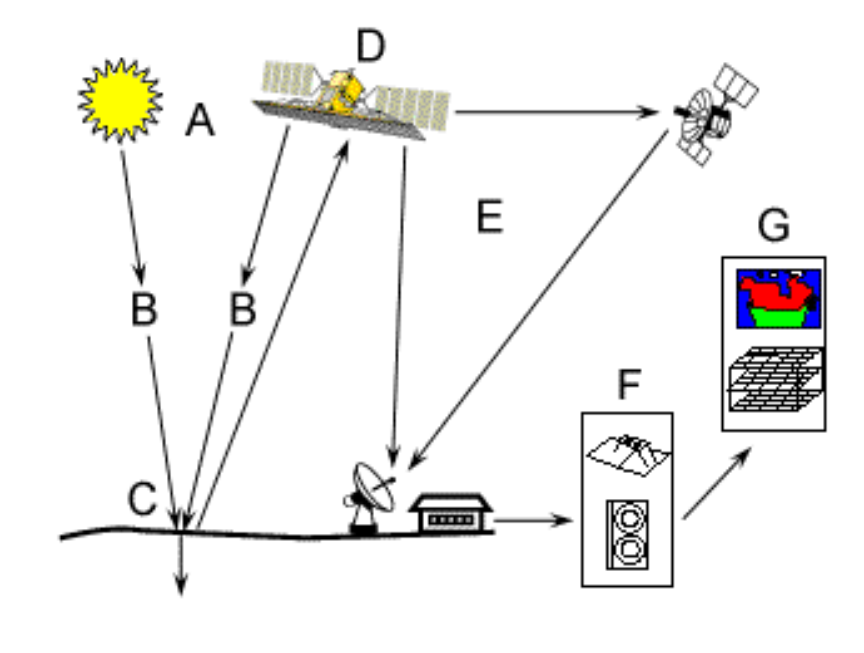
Introduction to Remote Sensing



Training Center

U.S. Geological Survey
Center for Earth Resources
Observation and Science (EROS)
Sioux Falls, South Dakota, USA

Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

Introduction to Remote Sensing

Michael Budde and James Rowland – SAIC / USGS EROS

Bamako , Mali

6 - 17 February, 2006

Remote Sensing Introduction/Overview

- Definition
- History
- Electromagnetic Radiation
- Atmospheric Effects
- Surface Reflective Properties

Remote Sensing Defined:

"…the science of acquiring information about the Earth's surface without being in direct contact with it"

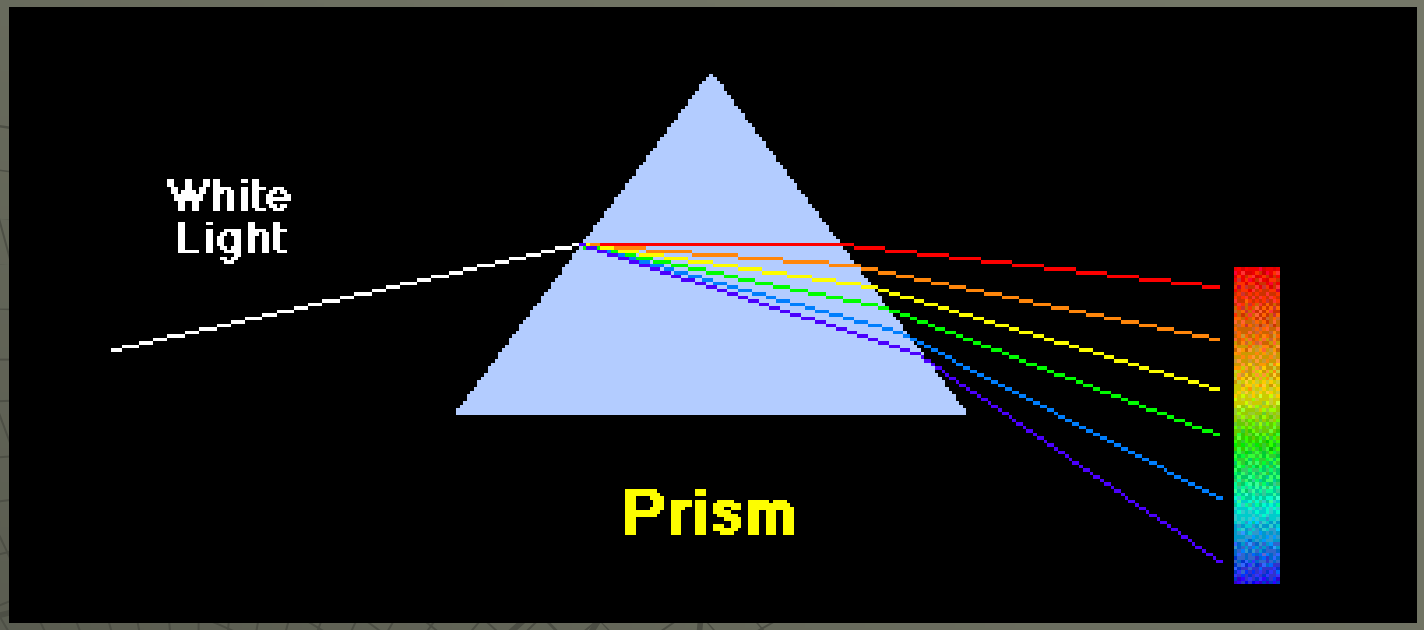
Remote sensing deals with the detection and measurement of phenomena with devices sensitive to electromagnetic energy such as:

- **hand-held sensors**
- **aircraft sensors and cameras**
- **satellite sensors**

History of Remote Sensing:

