

## **Resolutions of Remote Sensing**

**1. *Spatial*** (*what area and how detailed*)

2. Spectral (what colors – bands)
3. Temporal (time of day/season/year)
4. Radiometric (color depth)

Spatial Resolution describes how much detail in a photographic image is visible to the human eye.

The ability to "resolve," or separate, small details is one way of describing what we call spatial resolution.

Spatial resolution of images acquired by satellite sensor systems is usually expressed in meters.

For example, we often speak of Landsat as having "30-meter" resolution, which means that two objects, thirty meters long or wide, sitting side by side, can be separated (resolved) on a Landsat image.

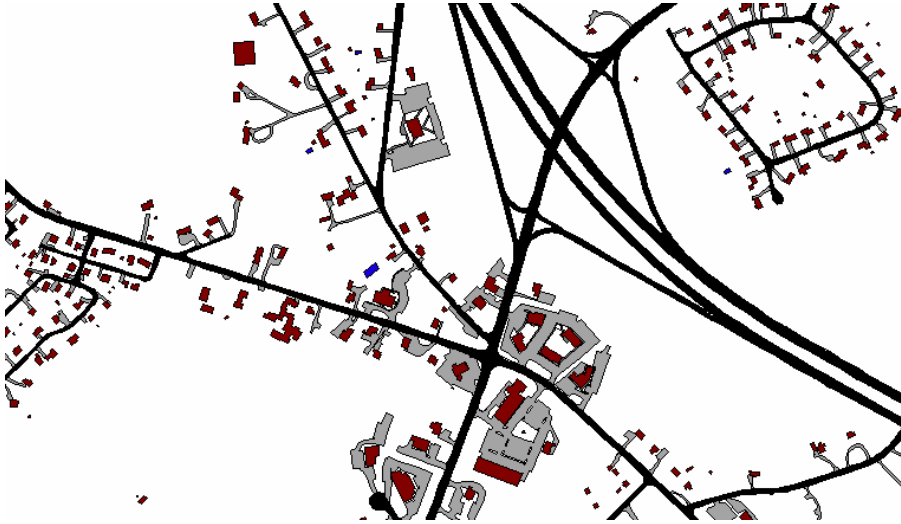
Other sensors have lower or higher spatial resolutions.

## Comparison of Landsat Sensors

|                                              | <b>Thematic Mapper (TM) Landsat 4 and 5</b>                                                                                                      | <b>Enhanced Thematic Mapper Plus (ETM+) Landsat 7</b>                                                                              | <b>Multispectral Scanner (MSS) Landsat 1-5</b>                     |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| <b>Spectral Resolution (μm)</b>              | 1. 0.45-0.52 (B)<br>2. 0.52-0.60 (G)<br>3. 0.63-0.69 (R)<br>4. 0.76-0.90 (NIR)<br>5. 1.55-1.75 (MIR)<br>6. 2.08-2.35 (MIR)<br>7. 10.4-12.5 (TIR) | 1. 0.45-0.52<br>2. 0.53-0.61<br>3. 0.63-0.69<br>4. 0.78-0.90<br>5. 1.55-1.75<br>6. 2.09-2.35<br>7. 10.4-12.5<br>8. 0.52-0.90 (Pan) | 0.5-0.6 (green)<br>0.6-0.7 (red)<br>0.7-0.8 (NIR)<br>0.8-1.1 (NIR) |
| <b>Spatial Resolution (meter)</b>            | 30 x 30<br>120 x 120 (TIR)                                                                                                                       | 15 x 15 (Pan)<br>30 x 30<br>60 x 60 (TIR)                                                                                          | 79 x 79                                                            |
| <b>Temporal Resolution (revisit in days)</b> | 16                                                                                                                                               | 16                                                                                                                                 | 18                                                                 |
| <b>Spatial coverage (km)</b>                 | 185 x 185                                                                                                                                        | 183 x 170                                                                                                                          | 185 x 185                                                          |
| <b>Altitude (km)</b>                         | 705                                                                                                                                              | 705                                                                                                                                | 915 (Landsat 1,2,3)                                                |

