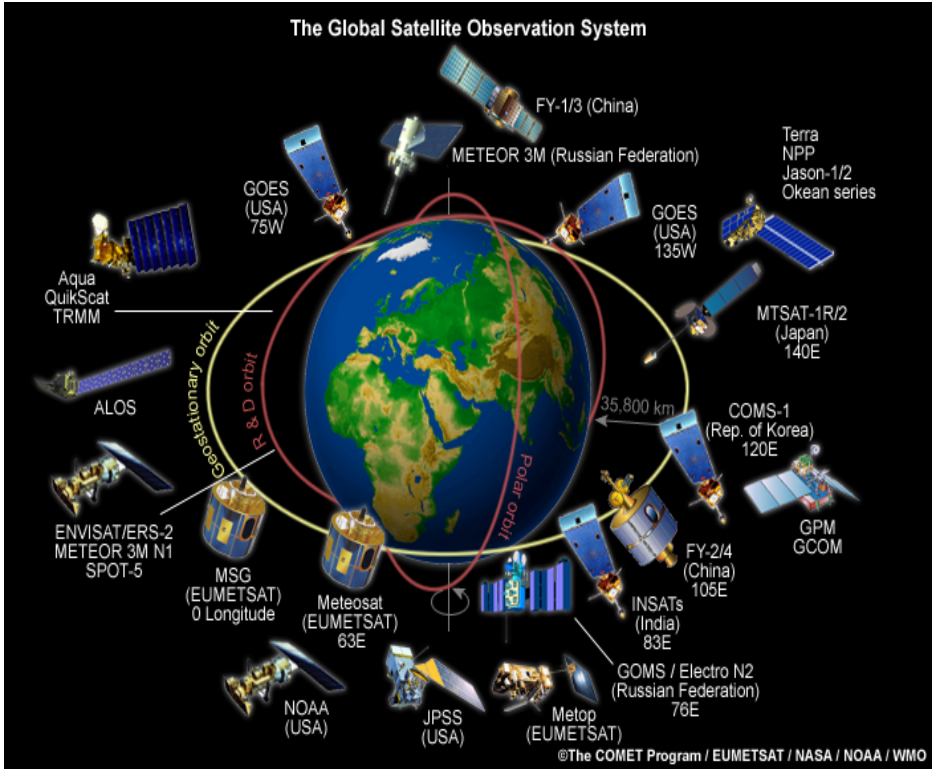




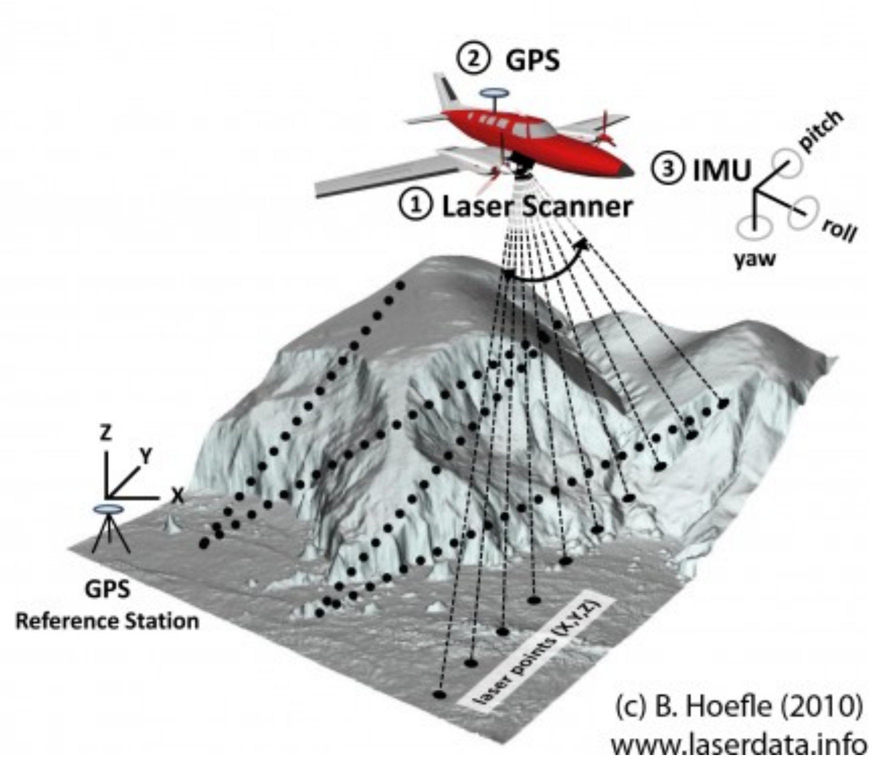
TYPES OF REMOTE SENSING

- Ground based platforms
- Airborne based platforms
- **Space based platforms**



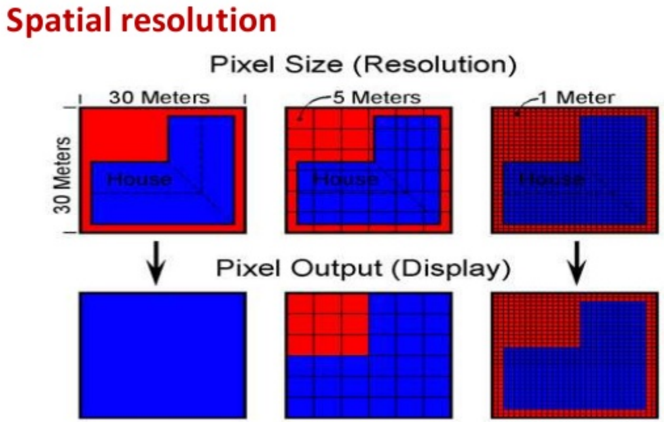
LIDAR

LIDAR is a surveying technology that measures distance by illuminating a target with a laser light. The term lidar was created as a combination of the words "light" and "radar". Lidar uses ultraviolet, visible, or near infrared light to image objects. It can target a wide range of materials, including non-metallic objects, rocks, rain, chemical compounds, aerosols, clouds or single molecules. A narrow laser-beam can map physical features with very high resolutions.



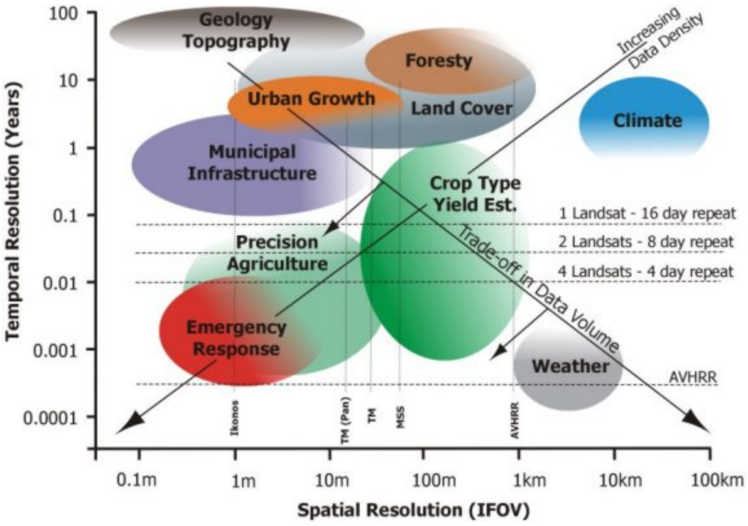
RESOLUTION

- The process or capability of making **distinguishable** the individual parts of an object.
- We may measure resolution (i.e. how distinguishable objects are) in differing ways for differing processes.
- Time, location, degree of detail, multi-spectral properties



TYPES OF RESOLUTION

- **Spatial resolution** – spatial detail & geographic extent
- **Spectral resolution** – colors or spectral differentiation (wavelength differentiation)
- **Temporal resolution** – when, or how often (monitoring)
- **Radiometric resolution** – how many gray levels, or levels of brightness differentiation



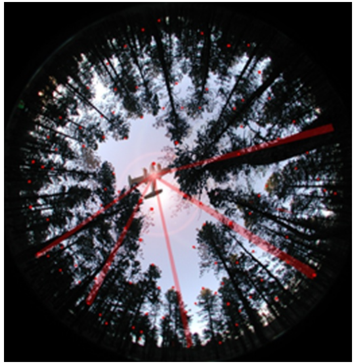
TYPES OF RESOLUTION

- **Spatial resolution** – what size can I observe?
- **Spectral resolution** – what wavelengths can I observe?
- **Temporal resolution** – how often do you observe?
- **Radiometric resolution** – degree of detail observed?

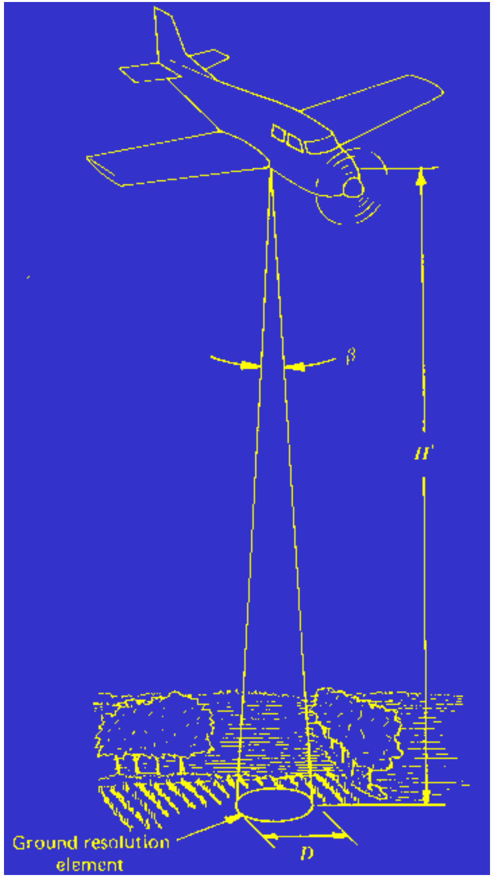
INSTANTANEOUS FIELD OF VIEW (IFOV)

Instantaneous Field of View (IFOV):

the area viewed by the instrument if it were possible to suspend the motion of the aircraft (satellite platform) and the scanning of the sensor for an instant



LiDAR spatial resolution: fundamentally different



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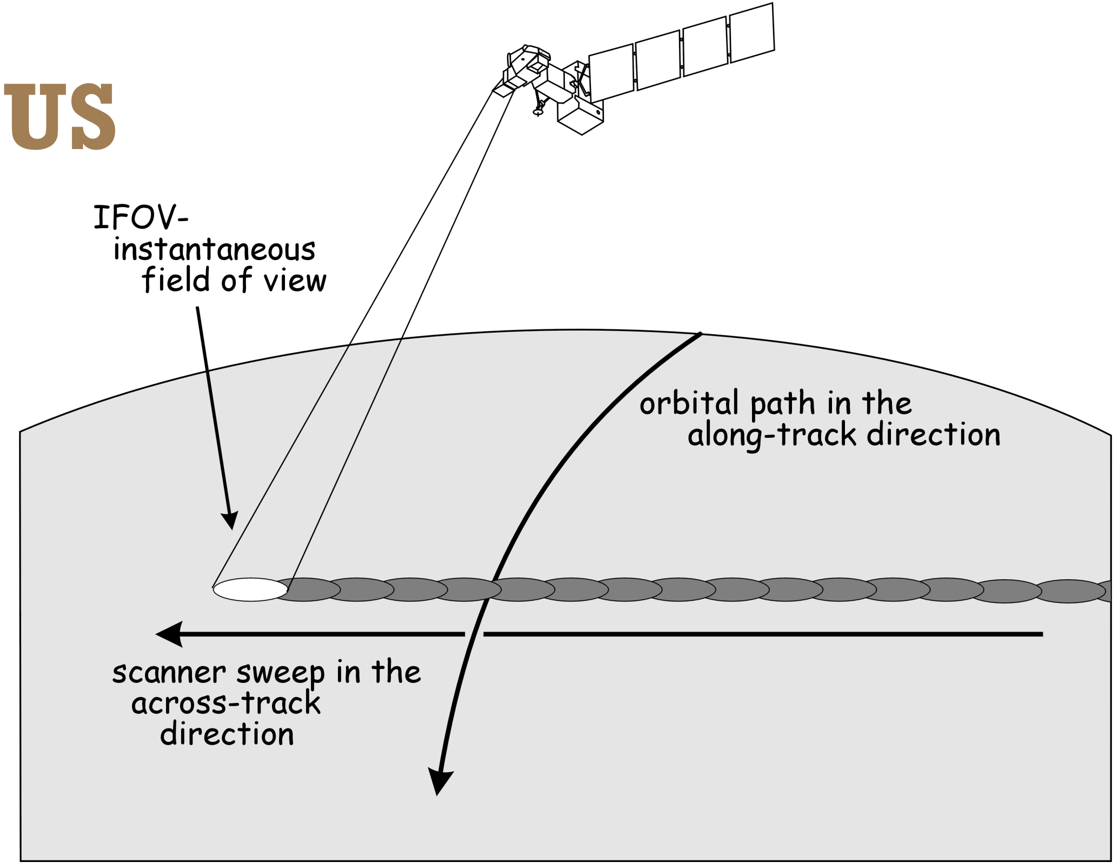
INSTANTANEOUS FIELD OF VIEW (IFOV)



As a general rule of thumb, in order to detect and/or map spatial objects on the ground, the pixel size should be about 1/3 the size of the object

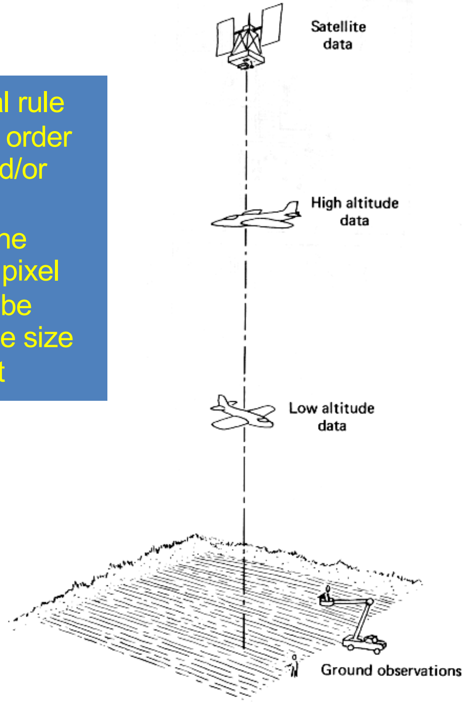
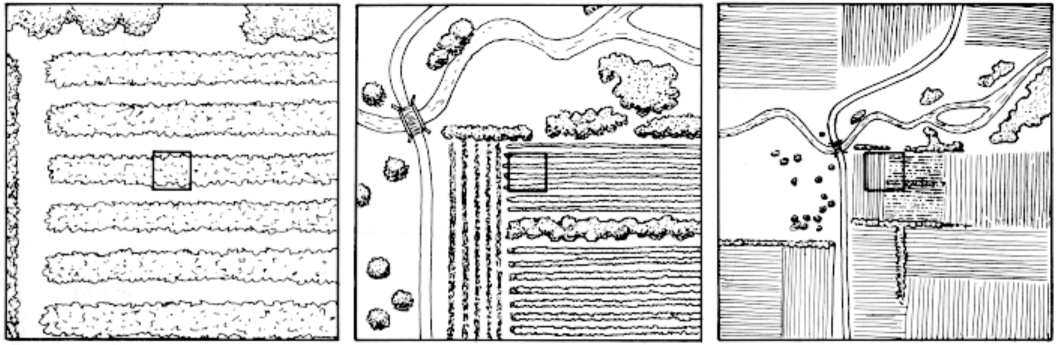


Figure 1.18 Multistage remote sensing concept.