1666 - Sir Isaac Newton, while experimenting with a prism, found that he could disperse light into a spectrum of red, orange, yellow, green, blue, indigo, and violet. Utilizing a second prism, he found that he could recombine the colors into white light.

http://encarta.msn.com/encyclopedia_761573959/Isaac_Newton.html



"Newton's first experiments with a prism helped change the view that white light was simply white. Passing a beam of sunlight through a prism, he saw that the beam spread out into a colored band of light, called a spectrum. Newton concluded through experimentation that sunlight is a combination of all the colors of the spectrum and that the sunlight separates when passed through the prism because its colors bend differently."

http://library.thinkquest.org/J0112188/sir_isaac_newton.htm

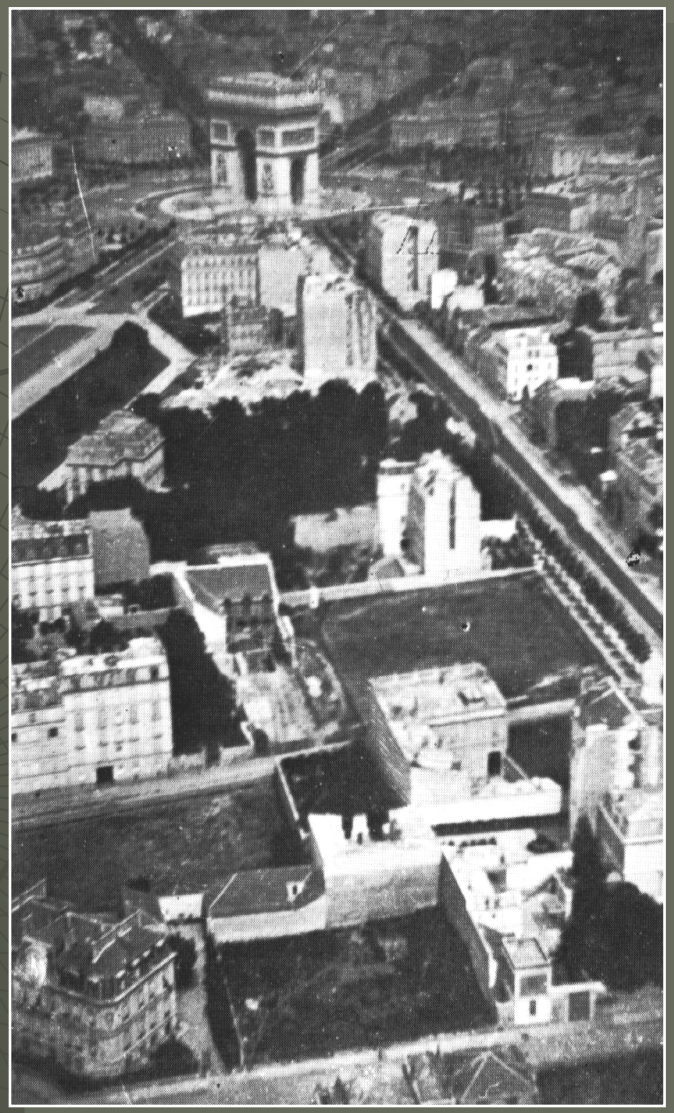
The First Photograph

The first photograph was obtained by Joseph Nicephore Niepce of his French estate courtyard in 1827.

- The exposure lasted 8 hours and used an emulsion of Bitumen of Judea (a kind of asphalt).

Jensen, 2000

First Aerial Photograph



- The first known aerial photograph was obtained by Gaspard Felix Tournachon from a tethered balloon 1,700-ft. above Paris, France in 1858