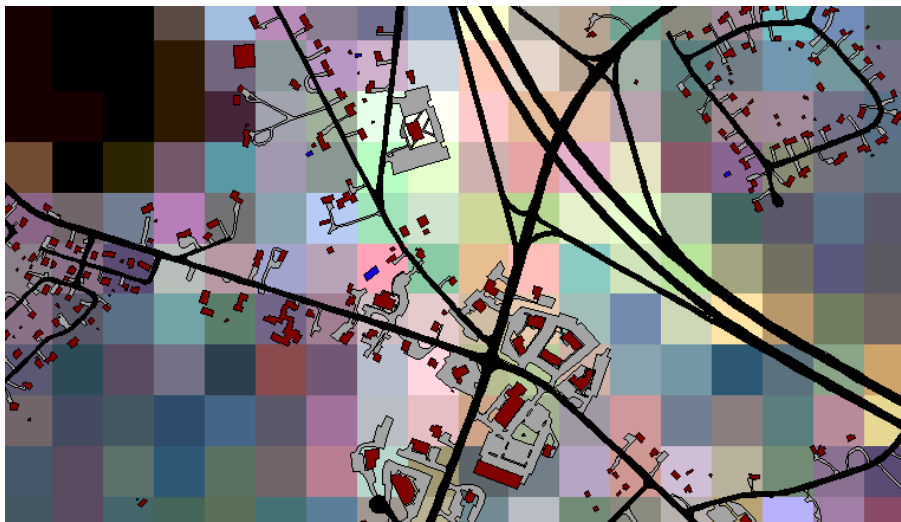
## Spatial Resolution

Planimetric data – roads, buildings, driveways



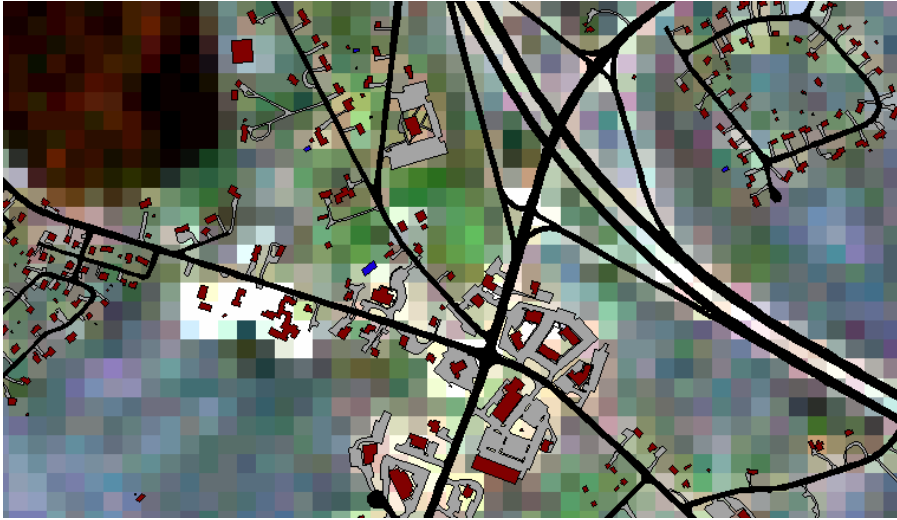
## Spatial Resolution

80 meter MSS w/ planimetric overlay



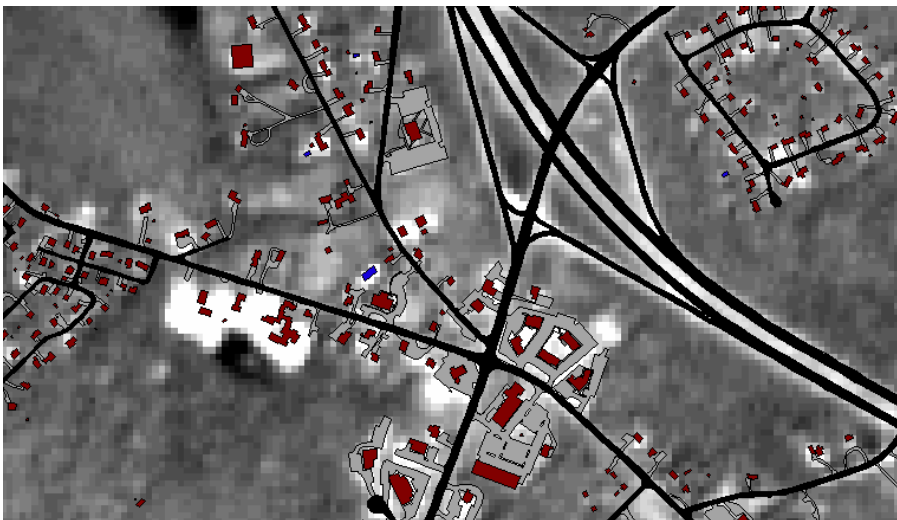
## Spatial Resolution

30 meter TM w/ planimetric overlay



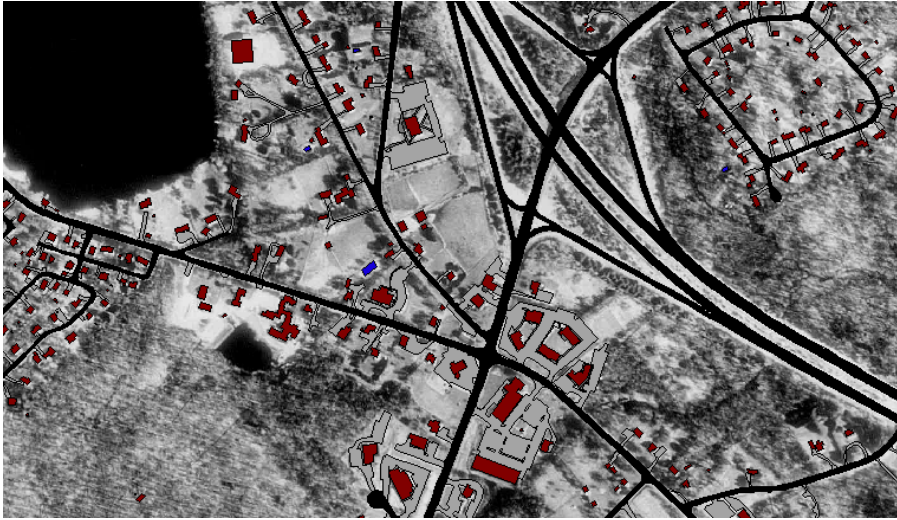
## Spatial Resolution

10 meter SPOT w/ planimetric overlay



## Spatial Resolution

1 meter DOQ w/ planimetric overlay



## Spatial Resolution

Sub-meter data w/ planimetric overlay



## Looking More Closely at Resolution



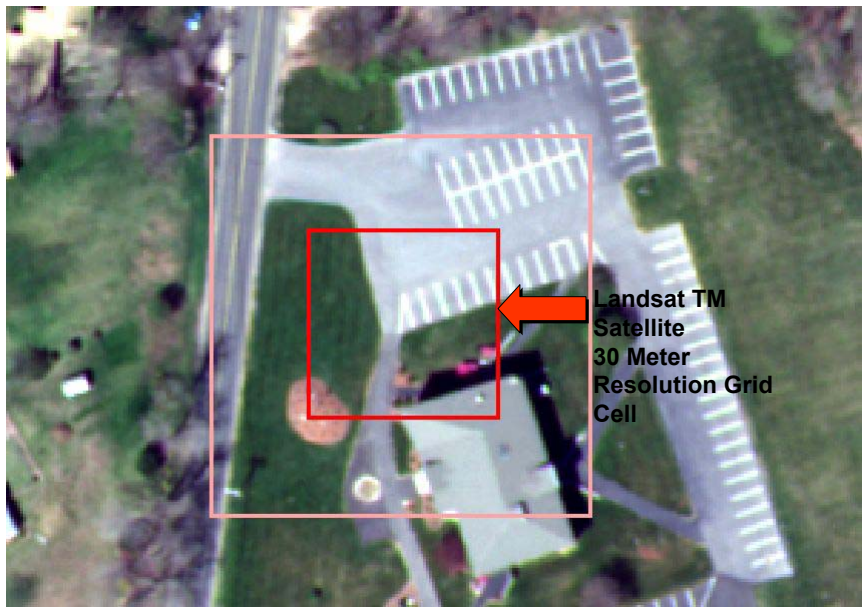
## Looking More Closely at Resolution



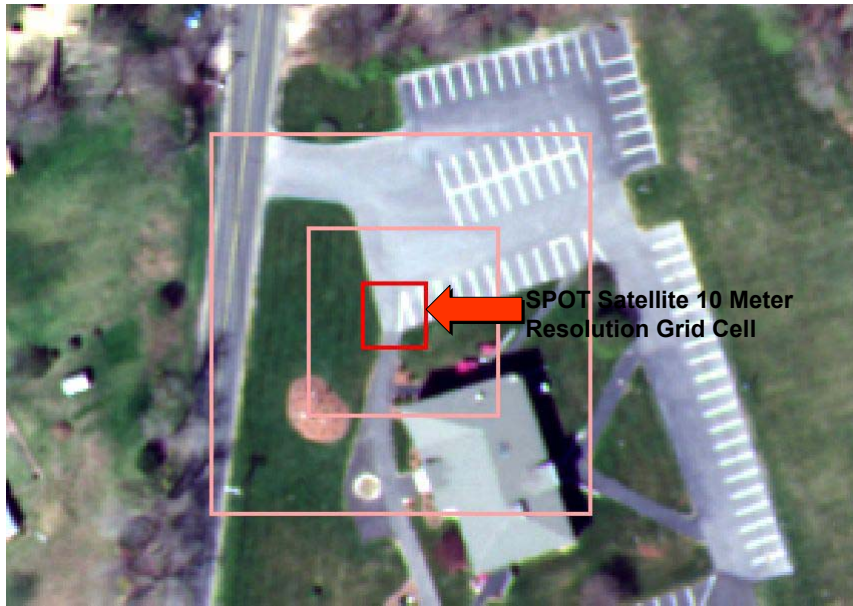