- Spatial resolution: refers to the pixel size, cell size, or instantaneous field of view (IFOV)
- Typically the lower the flying height the greater the detail (larger scale), smaller the individual pixel size
- Trade-offs exist between high spatial resolution and overall ground area encompassed by an image



(a) Small ground resolution cell size

(b) Intermediate ground resolution cell size

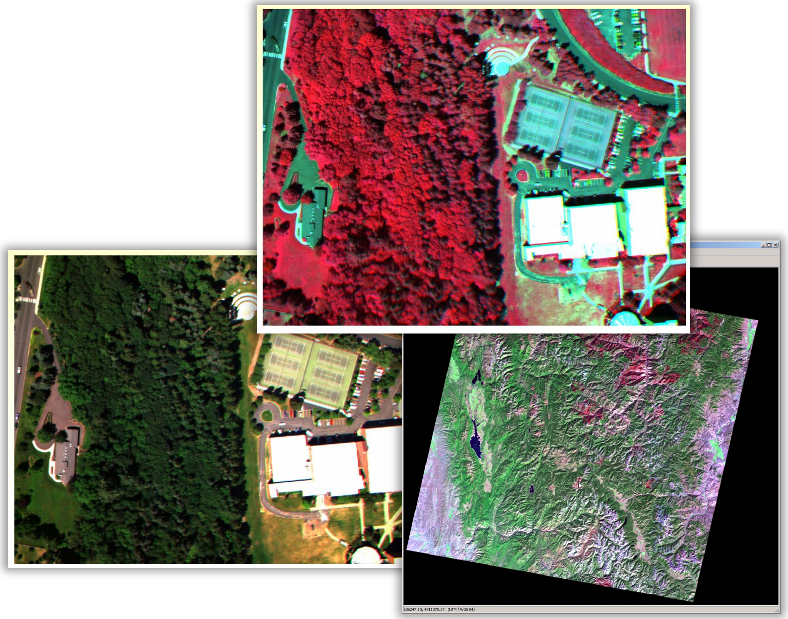
(c) Large ground resolution cell size

Figure 1.17 Ground resolution cell size effect.

High spatial resolution | **Intermediate spatial resolution** | **Low spatial resolution**

THE VALUE OF REMOTE SENSING

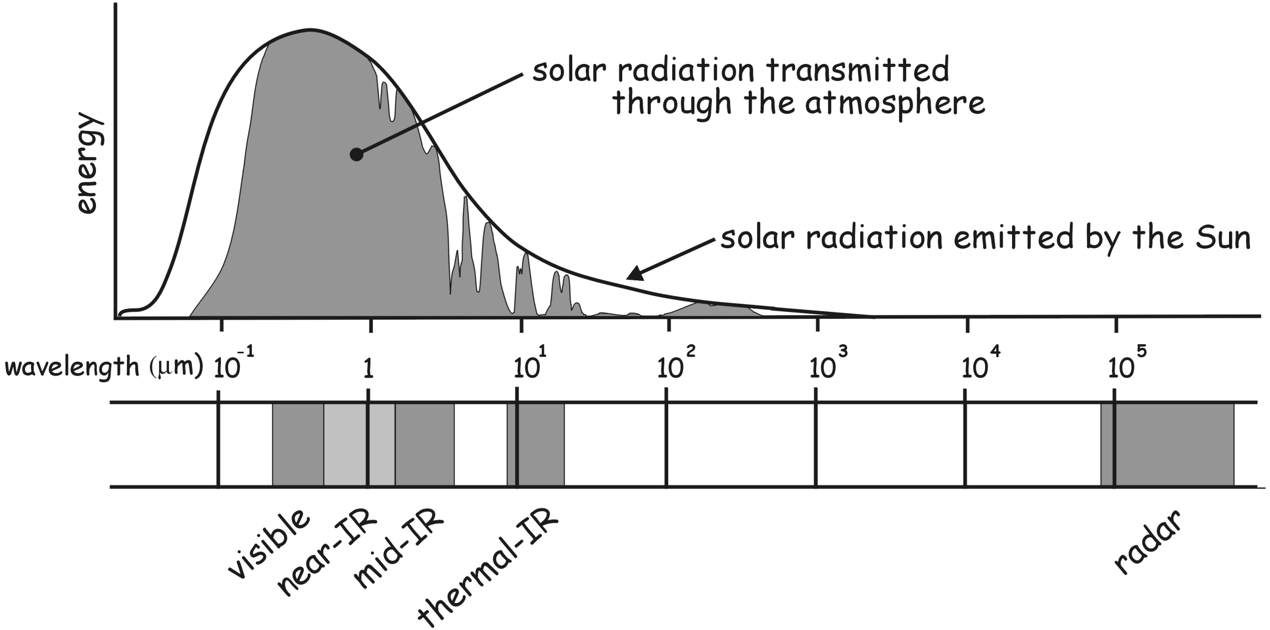
- Trade-offs exist between high spatial resolution and overall ground area encompassed by an image
- However, remote sensing and the overhead perspective also provide us with a unique ability to perceive context, adjacency and spatial patterns. Digital images allow us to quickly zoom and pan so that we can look at context as well as detail – such as orthographic vs. perspective
- Computers and digital imaging technologies provide a tremendous expansion of our ability to map and monitor at a variety of scales and perspectives.
- Satellite images vs. aerial photos – digital technologies have bridged the gaps and differences
- Remote sensing images provide a permanent record of ground conditions/patterns at a point in time



ELECTROMAGNETIC SPECTRUM (EM) AND WAVELENGTHS

Light can be divided up into bands that have differing wavelengths.

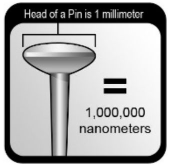
Objects of differing composition (trees, grass, rocks) reflect the varied wavelengths of light in differing ways.

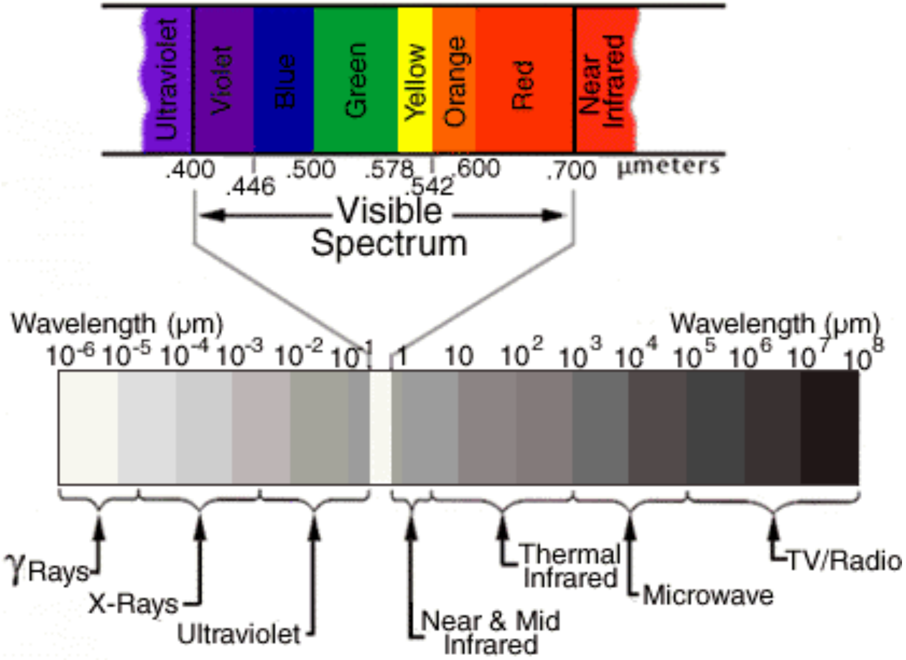


SPECTRAL RESOLUTION

Spectral resolution: refers to the number of colors or spectral bands we can acquire with a particular sensor or camera

Traditional cameras capture visible wavelengths of light (B,G,R), and many newer sensors can capture or image wavelength bands (channels) outside of the visible spectrum (NIR, MIR, TIR). A band refers to a range along the electromagnetic spectrum. (Red band = ~.6-.7 μmeters)

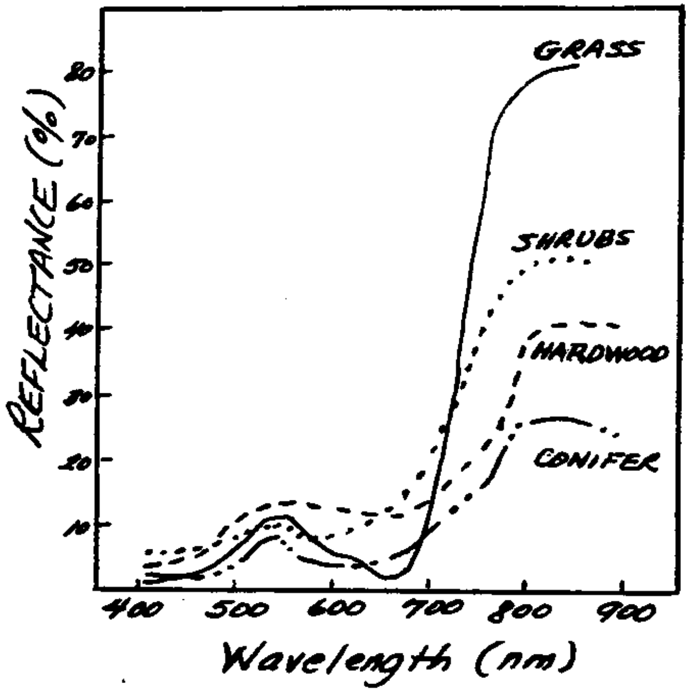




SPECTRAL PROFILES

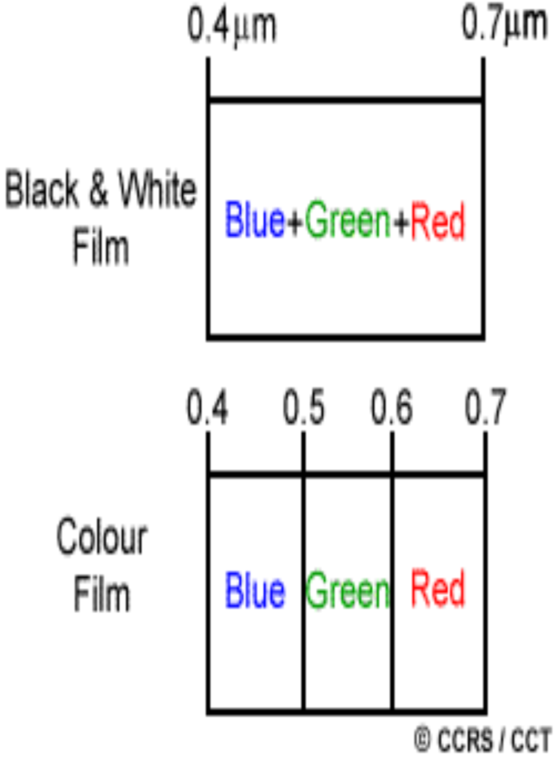
Characteristic curves for different earth surface phenomena

These variations in reflectance cause differences in brightness as captured on film



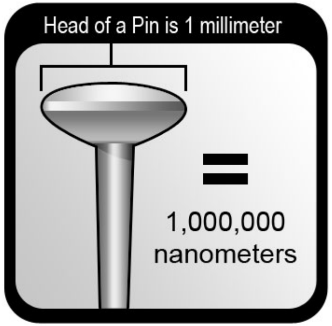
SPECTRAL RESOLUTION

- Spectral resolution describes the ability of a sensor to define fine wavelength intervals.
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

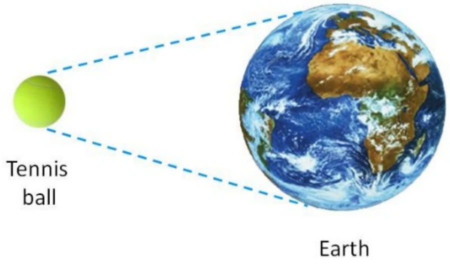


WHAT IS A NANOMETER?