Jensen, 2000

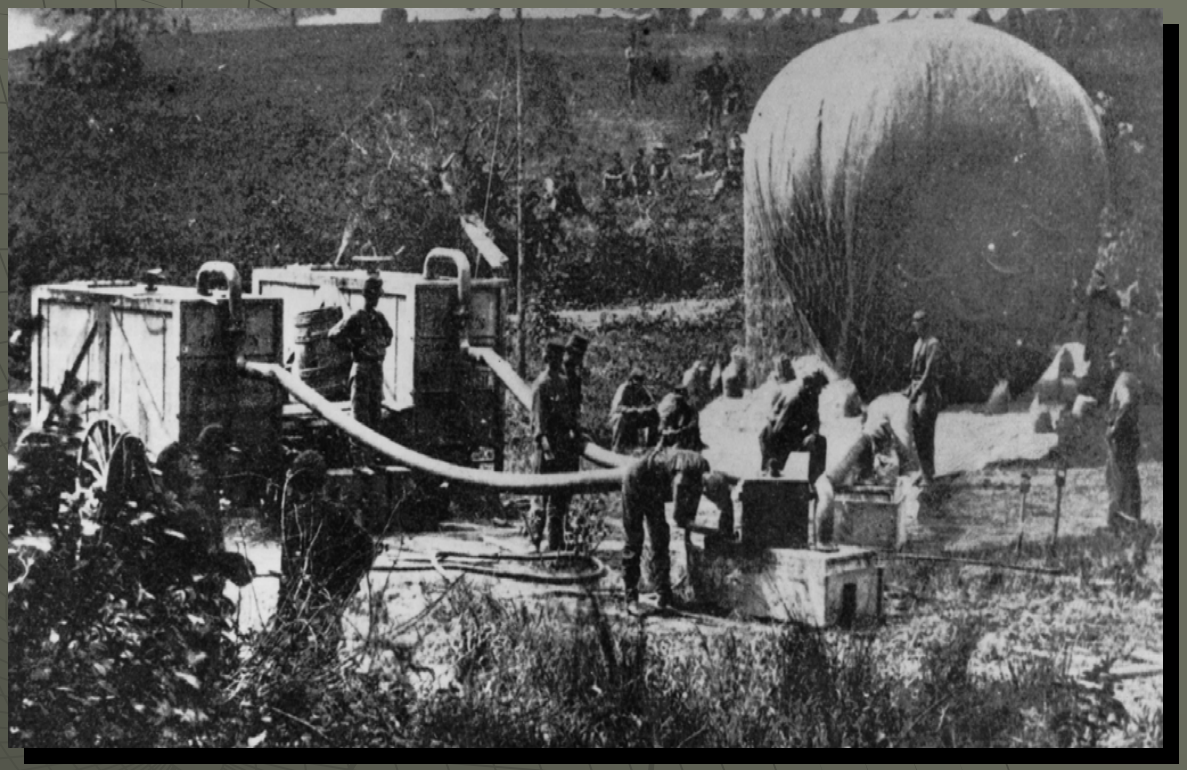
Balloon Photography

- Oblique aerial photograph of downtown Boston obtained by Samuel A. King and J. W. Black from a balloon at an altitude of 1,200 ft. on October 13, 1860.

- First aerial photograph taken from a captive balloon in the United States.

Jensen, 2000

Balloon *Intrepid*



• *Intrepid* being inflated during the Civil War battle of Fair Oaks on June 1, 1862 using Thaddeus S. C. Lowe's portable hydrogen generating system.

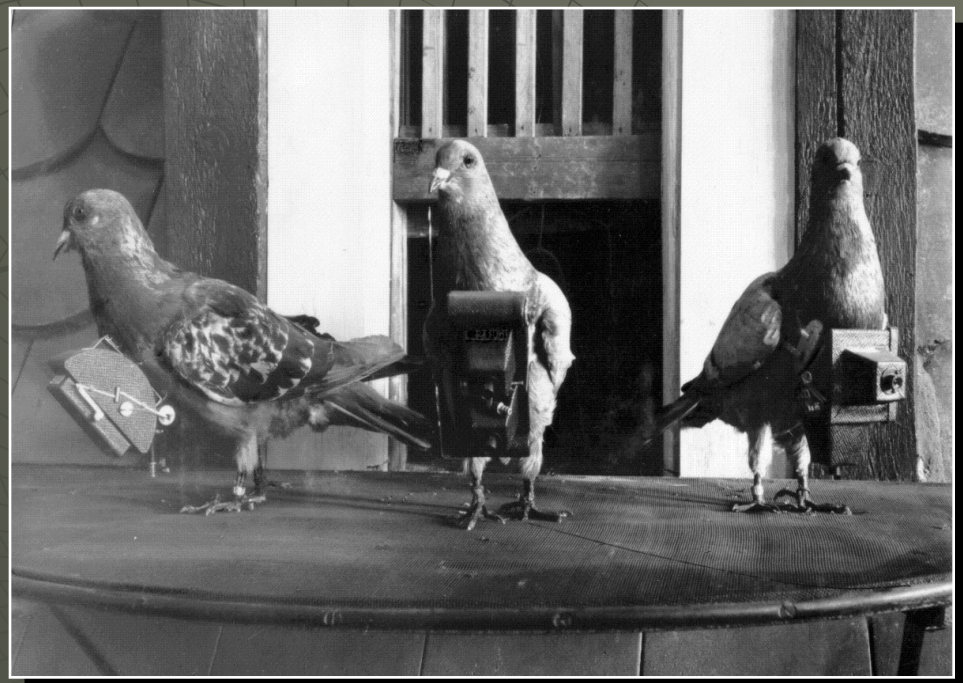
Jensen, 2000

Balloon *Intrepid*

- *Intrepid* tethered during the Civil War battle of Fair Oaks on June 1, 1862.

Jensen, 2000

Pigeons



- In 1903, Julius Neubronner patented a breast-mounted camera for carrier pigeons that weighed only 70 grams.

- A squadron of pigeons is equipped with light-weight 70-mm aerial cameras.