## Looking More Closely at Resolution



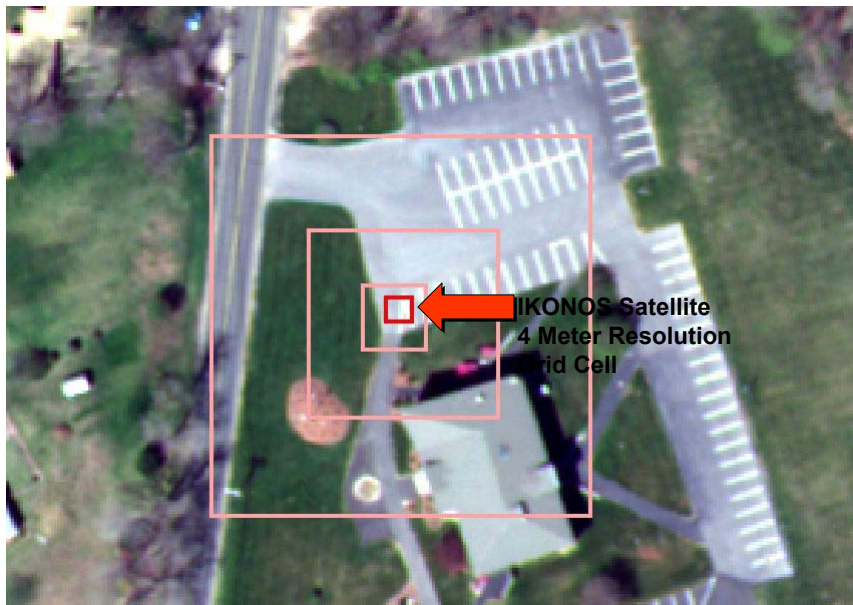
## Looking More Closely at Resolution



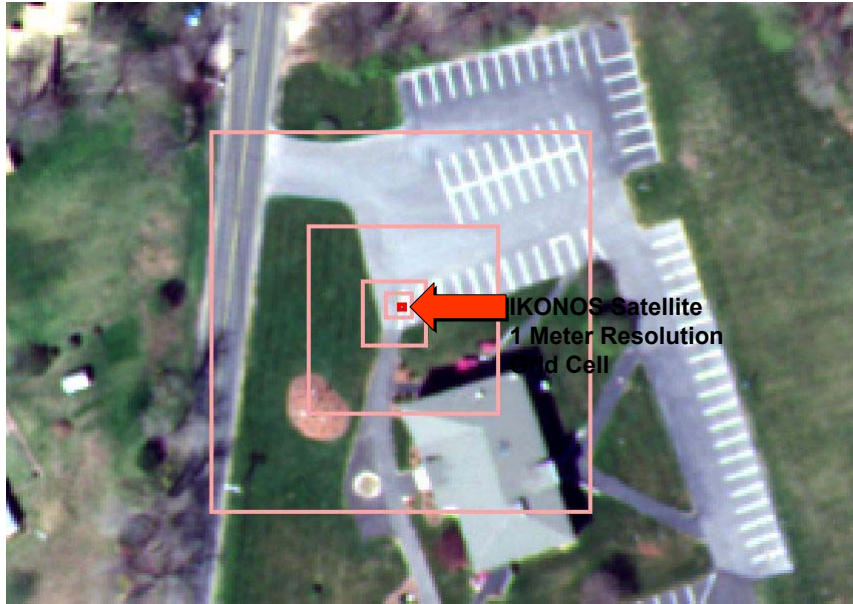
## Looking More Closely at Resolution



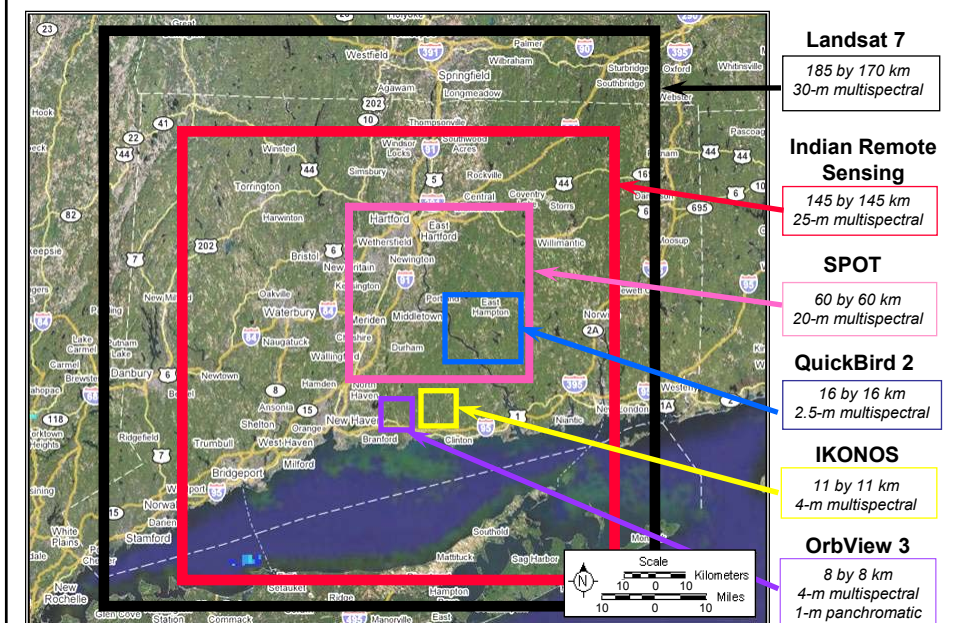
## Looking More Closely at Resolution



## Looking More Closely at Resolution



## Selected Satellite Footprints

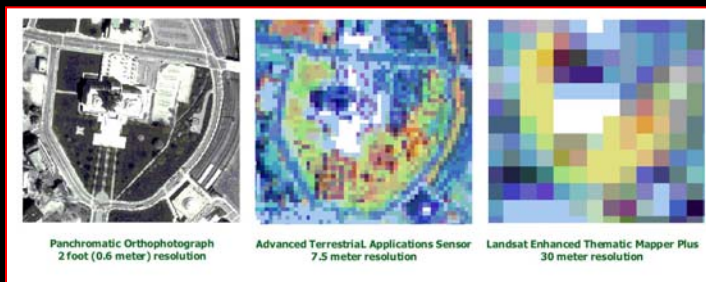


# Resolutions of Remote Sensing

## 1. *Spatial* (what area and how detailed)

2. Spectral (what colors – bands)
3. Temporal (time of day/season/year)
4. Radiometric (color depth)

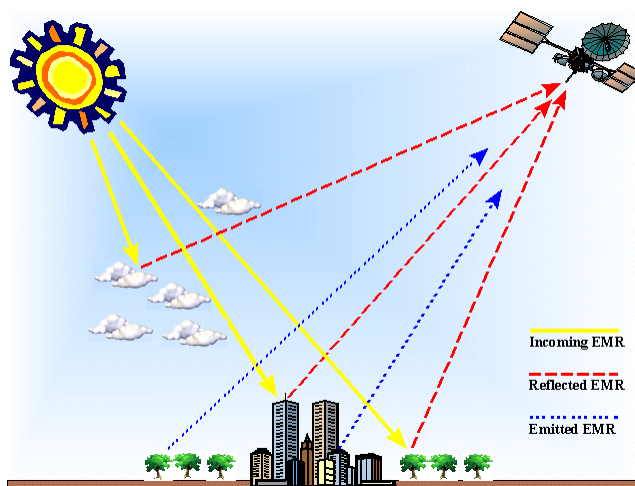
## The best spatial resolution?