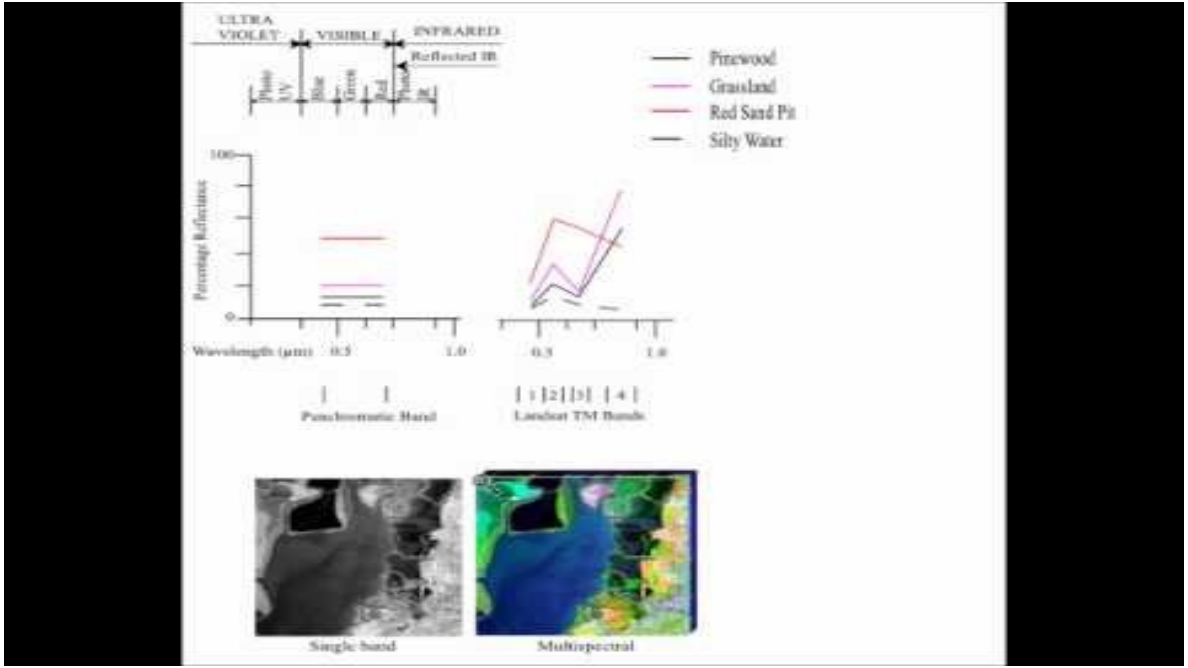
A **nanometer** is a unit of spatial measurement that is 10^{-9} meter, or one billionth of a meter.



One nanometer is to a tennis ball what a tennis ball is to the Earth



SPECTRAL RESOLUTION IN 3 MIN



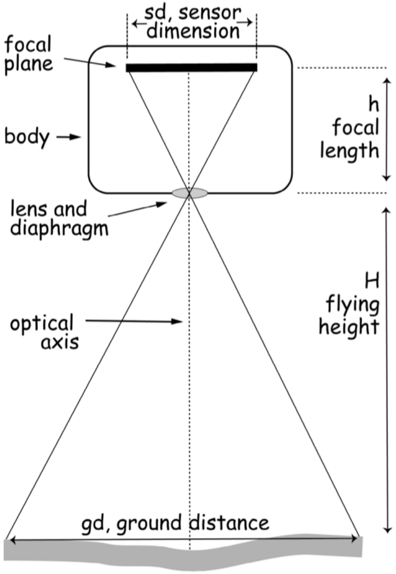
REMOTE SENSORS

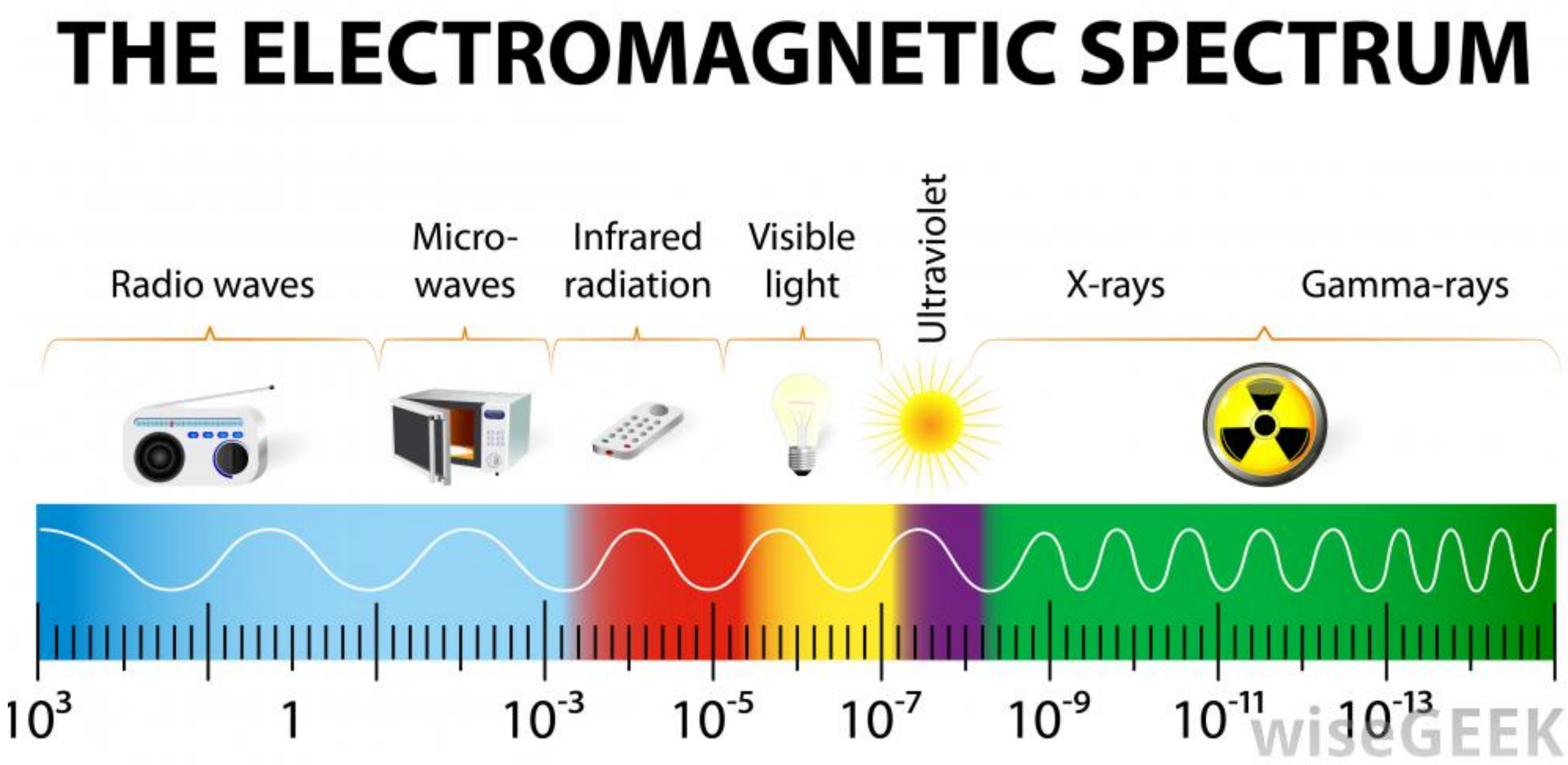
Image Extent – the area covered by an image, and depends on the physical size of the sensing area (sd), the camera focal length (h) and the flying height (H).

$$GD = sd * H / h$$

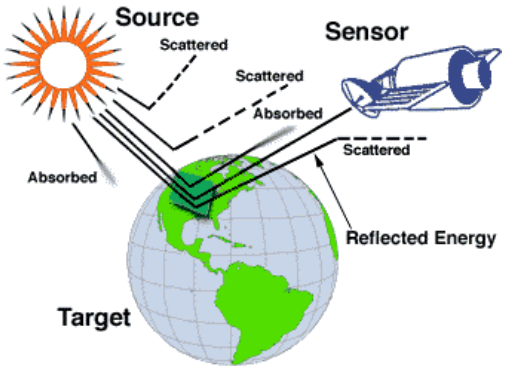
The **ground resolution** on aerial images can be determined by substituting the **cell dimension** for sensor dimension

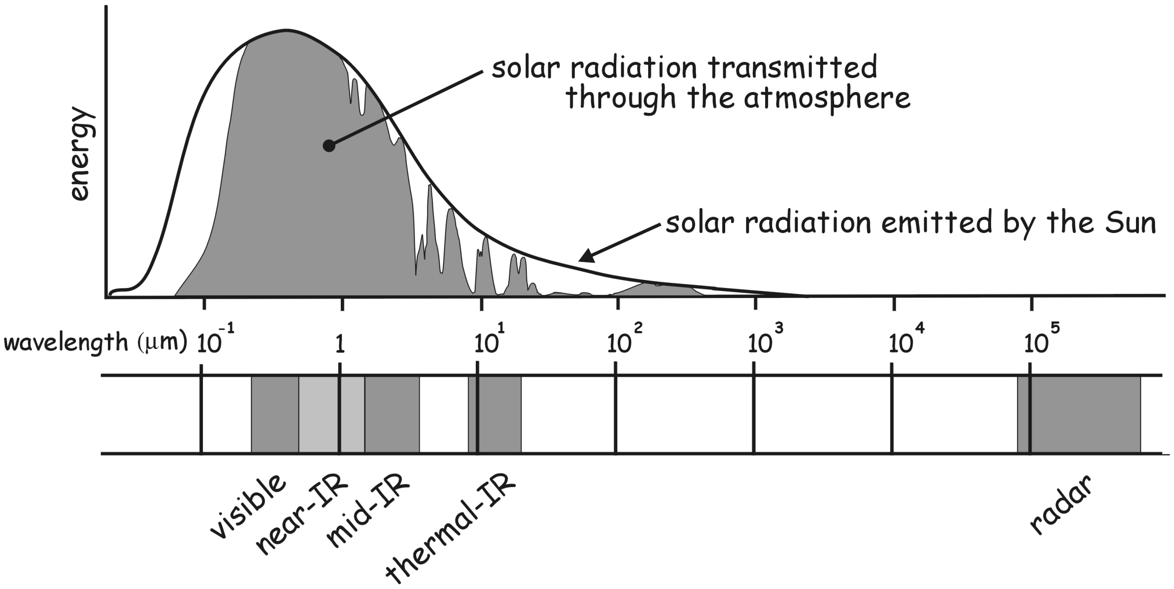
$$GD = cd * H / h$$



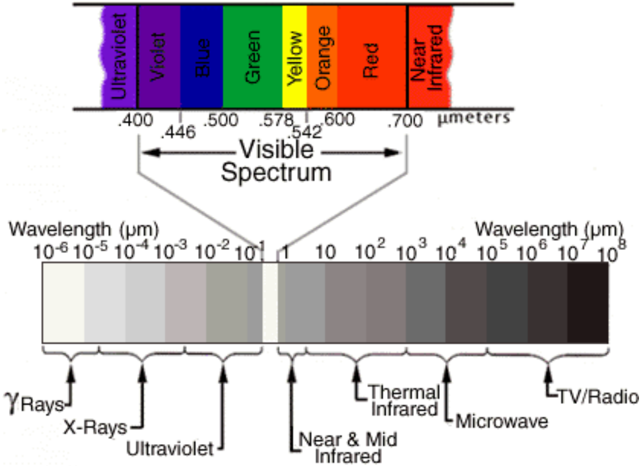

THE ELECTROMAGNETIC SPECTRUM
Radio waves
Micro-waves
Infrared radiation
Visible light
Ultraviolet
X-rays
Gamma-rays
10^3
1
10^-3
10^-5
10^-7
10^-9
10^-11
10^-13
wiseGEEK