Jensen, 2000

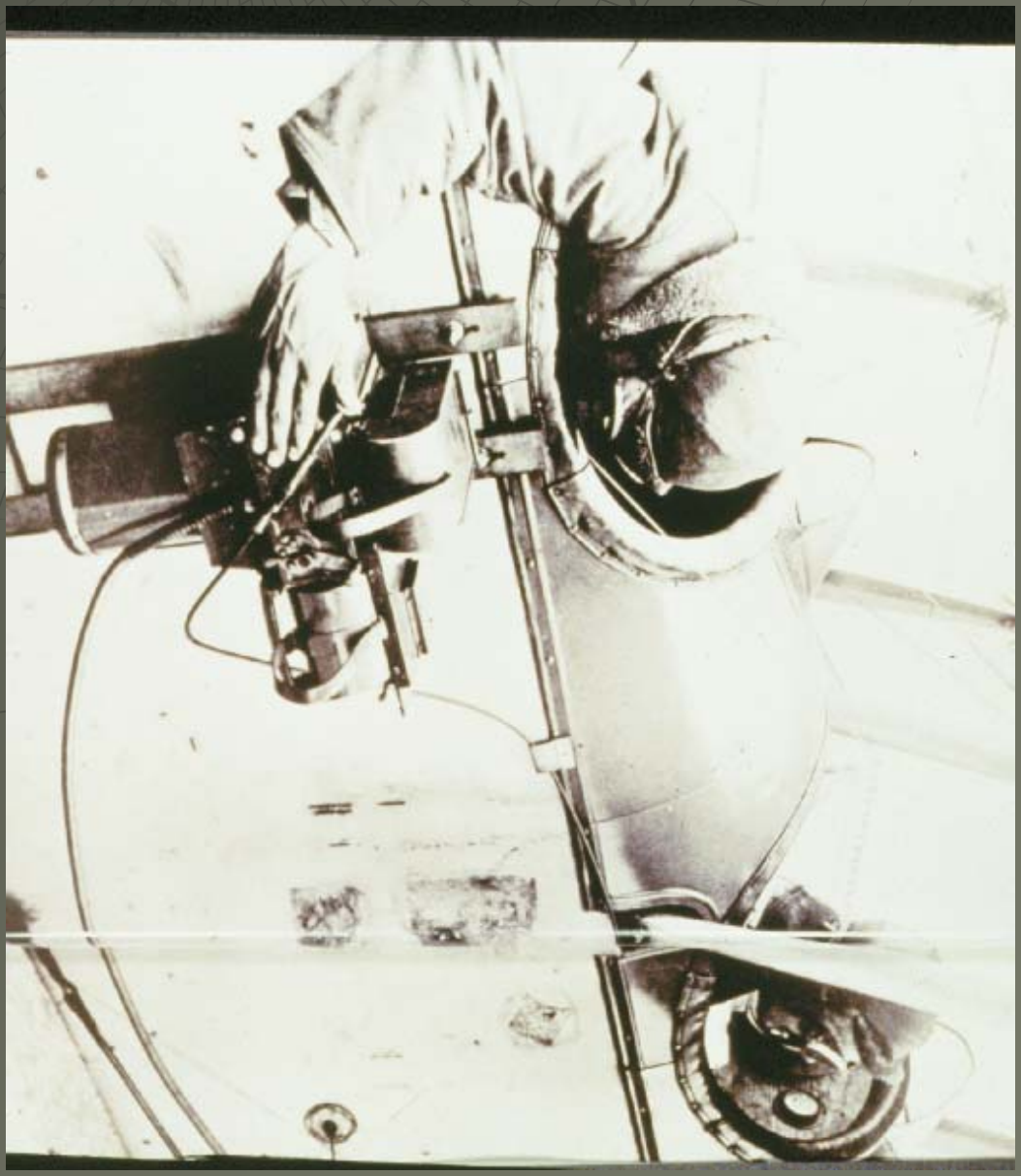
Pigeons

- Oblique aerial photograph of a European castle obtained from a camera mounted on a carrier pigeon. The pigeon's wings are visible.

Jensen, 2000

Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

Photo's from planes WW1



U-2

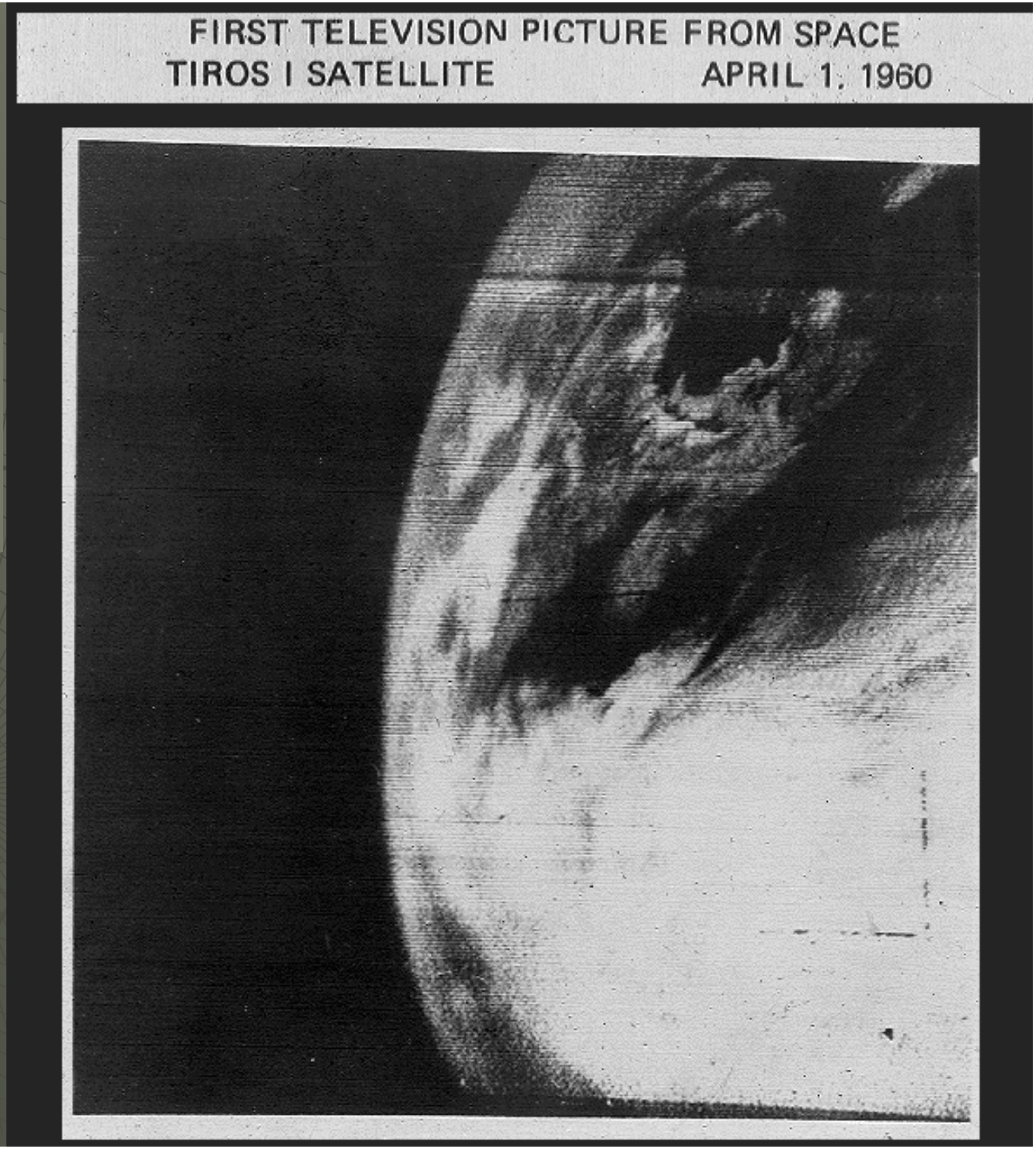
- Lockheed U-2 high altitude reconnaissance aircraft. Many U-2s are still in service as earth resource observation aircraft.