# Resolutions of Remote Sensing

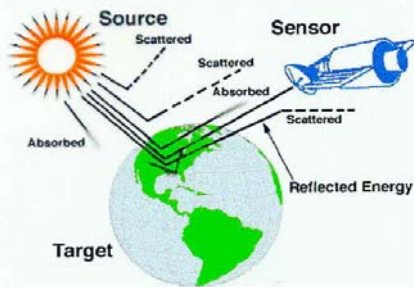
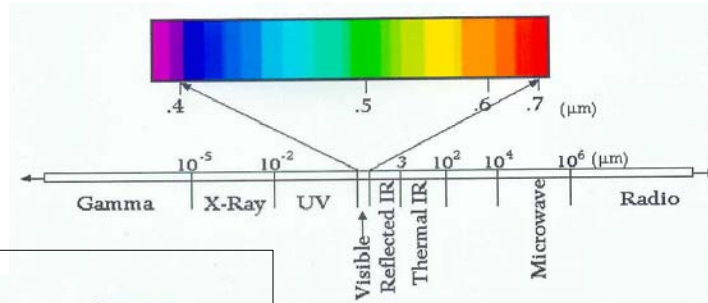
1. Spatial (what area and how detailed)
2. **Spectral** (*what colors – bands*)
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## Spectral Response Curve

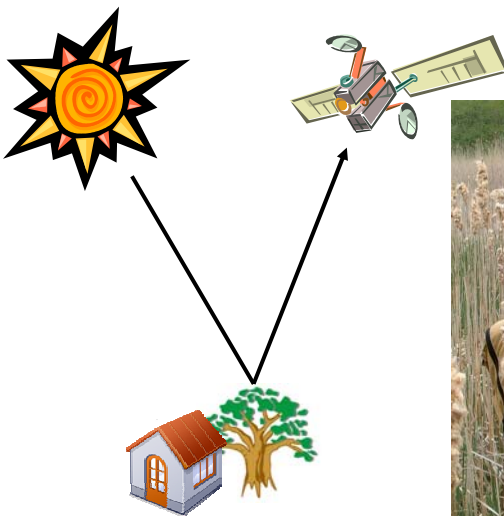


EMR patterns are recorded by sensors with separated spectral bands.

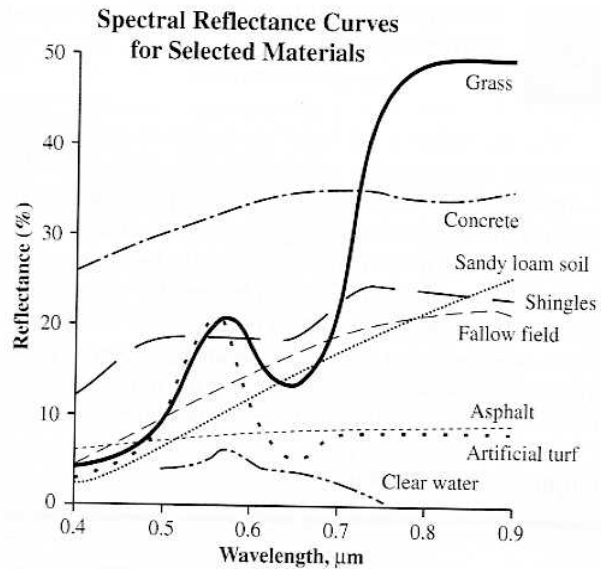
## Electromagnetic Radiation (EMR)



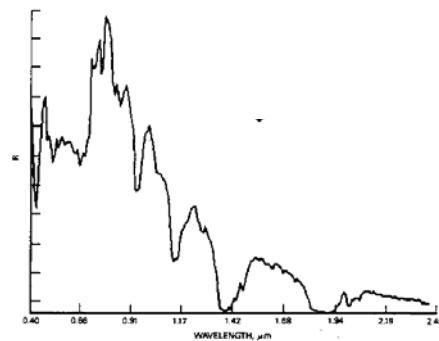
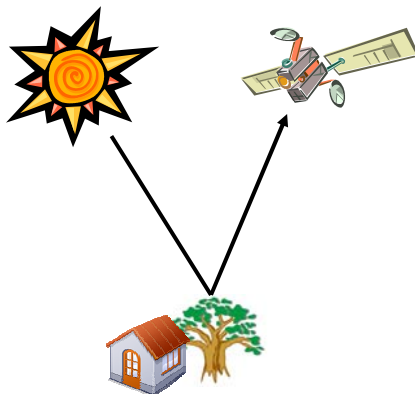
## Spectral Response Curve



The spectral reflectance curves, or spectral signatures, of different types of ground targets provide the knowledge base for information extraction.

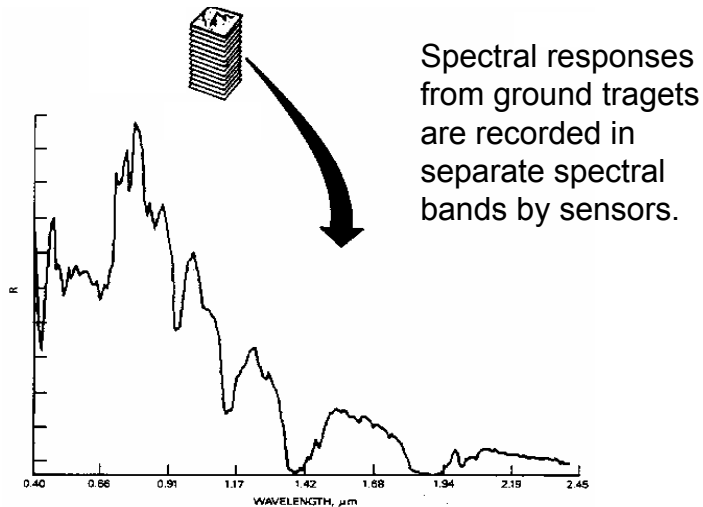


## Spectral Response Curve



# Spectral Response Curve

## Concept of Spectral Bands



## Spectral Resolution

- Number of spectral bands (red, green, blue, NIR, Mid-IR, thermal, etc.)
- Width of each band
- Certain spectral bands (or combinations) are good for identifying specific ground features
- Panchromatic – 1 band (B&W)
- Color – 3 bands (RGB)
- Multispectral – 4+ bands (e.g. RGBNIR)
- Hyperspectral – hundreds of bands