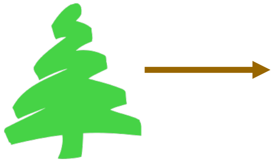
SPECTRAL RESOLUTION

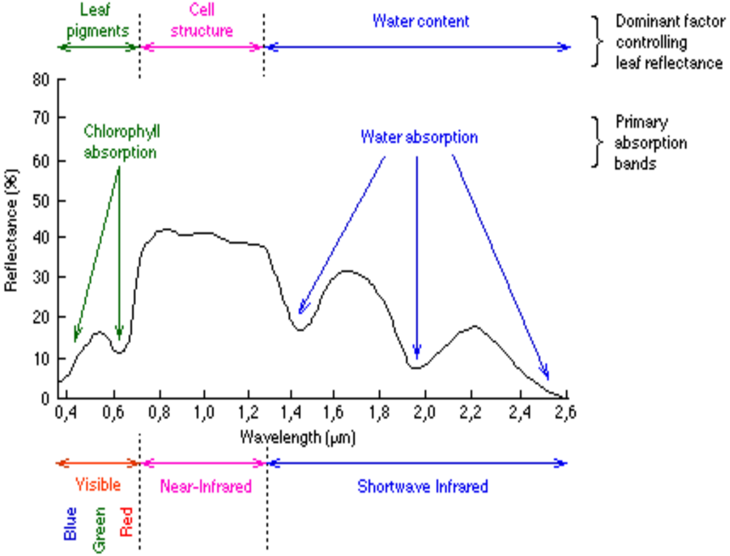




SPECTRAL RESOLUTION







SPECTRAL RESOLUTION

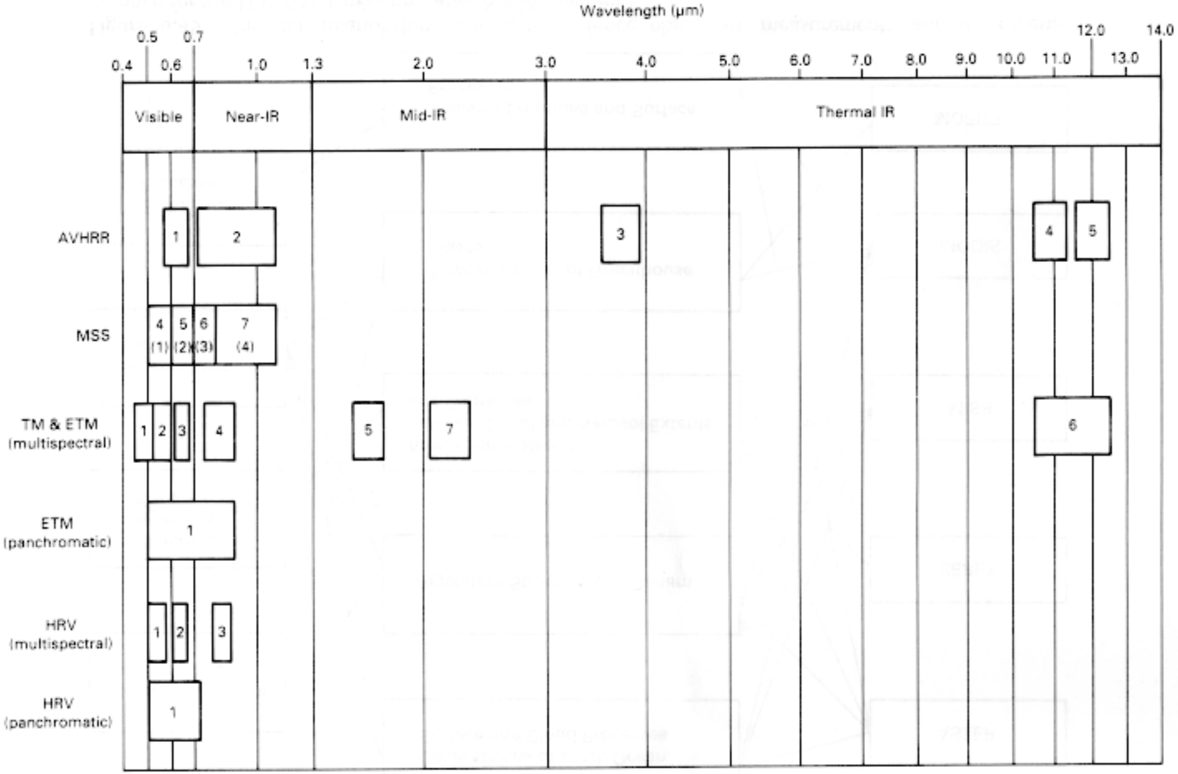
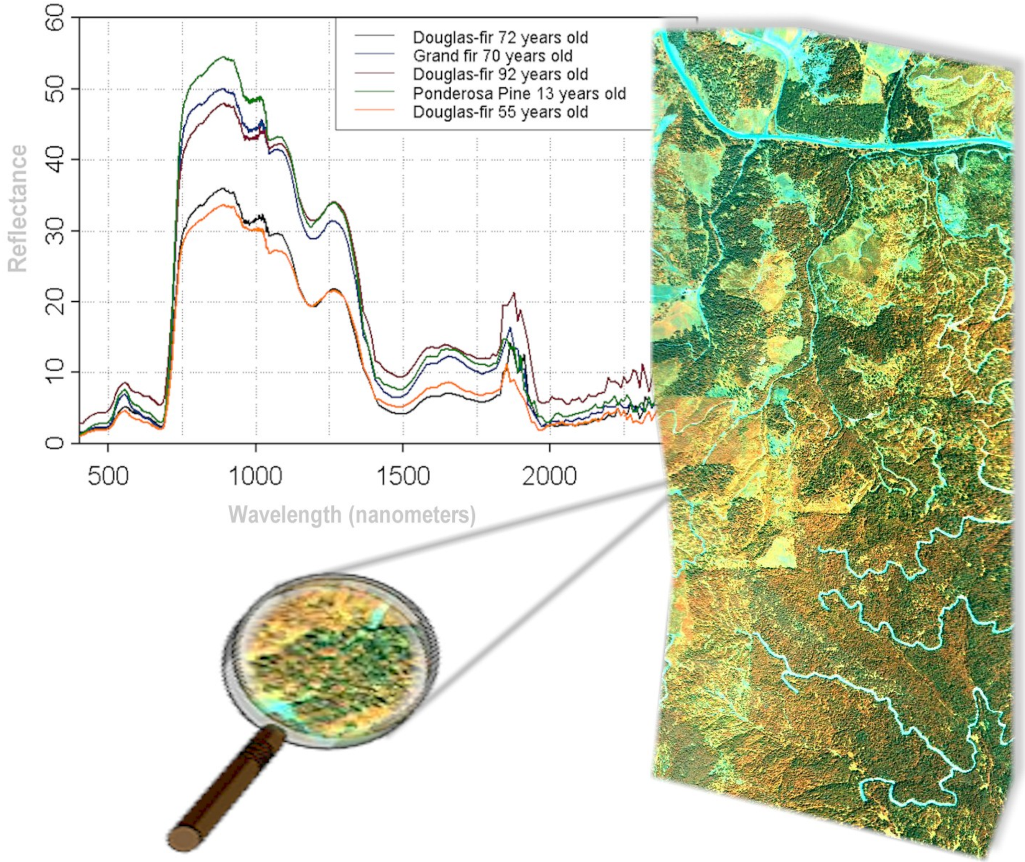
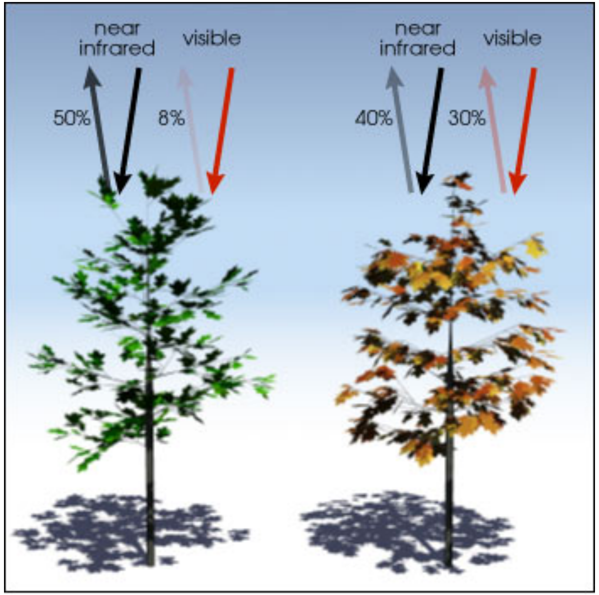


Figure 6.43 Summary of spectral sensitivity of NOAA AVHRR, Landsat MSS, TM, and ETM (planned for Landsat-6) and SPOT HRV.

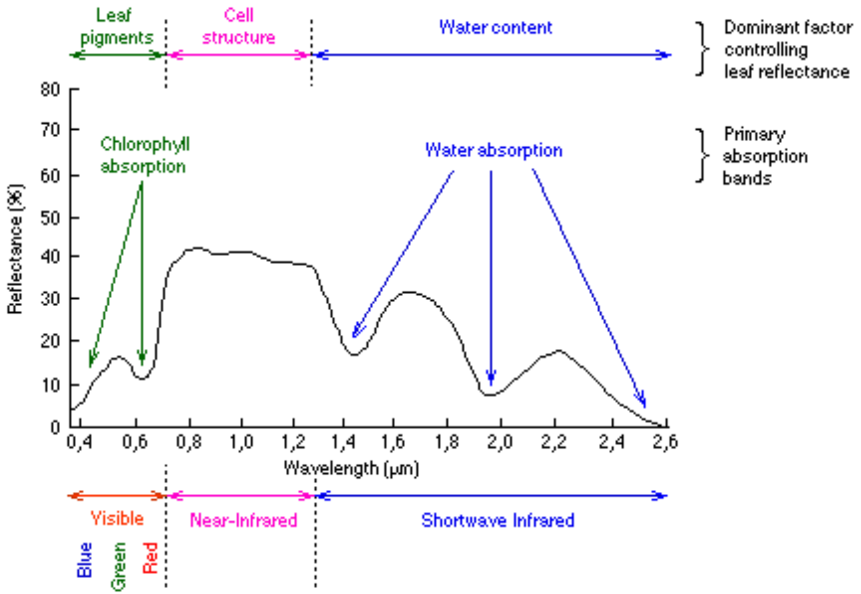
Hyperspectral (224 channels)

(Lillesand & Kiefer, 1996)


Douglas-fir 72 years old
Grand fir 70 years old
Douglas-fir 92 years old
Ponderosa Pine 13 years old
Douglas-fir 55 years old
Reflectance
0
10
20
30
40
50
60
500
1000
1500
2000
Wavelength (nanometers)



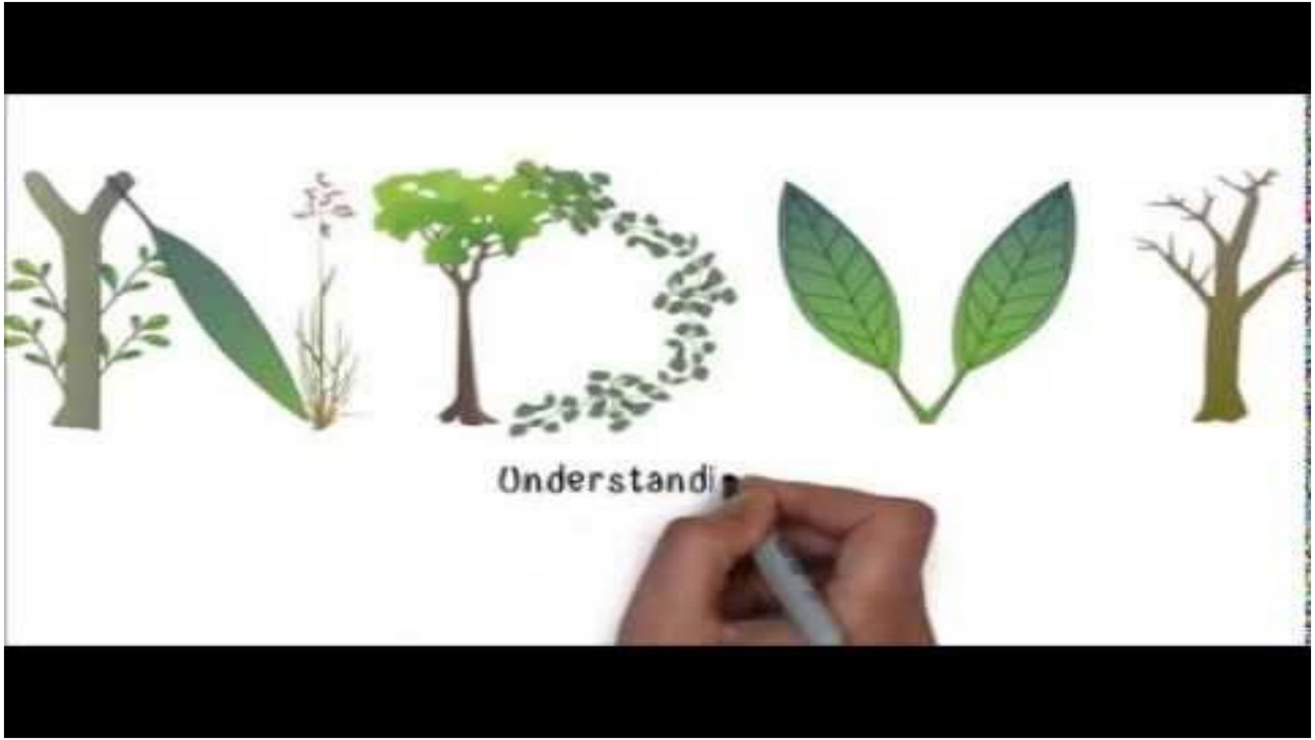
$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$



$$\text{Normalized Difference Vegetation Index: NDVI} = \frac{\text{NIR - visible}}{\text{NIR + visible}}$$

The **normalized difference vegetation index** (**NDVI**) is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not.

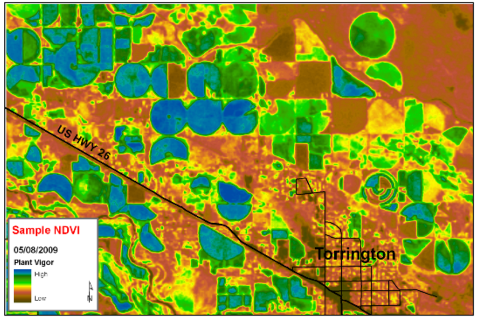
NDVI



NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

$$\frac{\text{NIR - visible}}{\text{NIR + visible}}$$

- The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 μm) for use in photosynthesis.
- The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm). The more leaves a plant has, the more these wavelengths of light are absorbed, respectively.
- By exploiting the strong differences in plant reflectance, we can determine their spatial distribution



NDVI can be used to quantify the photosynthetic capacity of plant canopies.

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or

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END OF LECTURE PART 1

TEMPORAL RESOLUTION

Temporal resolution refers to the frequency with which we can acquire repeat images of the same area on the ground

Different applications require different temporal resolutions. Topographic mapping vs. crop monitoring

Mapping – often only requires one point in time

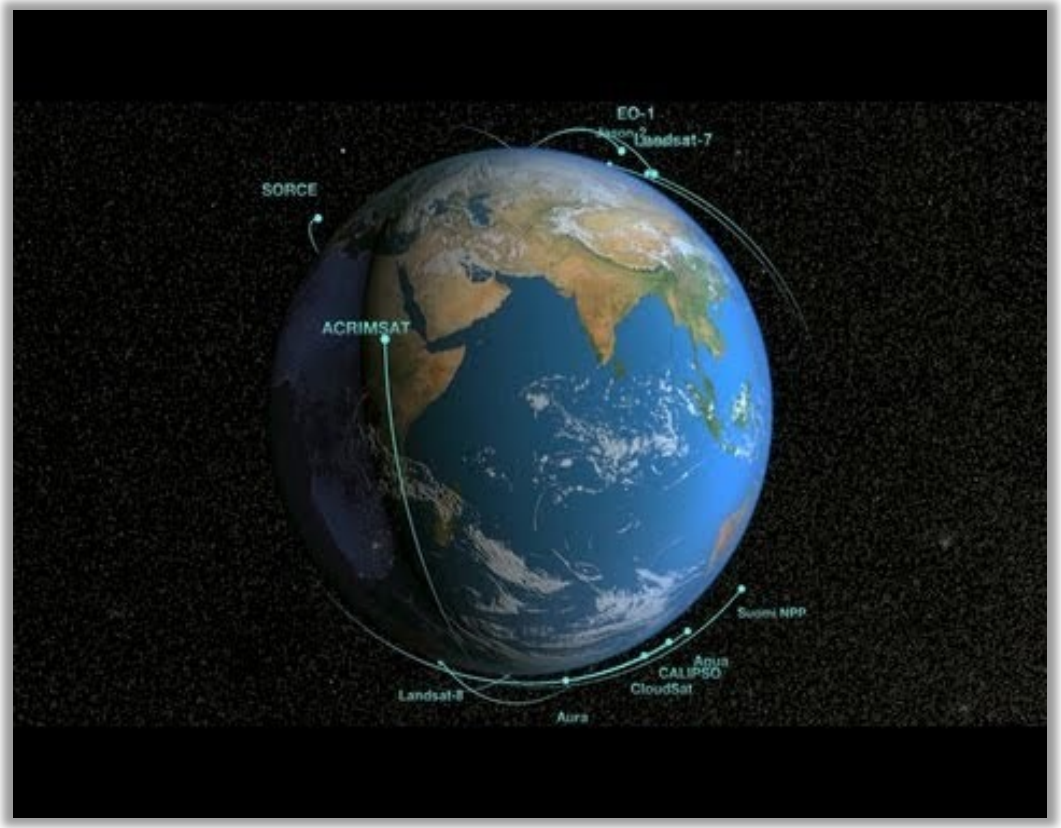
Monitoring – requires repeat coverage to quantify changes that have occurred