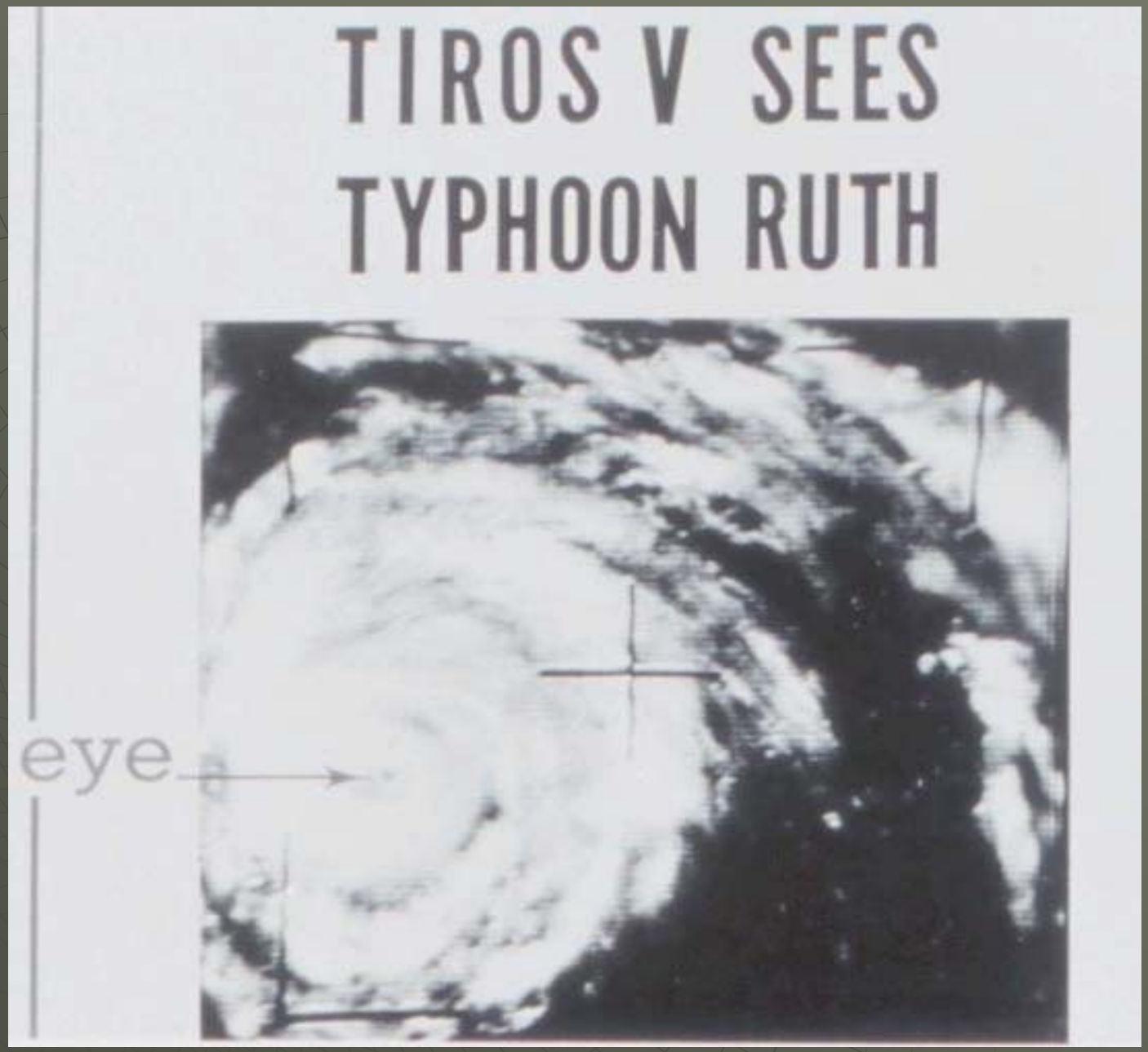
1st flight in 1954.

Jensen, 2000

Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

First television picture from a satellite in space - 1960.