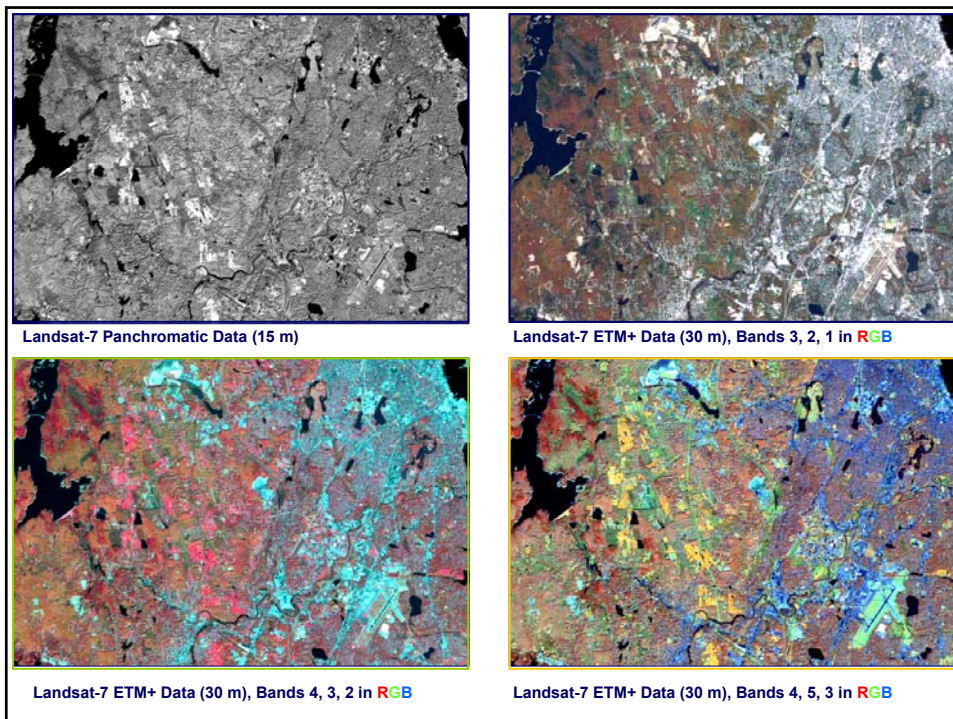
## Comparison of Landsat Sensors

|                                                               | Thematic Mapper<br>(TM) Landsat 4 and 5                                                                                                          | Enhanced Thematic<br>Mapper Plus (ETM+)<br>Landsat 7                                                                               | Multispectral<br>Scanner (MSS)<br>Landsat 1-5                      |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| <b>Spectral<br/>Resolution<br/>(<math>\mu\text{m}</math>)</b> | 1. 0.45-0.52 (B)<br>2. 0.52-0.60 (G)<br>3. 0.63-0.69 (R)<br>4. 0.76-0.90 (NIR)<br>5. 1.55-1.75 (MIR)<br>6. 2.08-2.35 (MIR)<br>7. 10.4-12.5 (TIR) | 1. 0.45-0.52<br>2. 0.53-0.61<br>3. 0.63-0.69<br>4. 0.78-0.90<br>5. 1.55-1.75<br>6. 2.09-2.35<br>7. 10.4-12.5<br>8. 0.52-0.90 (Pan) | 0.5-0.6 (green)<br>0.6-0.7 (red)<br>0.7-0.8 (NIR)<br>0.8-1.1 (NIR) |
| <b>Spatial<br/>Resolution<br/>(meter)</b>                     | 30 x 30<br>120 x 120 (TIR)                                                                                                                       | 15 x 15 (Pan)<br>30 x 30<br>60 x 60 (TIR)                                                                                          | 79 x 79                                                            |
| <b>Temporal<br/>Resolution<br/>(revisit in days)</b>          | 16                                                                                                                                               | 16                                                                                                                                 | 18                                                                 |
| <b>Spatial<br/>coverage (km)</b>                              | 185 x 185                                                                                                                                        | 183 x 170                                                                                                                          | 185 x 185                                                          |
| <b>Altitude (km)</b>                                          | 705                                                                                                                                              | 705                                                                                                                                | 915 (Landsat 1,2,3)                                                |



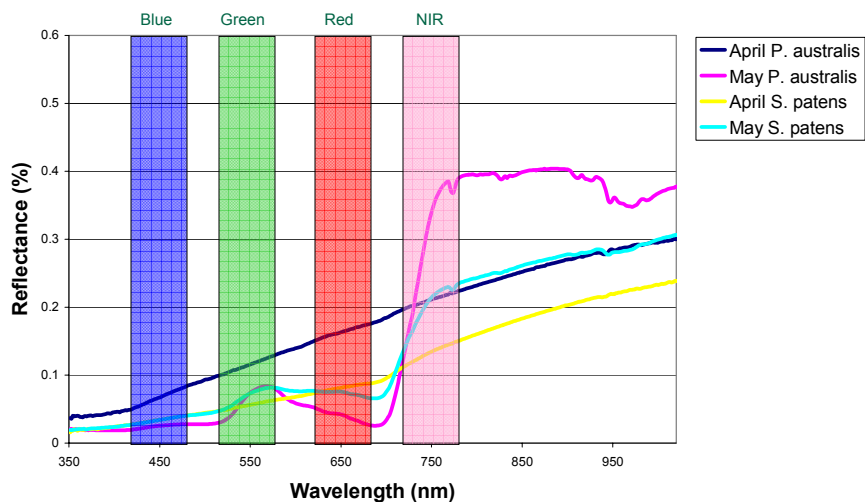
QuickBird Satellite  
True-color and  
Pseudo-color Images  
2.5-m Spatial Resolution