Satellites typically have a fixed orbit

Landsat – covers the same location every 16 days, some satellite have “pointable” optics

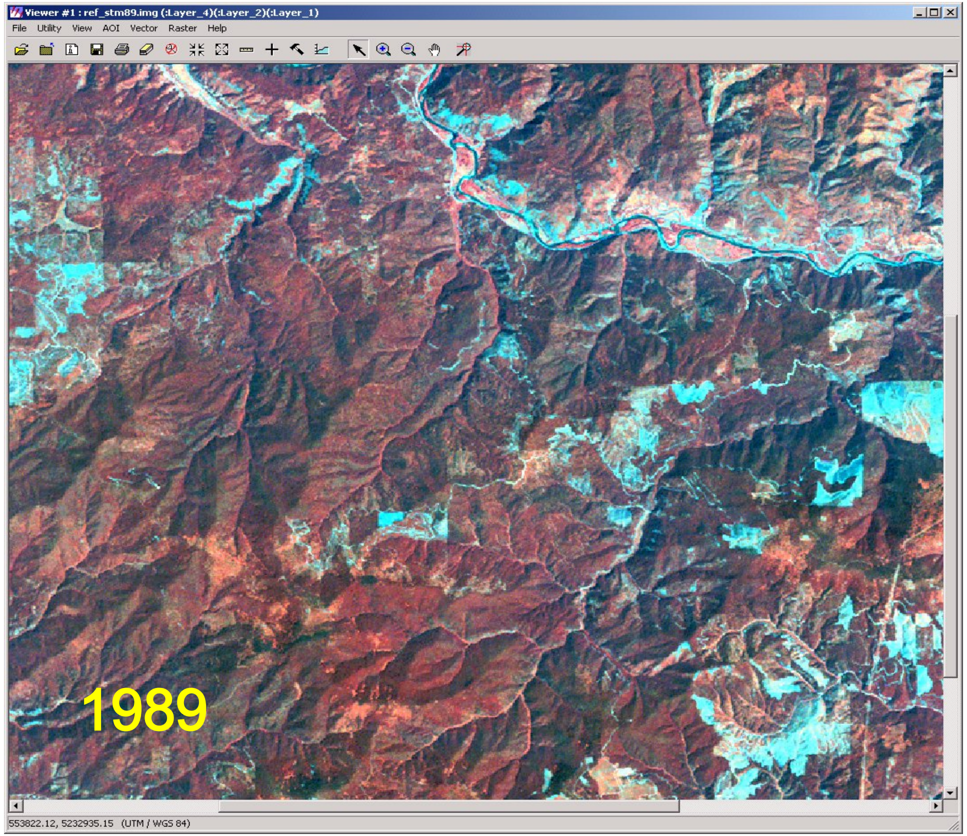
Airborne sensors can be flown whenever needed – depending on available funds

Alternative RS options are beginning to become affordable (kites, drones)

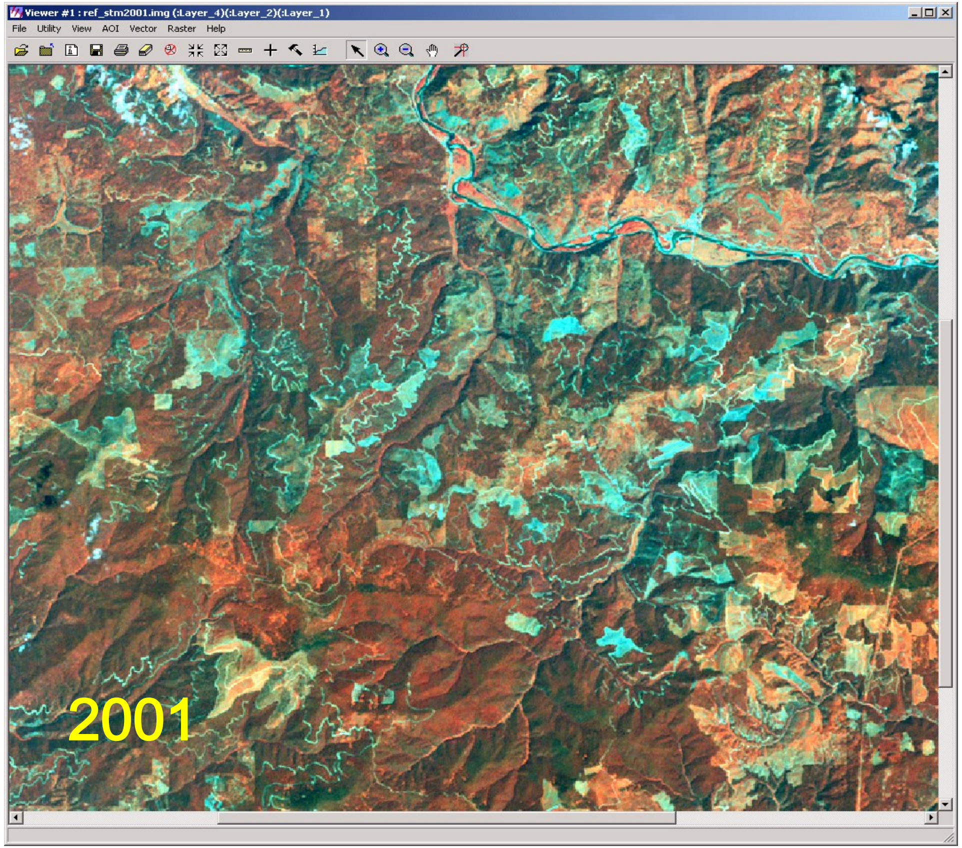

EO-1
Landsat-7
SORCE
ACRIMSAT
Suomi NPP
Aqua
CALIPSO
CloudSat
Landsat-8
Aura

FOREST MONITORING MAPS

Can use multi spectral imagery for annual regional assessments



FOREST MONITORING MAPS



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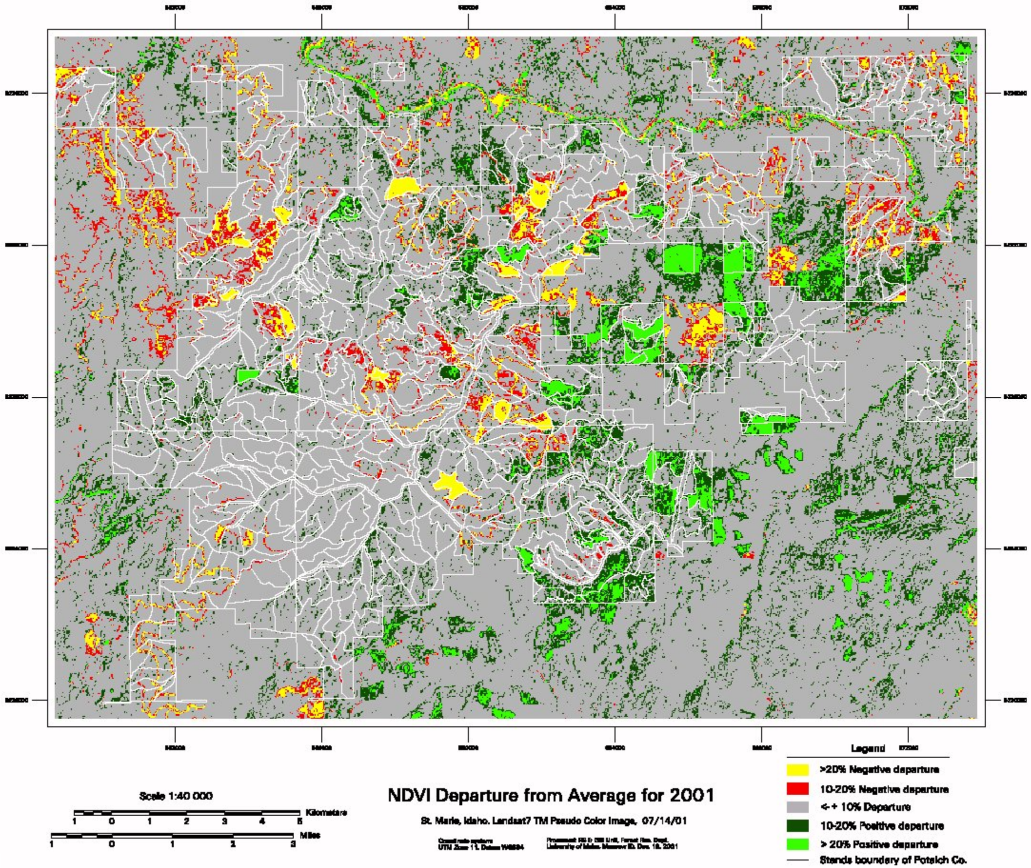
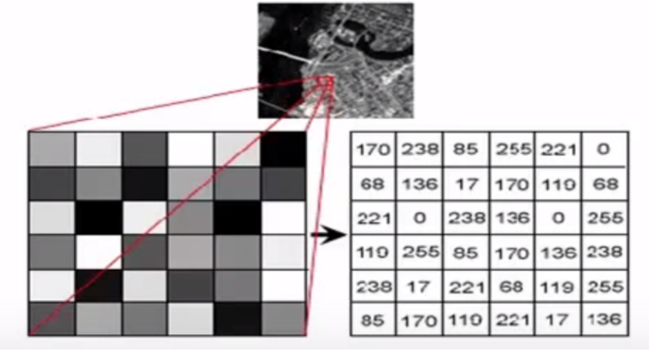

Legend
>20% Negative departure
10-20% Negative departure
<+ 10% Departure
10-20% Positive departure
> 20% Positive departure
Stands boundary of Potalch Co.
Scale 1:40 000
Kilometers
Miles
NDVI Departure from Average for 2001
St. Marie, Idaho. Landsat7 TM Pseudo Color Image, 07/14/01

RADIOMETRIC RESOLUTION

The smallest “slice” of a band or portion of the EM spectrum in which the reflectance of the feature may be assigned a digital number.

In other words, the finest distinctions that can be made between objects viewed in the same part of the EM spectrum.

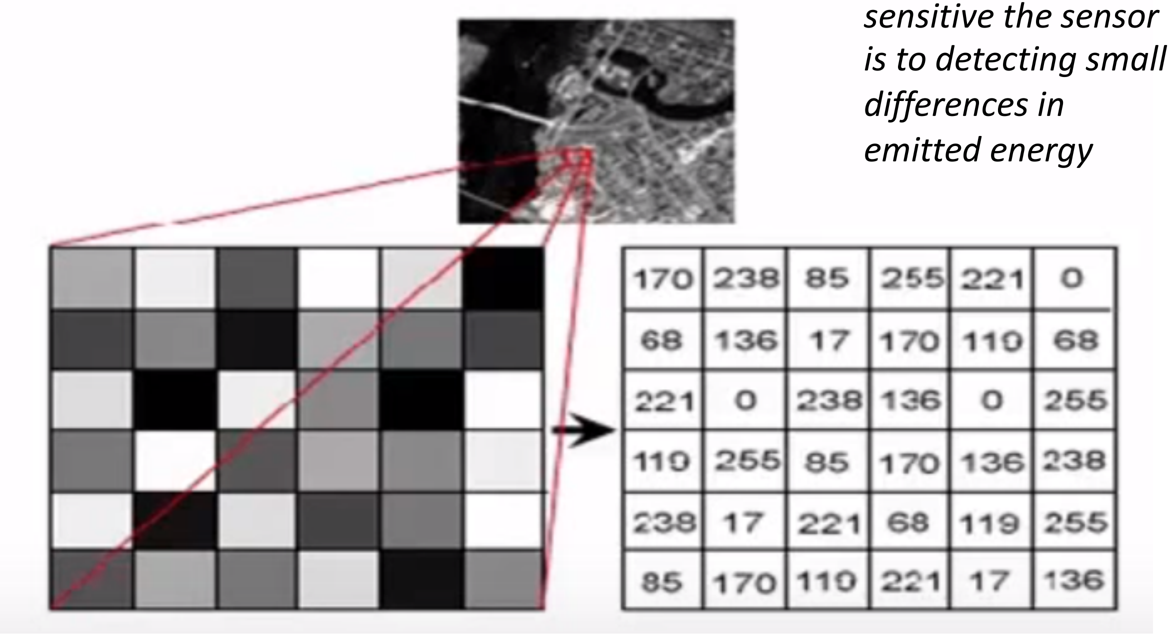
Scanning systems with a 2^6 (64 bit) radiometric resolution are not able to make as many distinctions as a scanning system with a 2^8 (256 bit) radiometric resolution



RADIOMETRIC RESOLUTION

The higher the radiometric resolution, the more sensitive the sensor is to detecting small differences in emitted energy

Higher radiometric resolution is especially important for quantitative applications such as sea-surface temperature mapping where the user wants to distinguish small differences in temperature.