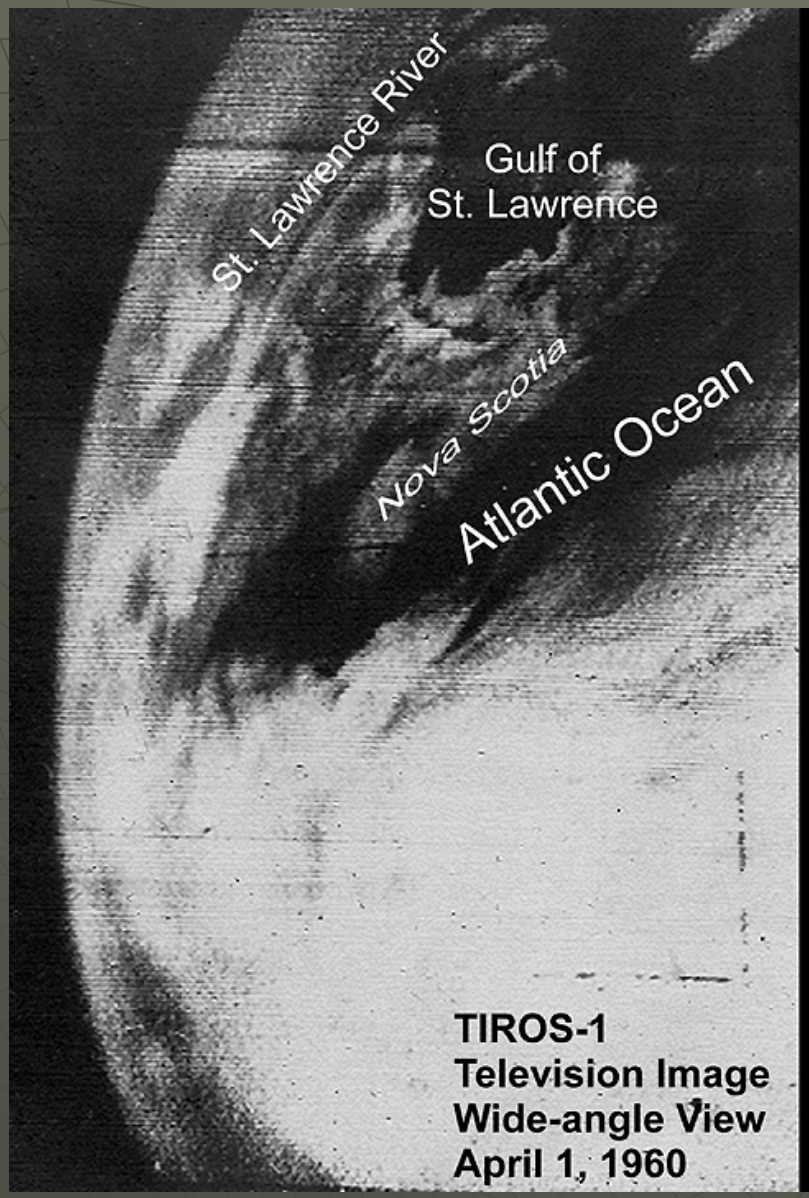




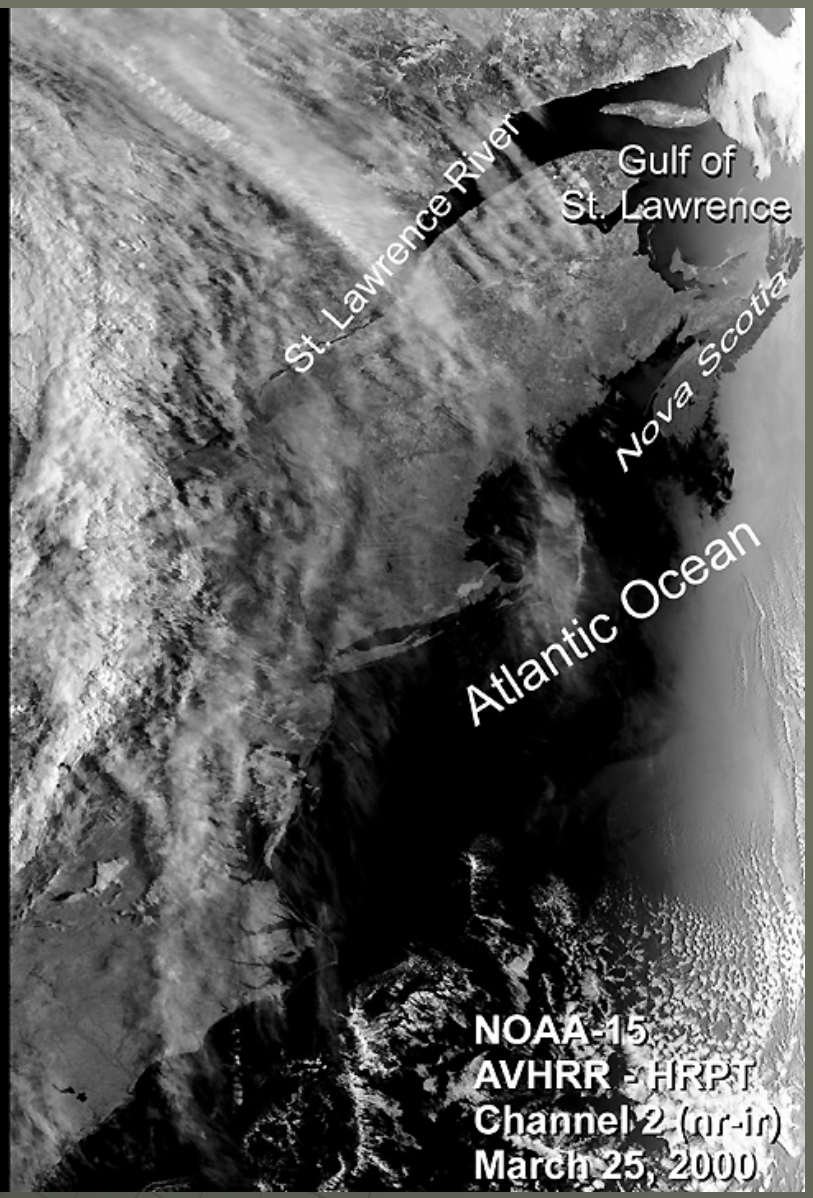
1964

Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

Then



Now



Remote Sensing Chronology:

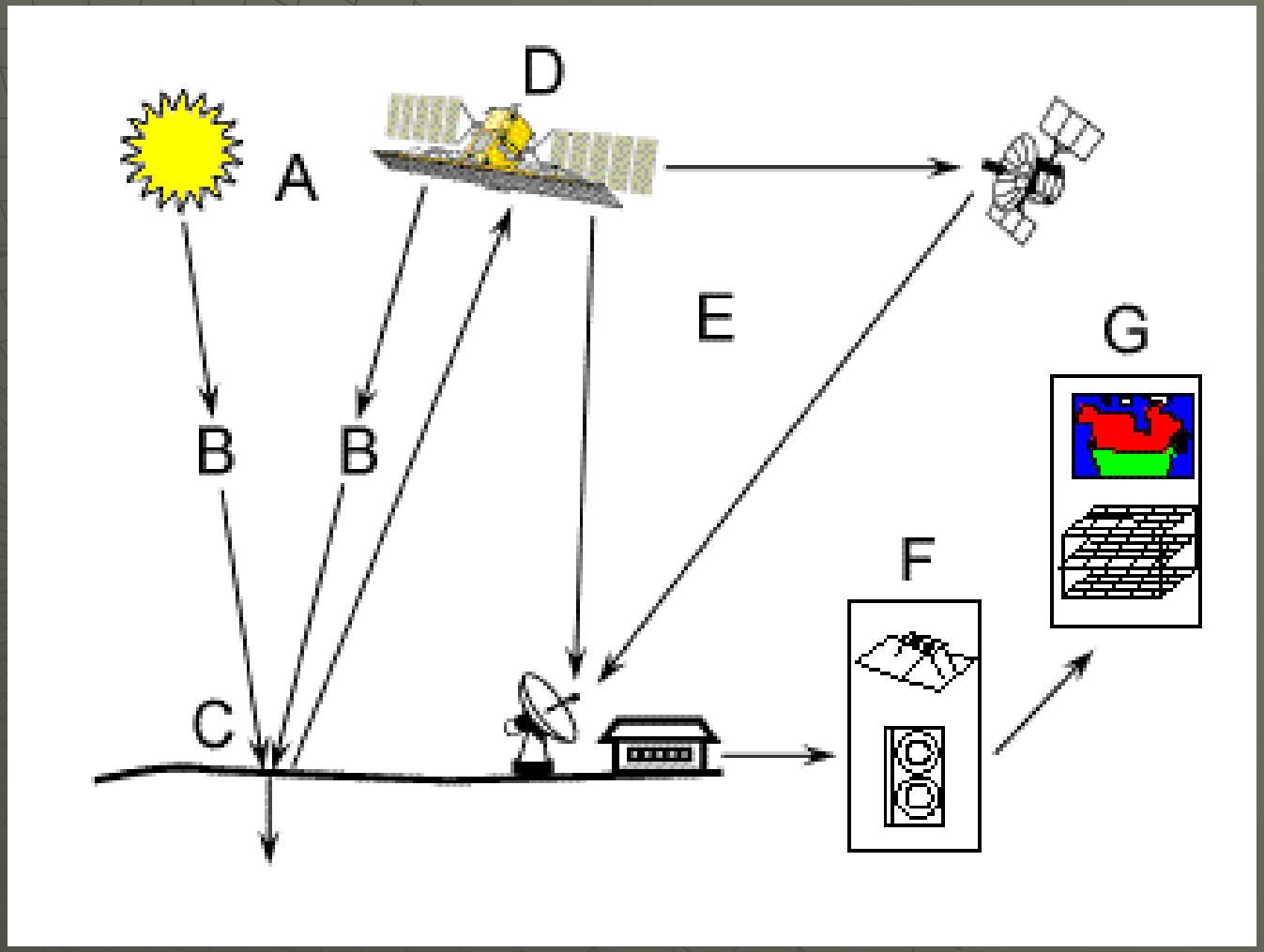
- **1914 - 1918** - WWI Air Reconnaissance
- **1930's** - Extensive use of aerial photographs in Earth sciences and agriculture.
- **1940 - 1945** - WWII brings tremendous advancements in aerial photography and photogrammetry.
- **1960's** - Considerable activity with multispectral photography applications

Remote Sensing Chronology:

- **1946** - Space Pictures obtained from v-2 rockets launched at White Sands Proving Ground (New Mexico)
- **1959 -** The United States' Explorer 6 transmitted the first space photograph of the Earth
- **1972** - Launch of ERTS (Landsat 1)