Concept of Multispectral  
And Pseudo-color Image

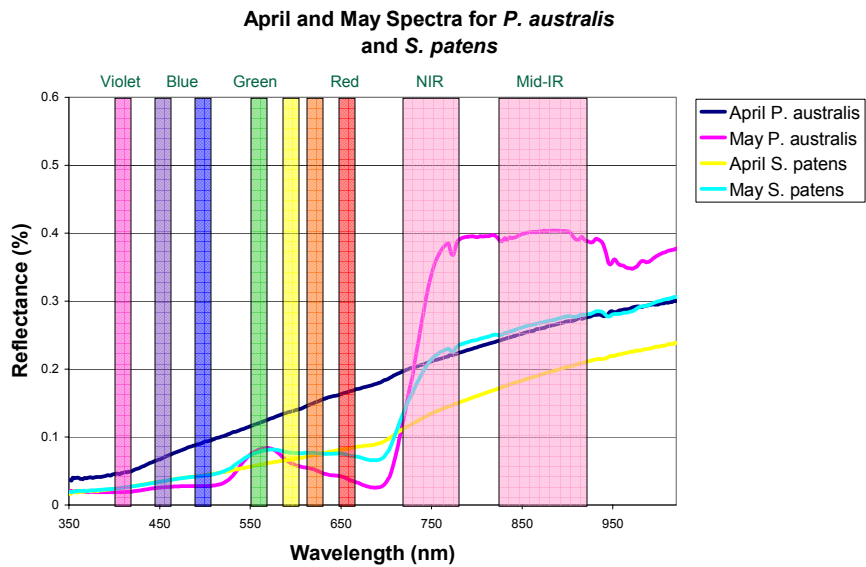


## Spectral Response Curve

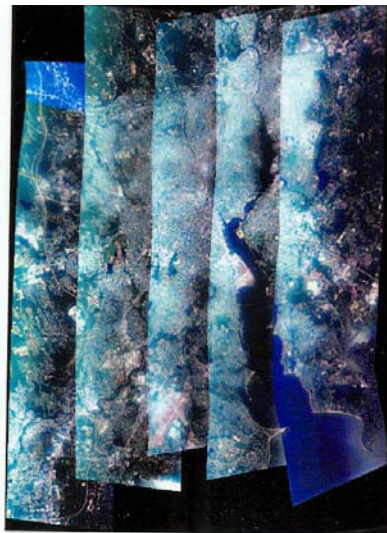
April and May Spectra for *P. australis* and *S. patens*



# Spectral Response Curves



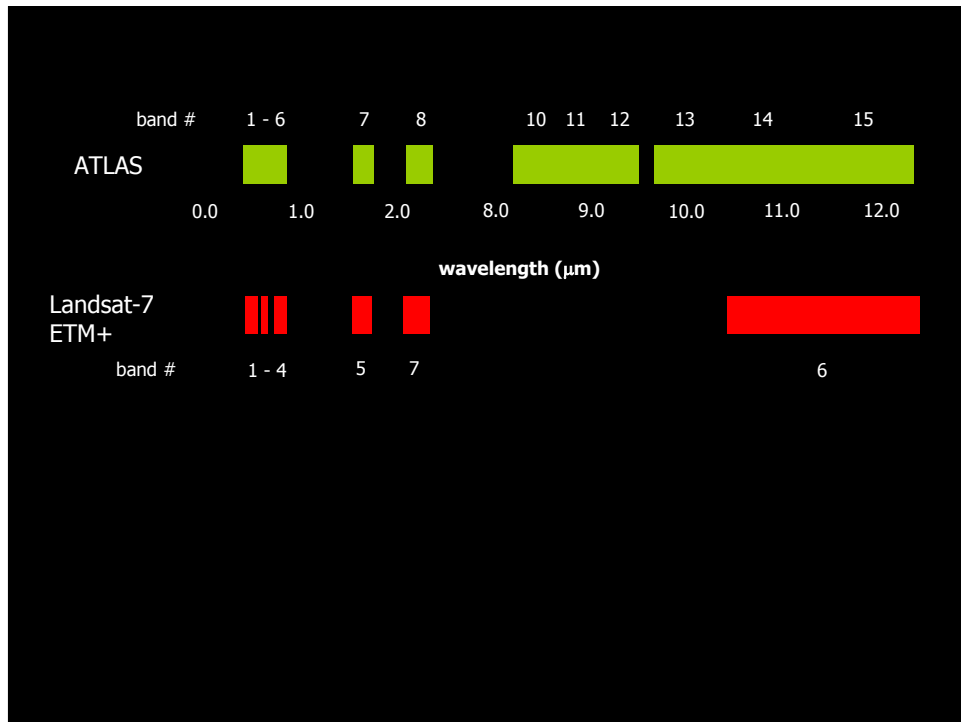
## Airborne Terrestrial Applications Sensor (ATLAS)



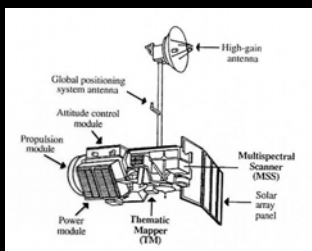
Band 4, 2, 1 in RGB



photograph from  
<http://www.crsp.ssc.nasa.gov>



## Spectral Cover of Landsat Sensors



### Band 1: 0.45-0.52 $\mu\text{m}$ (blue).

Provide increased penetration of water bodies, as well as supporting analysis of land use, soil, and vegetation characteristics.

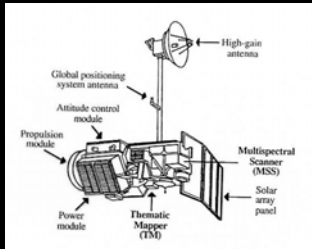
### Band 2: 0.52-0.60 $\mu\text{m}$ (green).

This band spans the region between the blue and red chlorophyll absorption bands and therefore corresponds to the green reflectance of healthy vegetation.

### Band 3: 0.63-0.69 $\mu\text{m}$ (red).

This is the red chlorophyll absorption band of healthy green vegetation and represents one of the most important bands for vegetation discrimination.

## Spectral Cover of Landsat Sensors



- **Band 4: 0.76-0.90 $\mu$ m (*reflective infrared*)**. This band is responsive to the amount of vegetation biomass present in the scene. It is useful for crop identification and emphasizes soil-crop and land-water contrasts.
- **Band 5: 1.55-1.75 $\mu$ m (*mid-infrared*)**. This band is sensitive to the amount of moisture in plants and therefore useful in crop draught and in plant vigor studies.
- **Band 6: 2.08-2.35 $\mu$ m (*thermal infrared*)**. This band measures the amount of infrared radiant flux emitted from surface.
- **Band 7: 2.08-2.35 $\mu$ m (*mid-infrared*)**. This is an important band for the discrimination of geologic rock formation. It is effective in identifying zones of hydrothermal alteration in rocks.

## Hyperspectral Data

### Example:

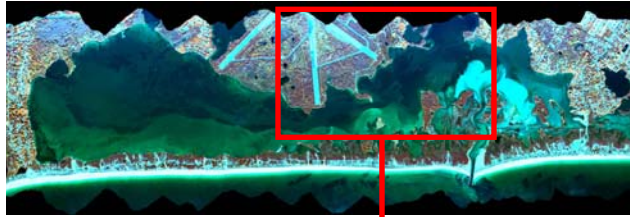
Hyperion hyperspectral sensor is capable of resolving 220 spectral bands at 10 nm interval (from 0.4 to 2.5  $\mu$ m) with a 30 meter spatial resolution.