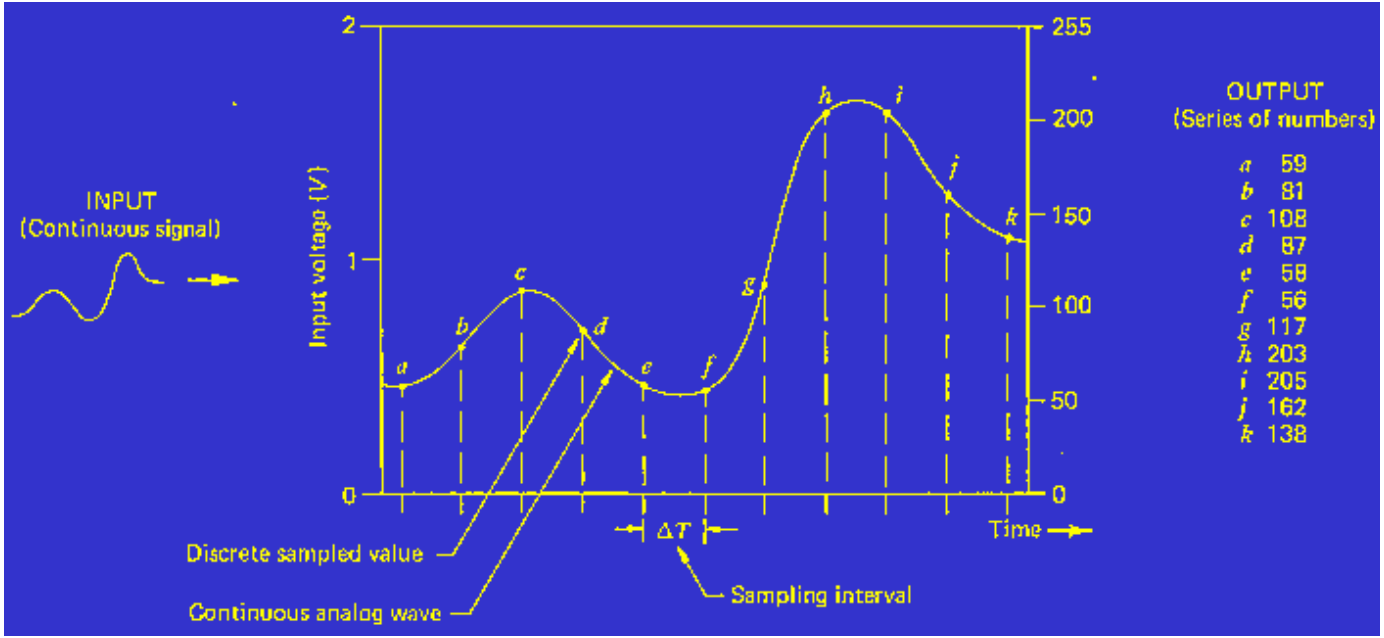


2-bit = 4 radiance levels

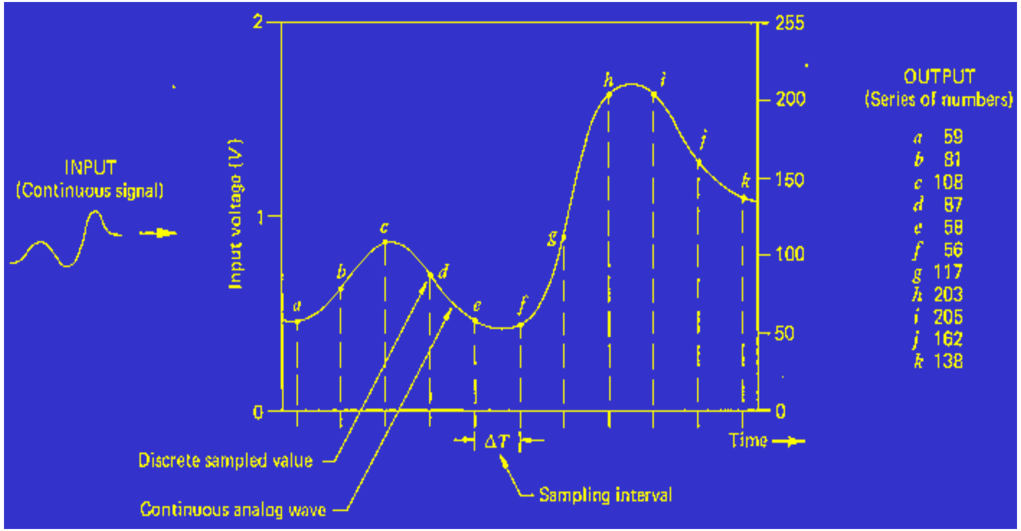
8-bit = 256 radiance levels

- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.

Radiometric resolution refers to the number of brightness levels we can sense for a particular wavelength band



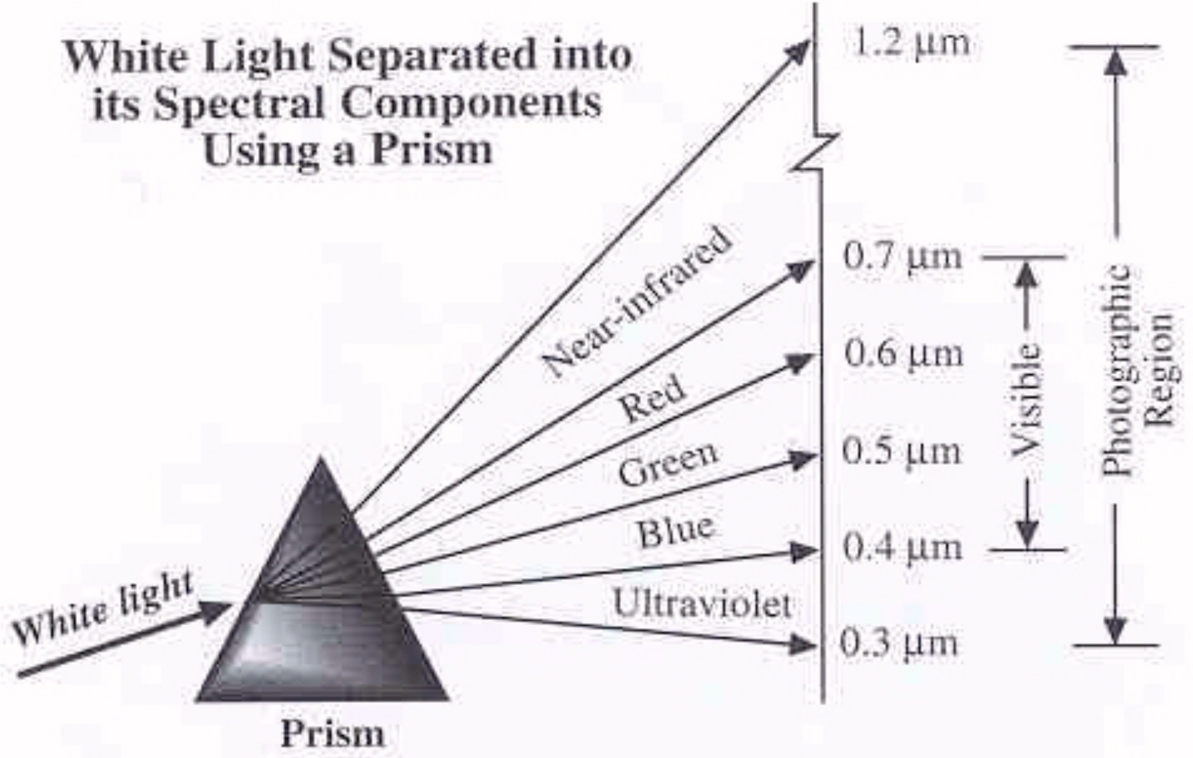
RADIOMETRIC RESOLUTION



We can represent Radiometric or brightness variations in a digital image in three principal ways:

1. Digital number;
2. radiance (physical value);
3. reflectance

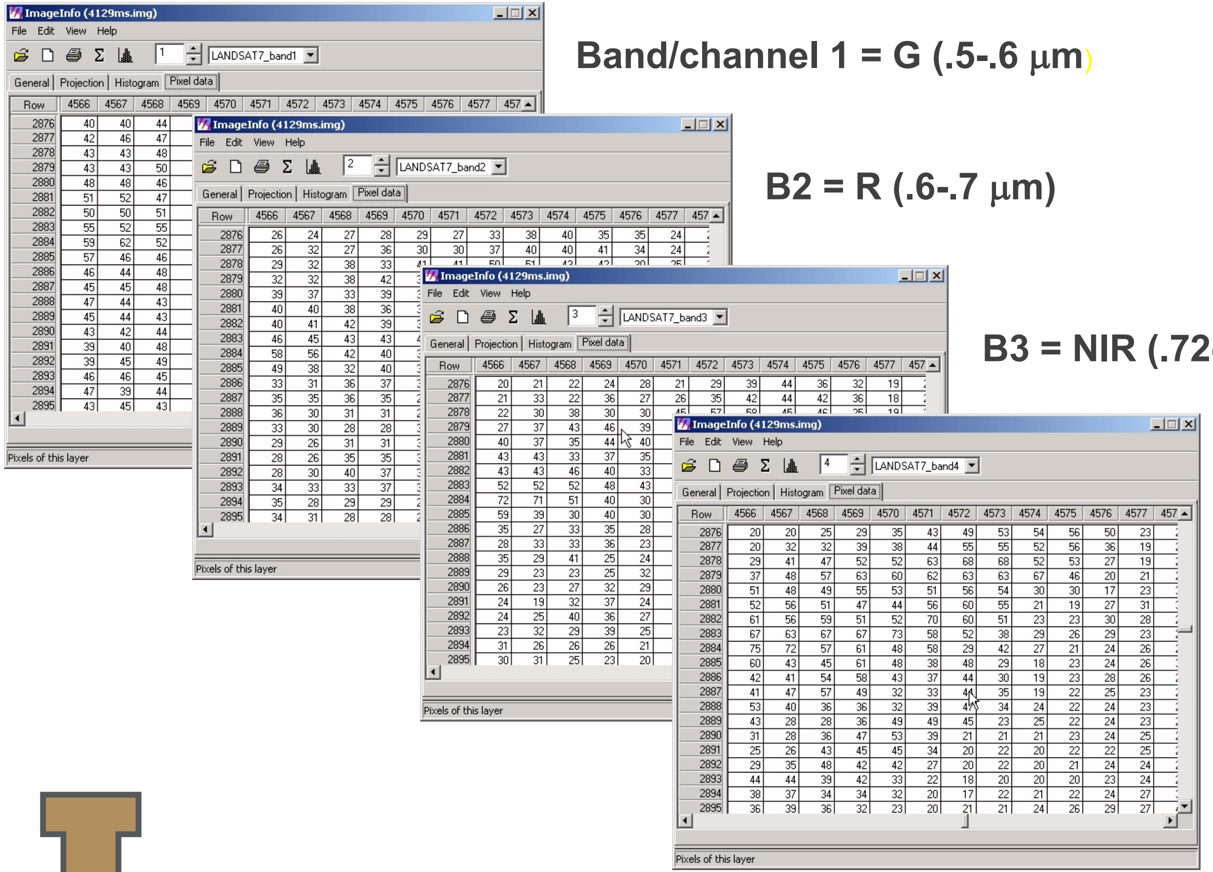
Reflectance has become the standard, represents as ratio of the incoming radiation to the amount that is reflected



The regions of the spectrum that photographic film/ or digital sensors can record:

Ultraviolet, visible, near-infrared

Digital images: what are they??



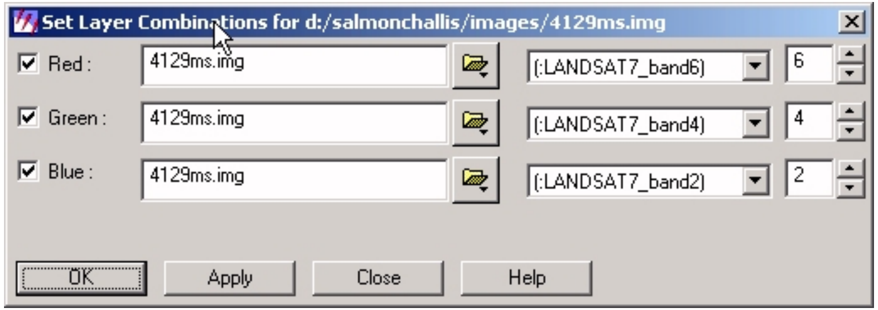
Band/channel 1 = G (.5-.6 μm)

B2 = R (.6-.7 μm)

B3 = NIR (.72-.9 μm)

B4 = ThIR (8.0-9.2 μm)

Hyperspectral bands: 10nm widths (.001 μm)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Red :
4129ms.img
(:LANDSAT7_band6)
6
Green :
4129ms.img
(:LANDSAT7_band4)
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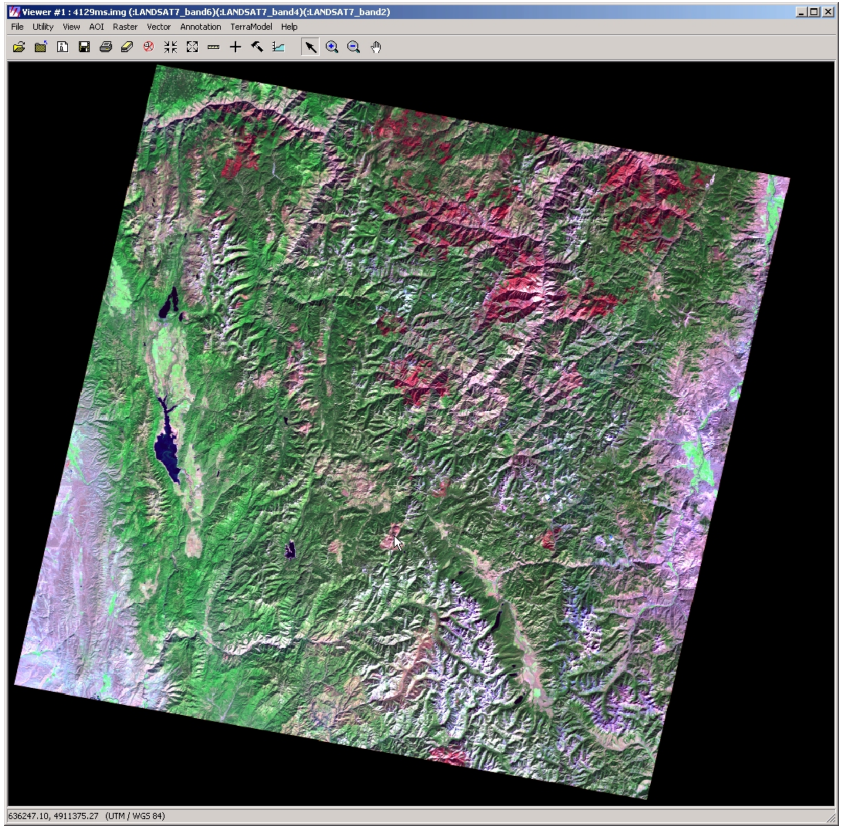
Blue :
4129ms.img
(:LANDSAT7_band2)
2
OK
Apply
Close
Help