The shown image, acquired April 6, 2004, is displayed as

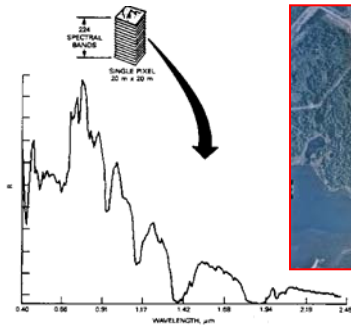
- 640.50  $\mu$ m in **Red** color
- 548.92  $\mu$ m in **Green** color
- 457.34  $\mu$ m in **Blue** color



# Hyperspectral Data

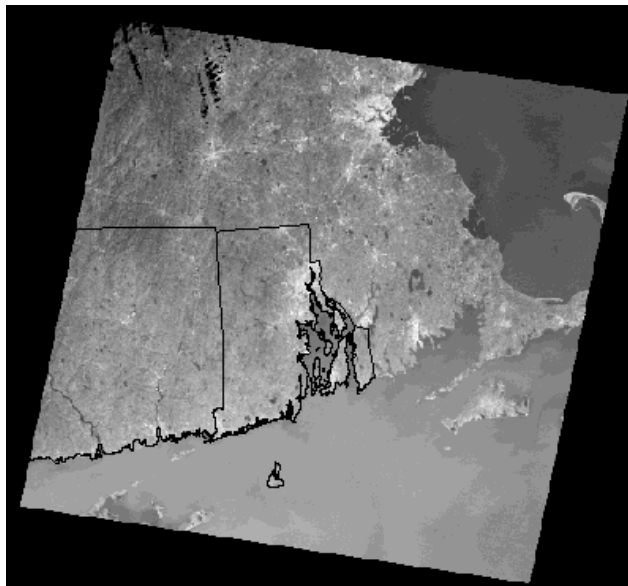


AVIRIS Data  
Ninigret Pond  
Rhode Island



True Color  
vs.  
Pseudo Color

## Thermal Band (Landsat TM band 6)



## Resolutions of Remote Sensing

1. Spatial (what area and how detailed)
2. Spectral (what colors – bands)
3. **Temporal** (time of day/season/year)
4. Radiometric (color depth)

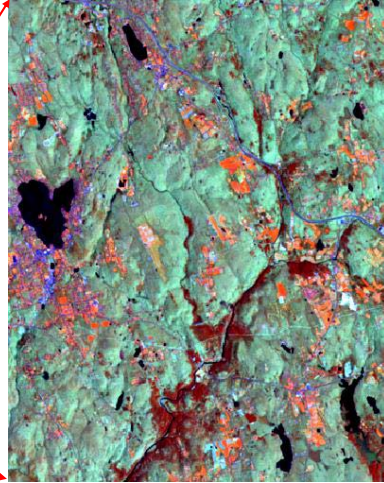
## Temporal Considerations

### *Time of day/season image acquisition*

- Leaf on/leaf off
- Tidal stage
- Seasonal differences
- Shadows
- Phenological differences
- Relationship to field sampling

## Seasonal Considerations

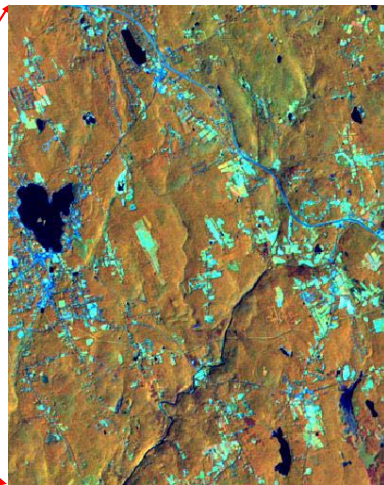
- Spatial
- Spectral
- *Temporal*  
(seasonal)
- Radiometric



Spring - bands 4,5,3

## Seasonal Considerations

- Spatial
- Spectral
- *Temporal*  
(seasonal)
- Radiometric



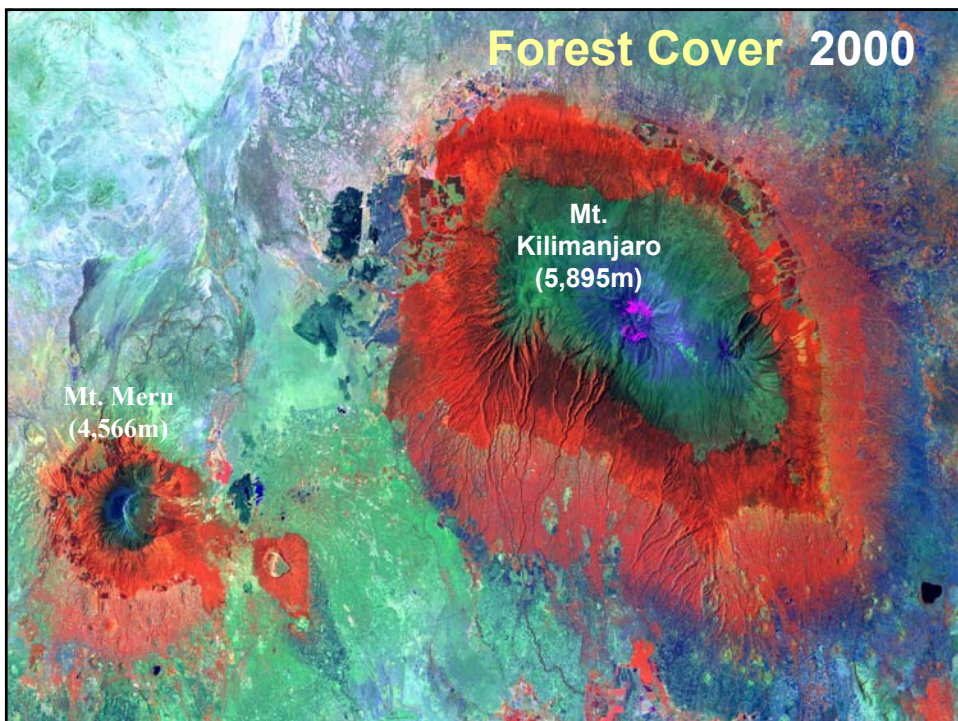
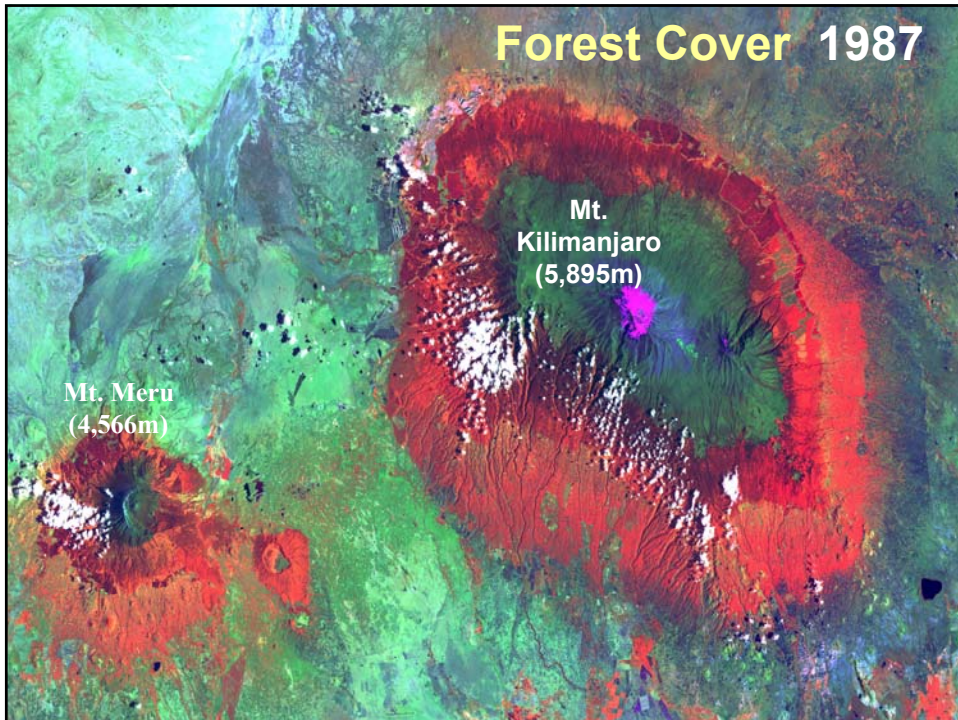
Summer - bands 4,5,3