Viewer #1 : 4129ms.img (:LANDSAT7_band6)(:LANDSAT7_band4)(:LANDSAT7_band2)
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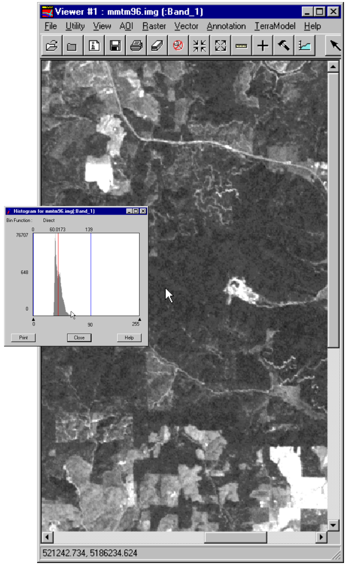
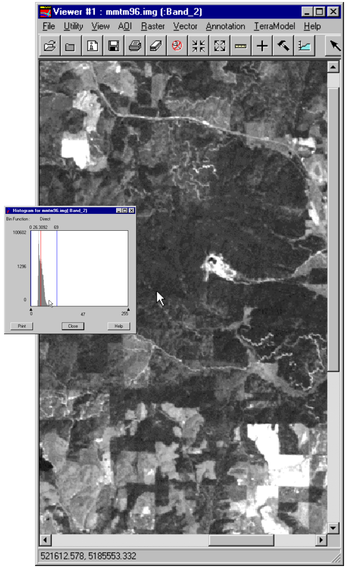
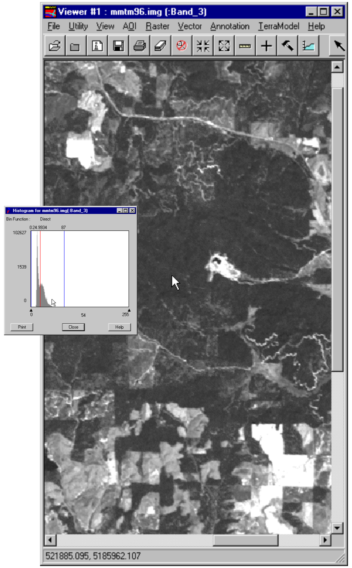
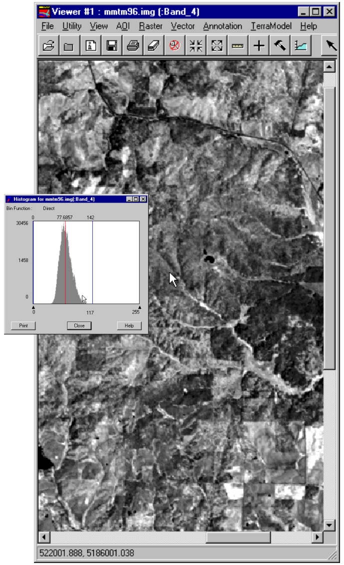
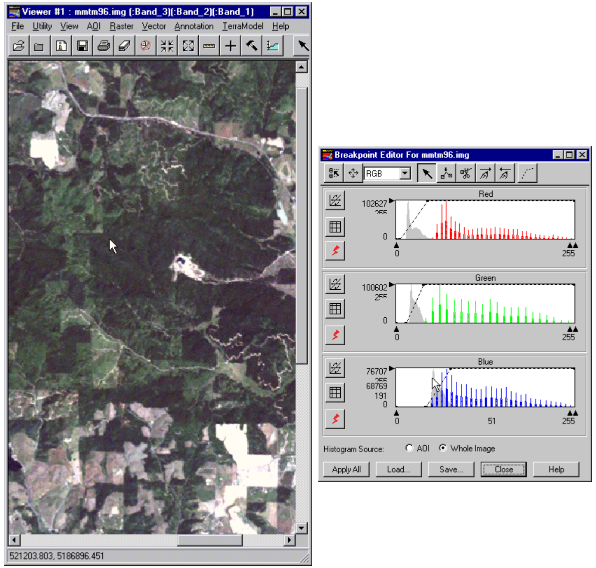
636247.10, 4911375.27 (UTM / WGS 84)

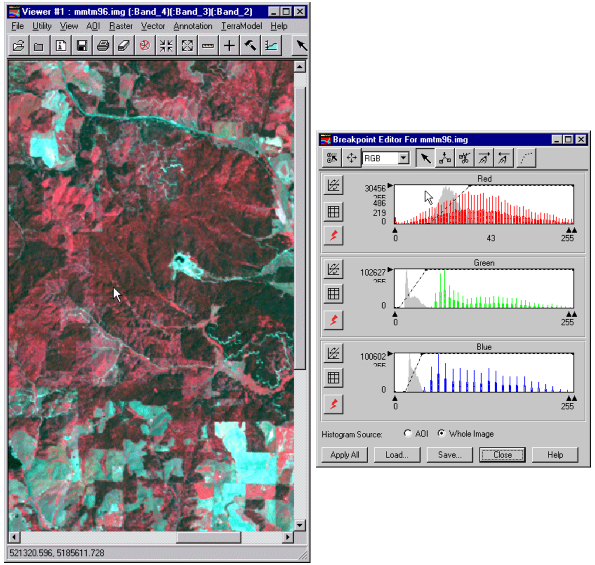

Viewer #1 : mmtm96.img (:Band_1)
File Utility View AOI Raster Vector Annotation TerraModel Help
521242.734, 5186234.624

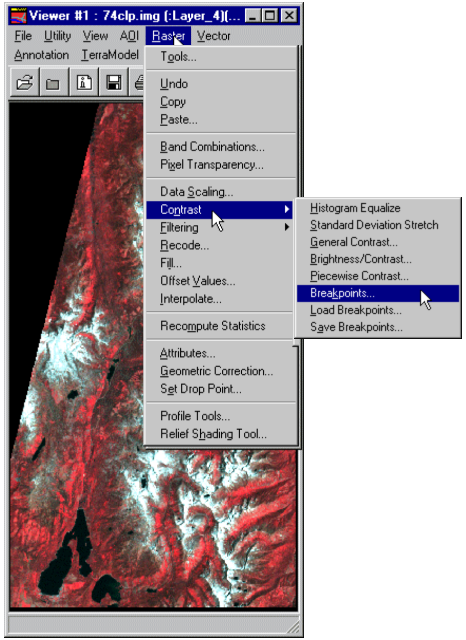

Viewer #1 : mmtm96.img (:Band_2)
File Utility View AOI Raster Vector Annotation TerraModel Help
521612.578, 5185553.332

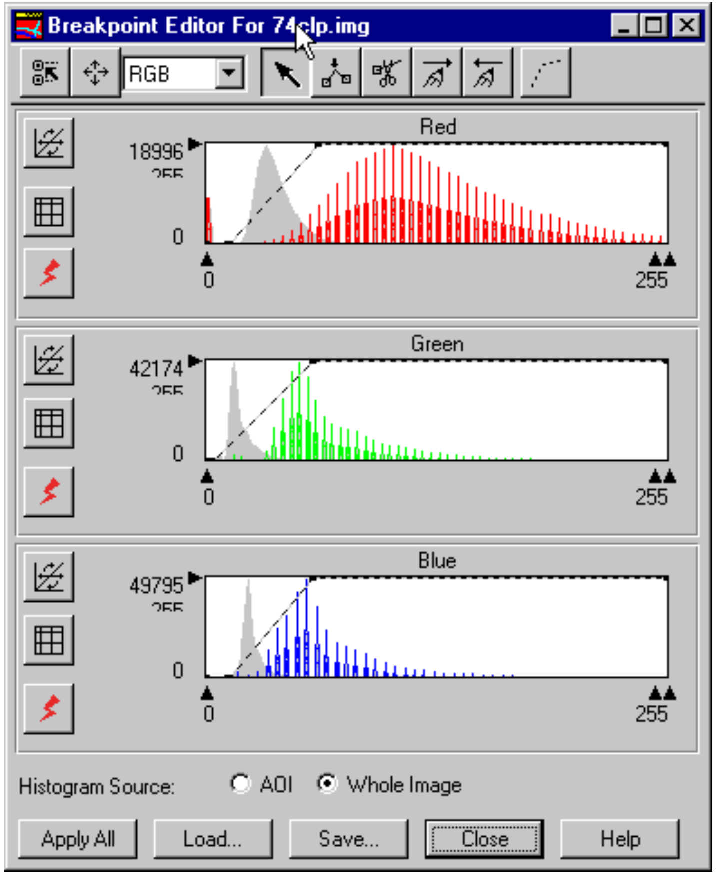

Viewer #1 : mmtm96.img (:Band_3)
File Utility View AOI Raster Vector Annotation TerraModel Help
521885.095, 5185962.107


Viewer #1 : mmtm96.img (:Band_4)
File Utility View AOI Raster Vector Annotation TerraModel Help
522001.888, 5186001.038


Viewer #1 : mmtm96.img (:Band_3)(:Band_2)(:Band_1)
File Utility View AOI Raster Vector Annotation TerraModel Help
521203.803, 5186896.451
Breakpoint Editor For mmtm96.img
RGB
Red
Green
Blue
Histogram Source: AOI Whole Image
Apply All Load... Save... Close Help


Viewer #1 : mmtm96.img (:Band_4)(:Band_3)(:Band_2)
File Utility View AOI Raster Vector Annotation TerraModel Help
521320.596, 5185611.728
Breakpoint Editor For mmtm96.img
RGB
Red
Green
Blue
Histogram Source: AOI Whole Image
Apply All Load... Save... Close Help


Viewer #1 : 74clp.img (:Layer_4)(...
File Utility View AOI Raster Vector
Annotation TerraModel
Tools...
Undo
Copy
Paste...
Band Combinations...
Pixel Transparency...
Data Scaling...
Contrast
Filtering
Recode...
Fill...
Offset Values...
Interpolate...
Recompute Statistics
Attributes...
Geometric Correction...
Set Drop Point...
Profile Tools...
Relief Shading Tool...
Histogram Equalize
Standard Deviation Stretch
General Contrast...
Brightness/Contrast...
Piecewise Contrast...
Breakpoints...
Load Breakpoints...
Save Breakpoints...


Breakpoint Editor For 74clp.img
RGB
Red
18996
0
0
255
Green
42174
0
0
255
Blue
49795
0
0
255
Histogram Source:
AOI
Whole Image
Apply All
Load...
Save...
Close
Help

How do we extract information from images?

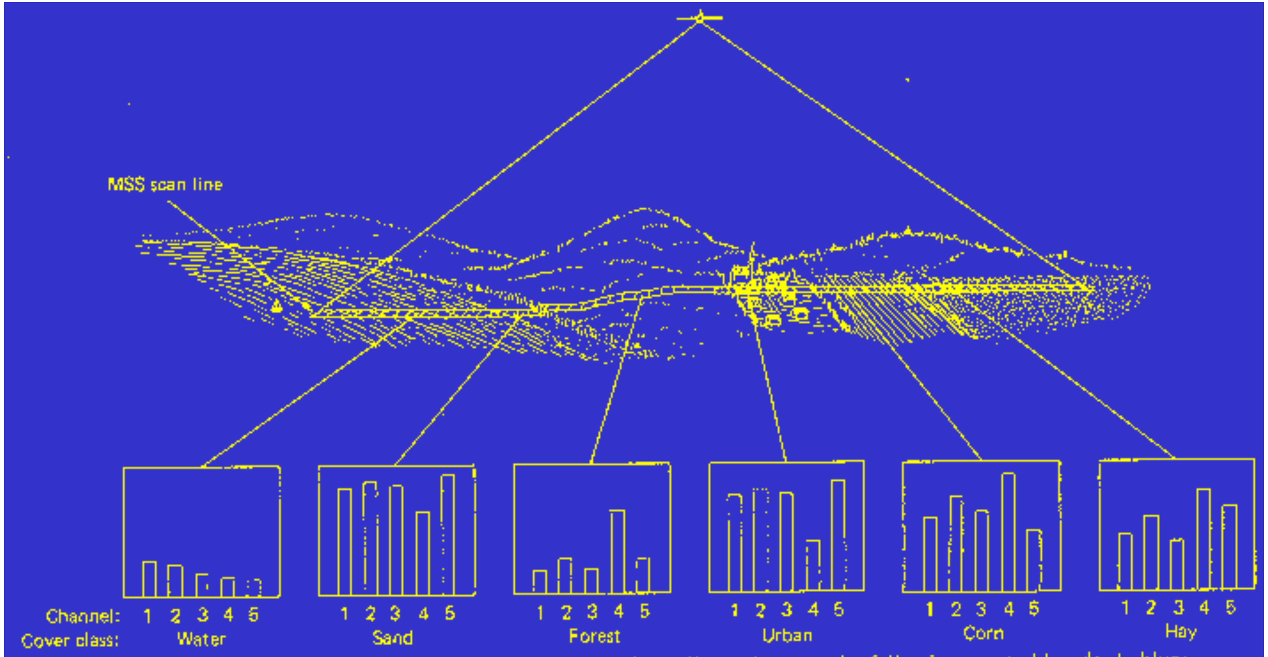
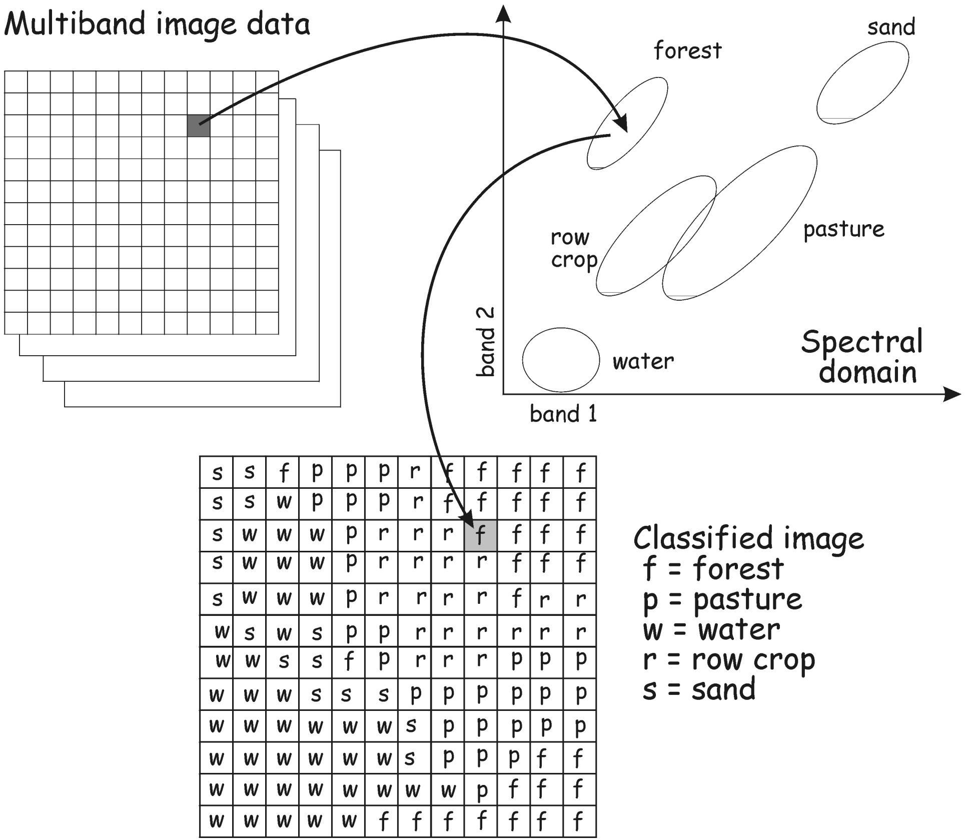
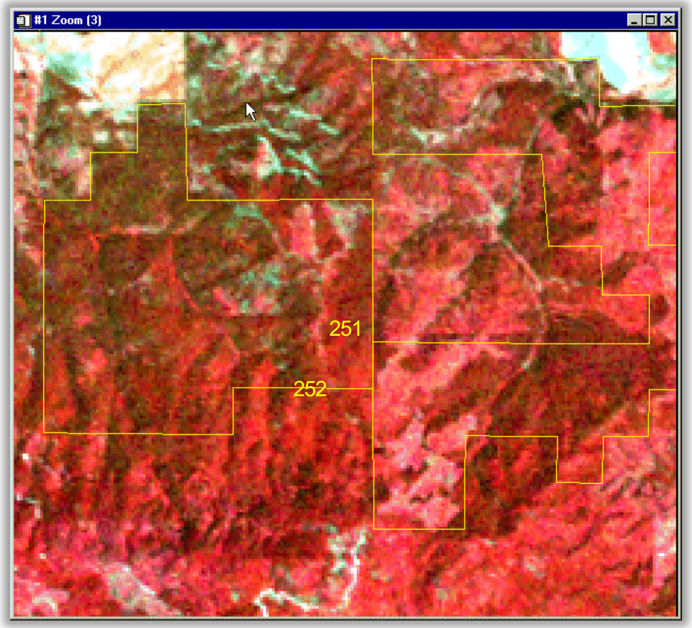
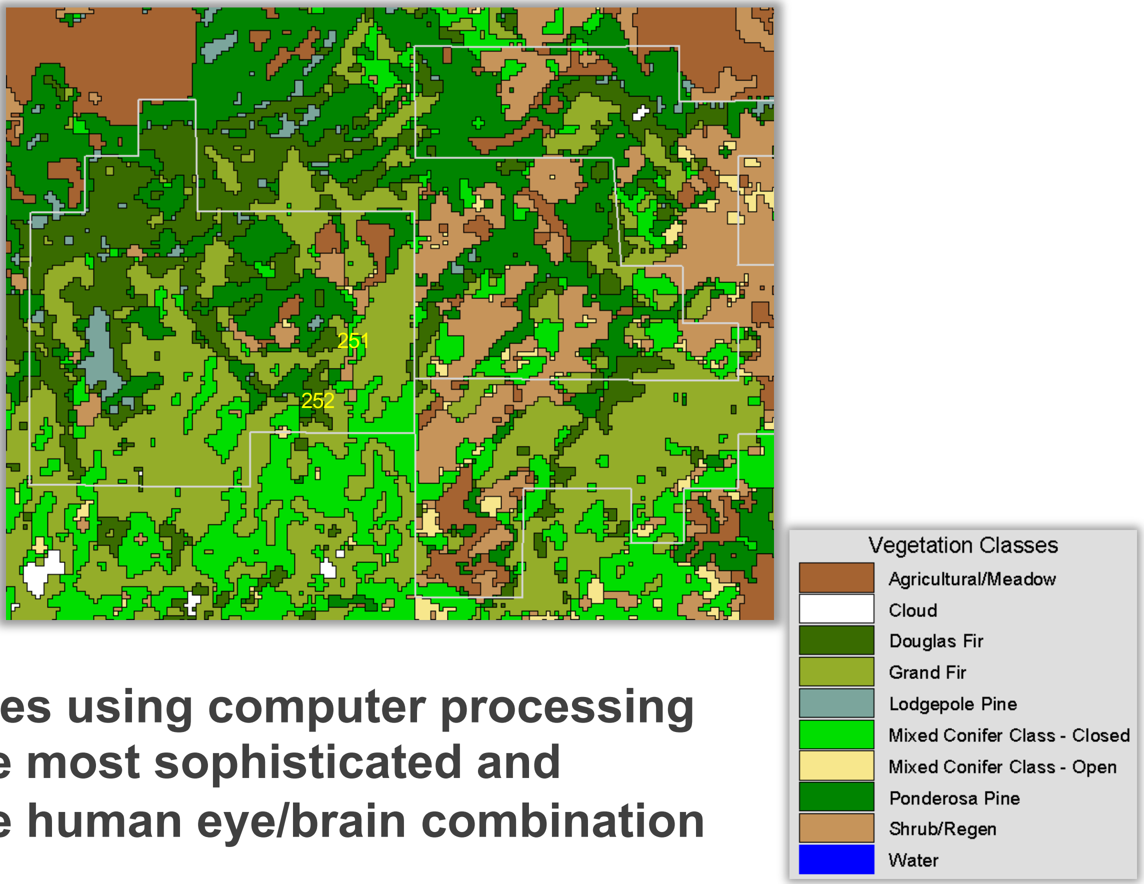


Figure 7.36 Selected MSS measurements made along one scan line. Channels cover the following spectral bands: 1, blue; 2, green; 3, red; 4, near infrared; 5, thermal infrared.

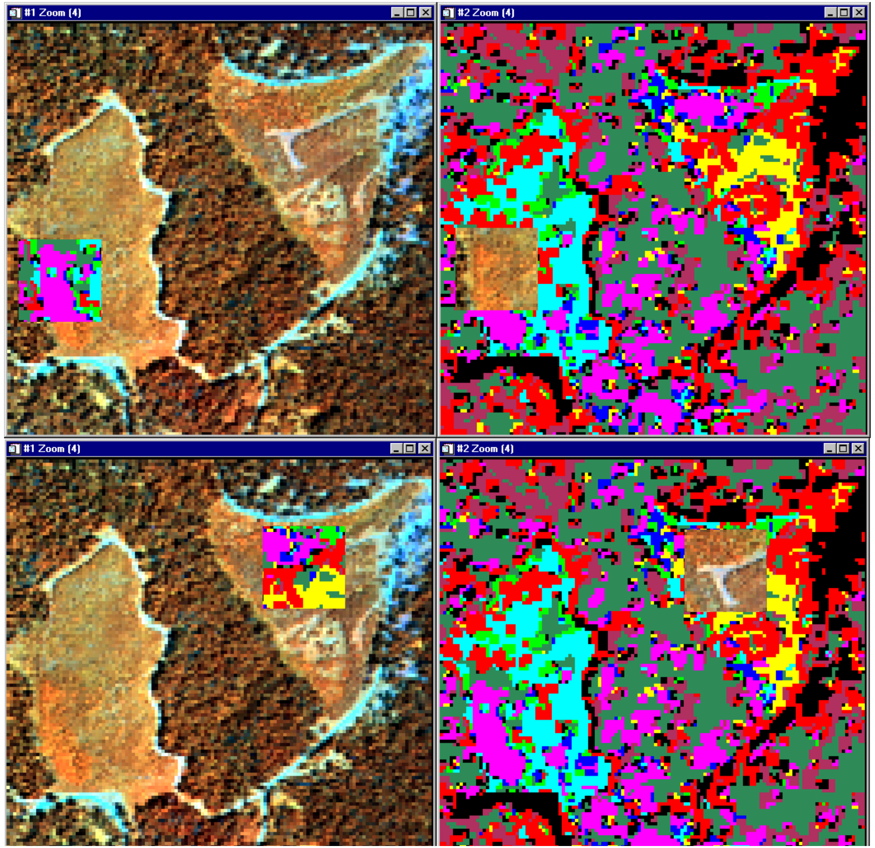
Land cover and land use classification is a common application of satellite images. The spectral reflectance patterns of each cover type are used to assign a unique land cover class to each cell. These data may then be imported into a GIS as a raster layer (Bolstad, 2014).



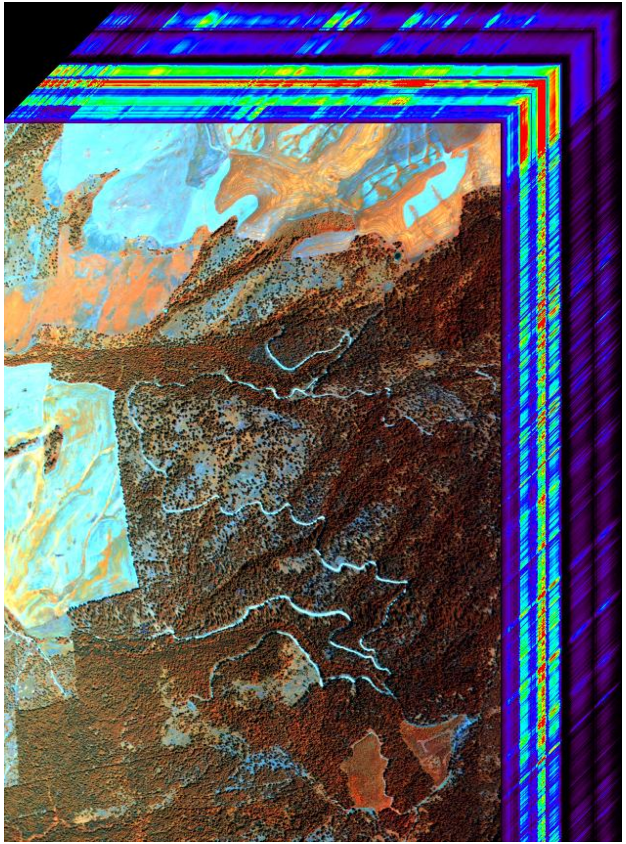




Can analyze digital images using computer processing techniques, however, the most sophisticated and powerful computer is the human eye/brain combination

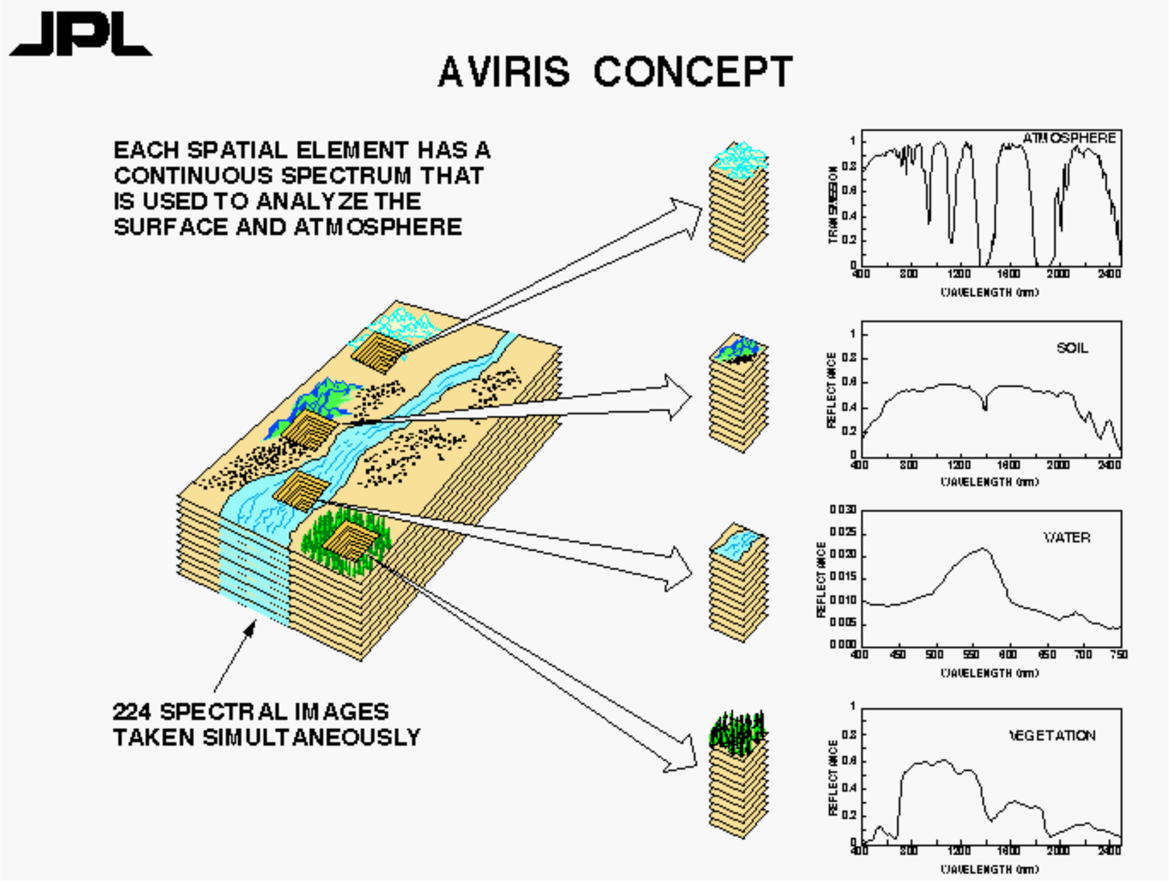


Unclassified
PP control 251
DF control 251
DF fertilized 251
PP fertilized 251
PP control 252
DF control 252
Mix forest high density
Mix forest middle density



We can remotely:

- discriminate tree species;
- discriminate differences in tree spectral responses due to specific parent material differences;
- discriminate differences in foliar chemistry due to fertilization (increased absorption of PAR, chlorophyll, cell structures);
- discriminate differences in tree physiological condition due to stress (water, insects, disease)



Airborne Visible Infrared Imaging Spectrometer

224 contiguous spectral channels (also called bands) with wavelengths from 400 to 2500 nanometers (nm).

INTRODUCTION TO REMOTE SENSING – WHAT YOU SHOULD KNOW

What you should know:

- what remote sensing is and how it can be used for obtaining primary data
- value of the overhead perspective – context, patterns, adjacencies
- basic concepts of <u>spatial</u>, <u>spectral</u>, <u>temporal</u> and <u>radiometric</u> resolution
- converting raw spectral images into information outputs or maps – image classification using statistical classifiers