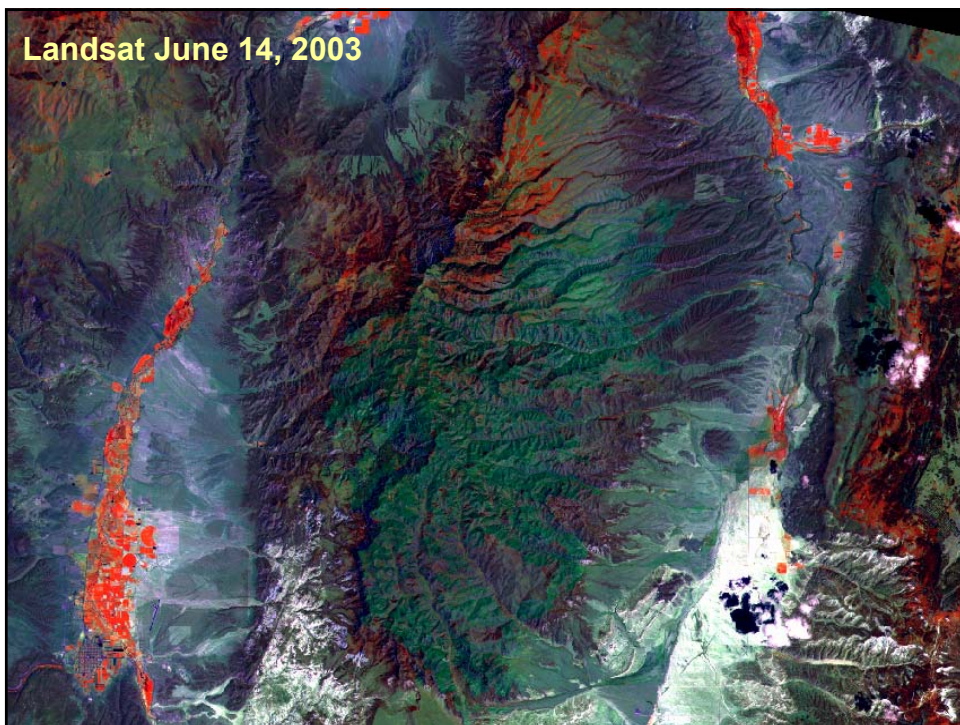
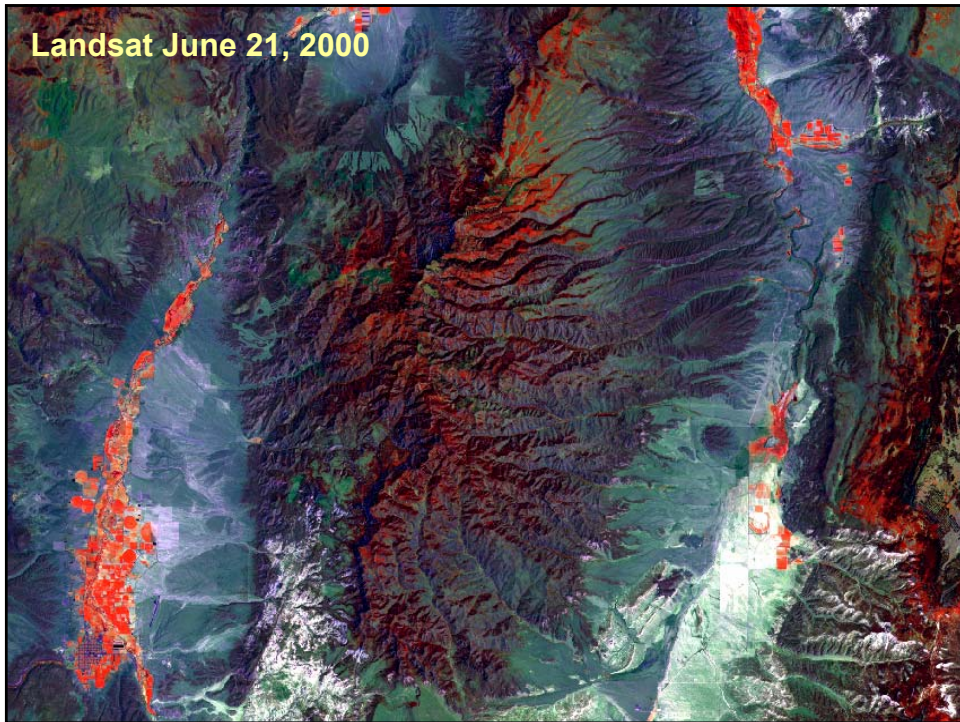
## Seasonal Leaf-on vs. Leaf-off



## Seasonal Leaf-on vs. Leaf-off







**How much has changed?  
How severe was the damage?  
What will be the ecosystem impacts?**

.....



## Repeat Coverage Considerations

- Revisit period for satellites – how often can you make a measurement for the same area
  - Landsat – 16 days (continuous collection)
  - Quickbird – varies (point-and-shoot)
  - MODIS – daily (continuous collection)
- Airborne images – collected as needed

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4. *Radiometric* (color depth)

## Radiometric Resolution

Every time an image is acquired by a sensor, its sensitivity to the magnitude of the electromagnetic energy determines the ***radiometric resolution***.

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

Imagery data are represented by positive digital numbers which vary from 0 to a selected power of 2. This range corresponds to the number of bits used for coding numbers in binary format. Each bit records an exponent of power 2.

The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded. Thus, if a sensor used 8 bits to record the data, there would be  $2^8=256$  digital values available, ranging from 0 to 255.

|   |   |   |    |    |    |     |     |     |      |      |                |
|---|---|---|----|----|----|-----|-----|-----|------|------|----------------|
| 1 | 2 | 3 | 4  | 5  | 6  | 7   | 8   | 9   | 10   | 11   | Number of bits |
| 2 | 4 | 8 | 16 | 32 | 64 | 128 | 256 | 512 | 1024 | 2048 | Maximum Values |

8 bits                      11 bits  
↓                                      ↓

Data volume will increase as the radiometric resolution increases?