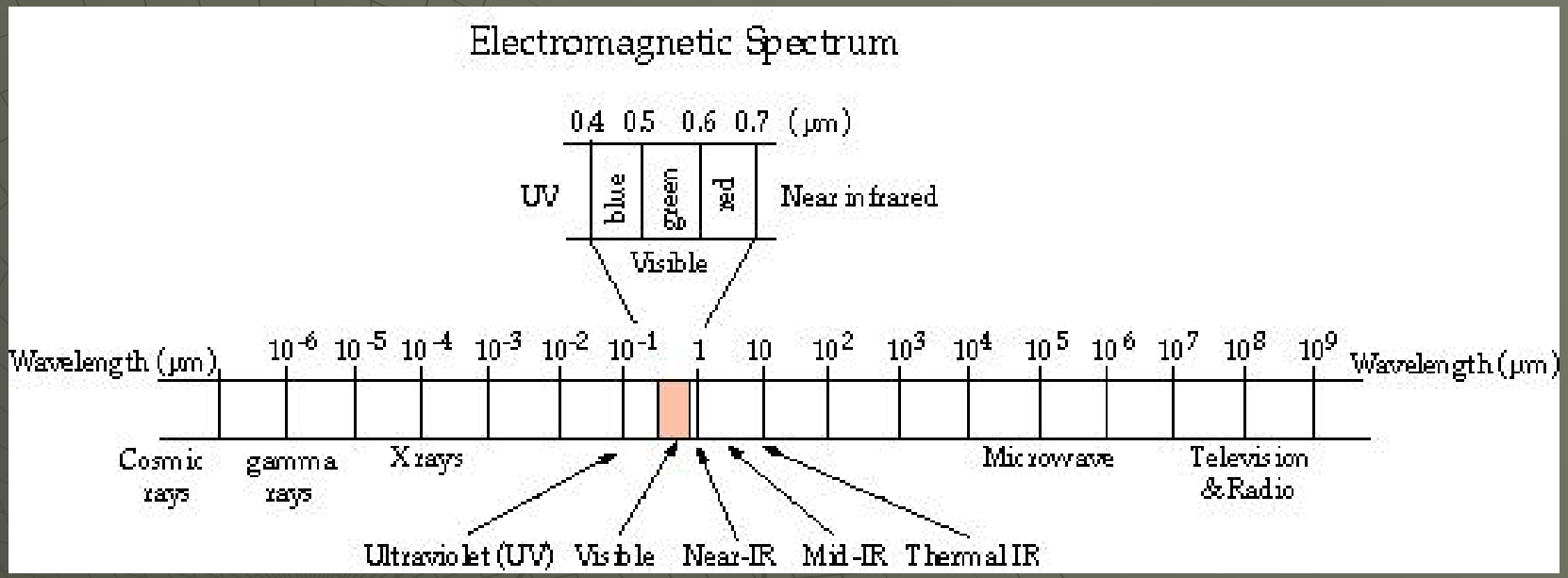
How Does it Work?:

Schematic of Satellite Remote Sensing Process

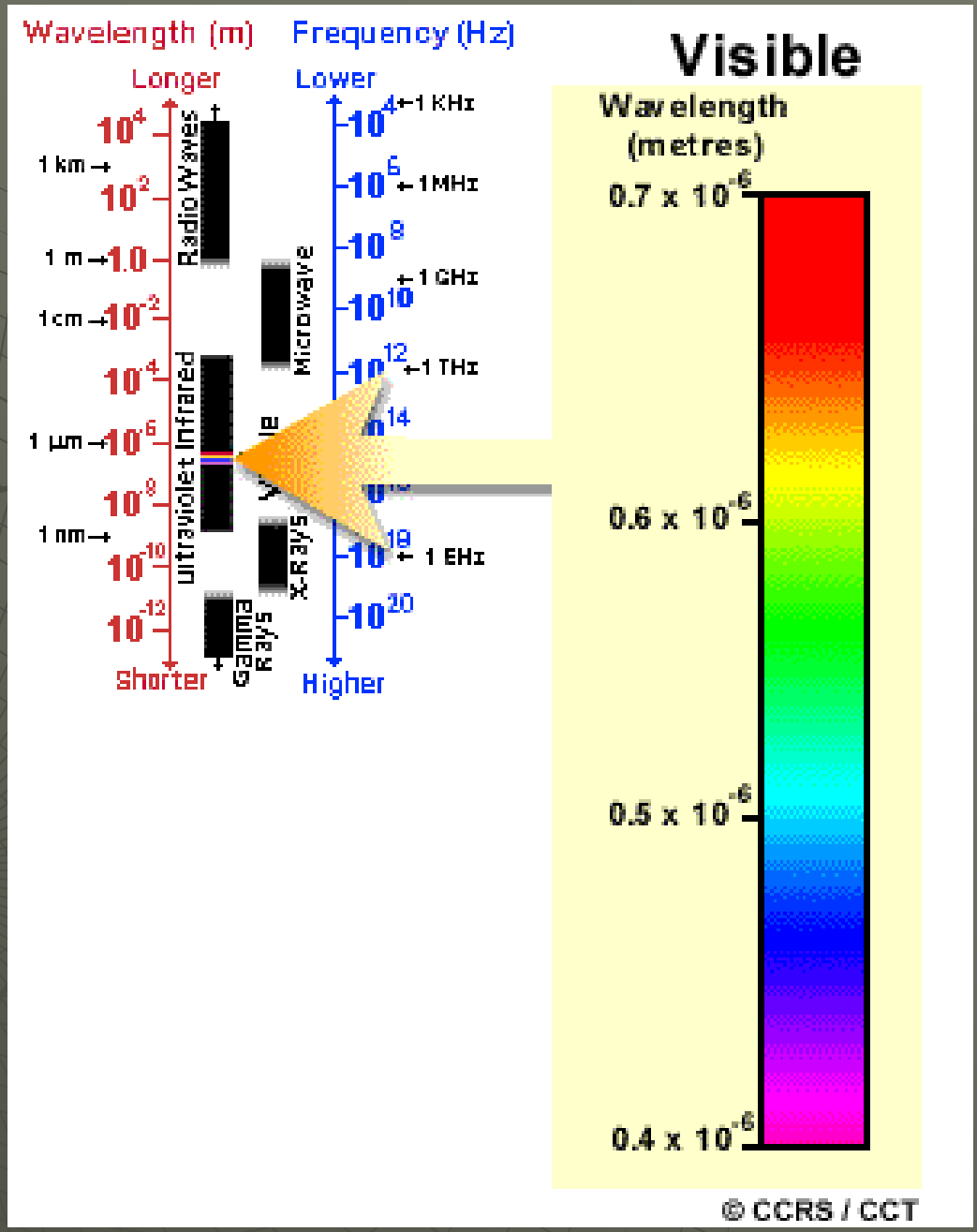


What are we measuring…

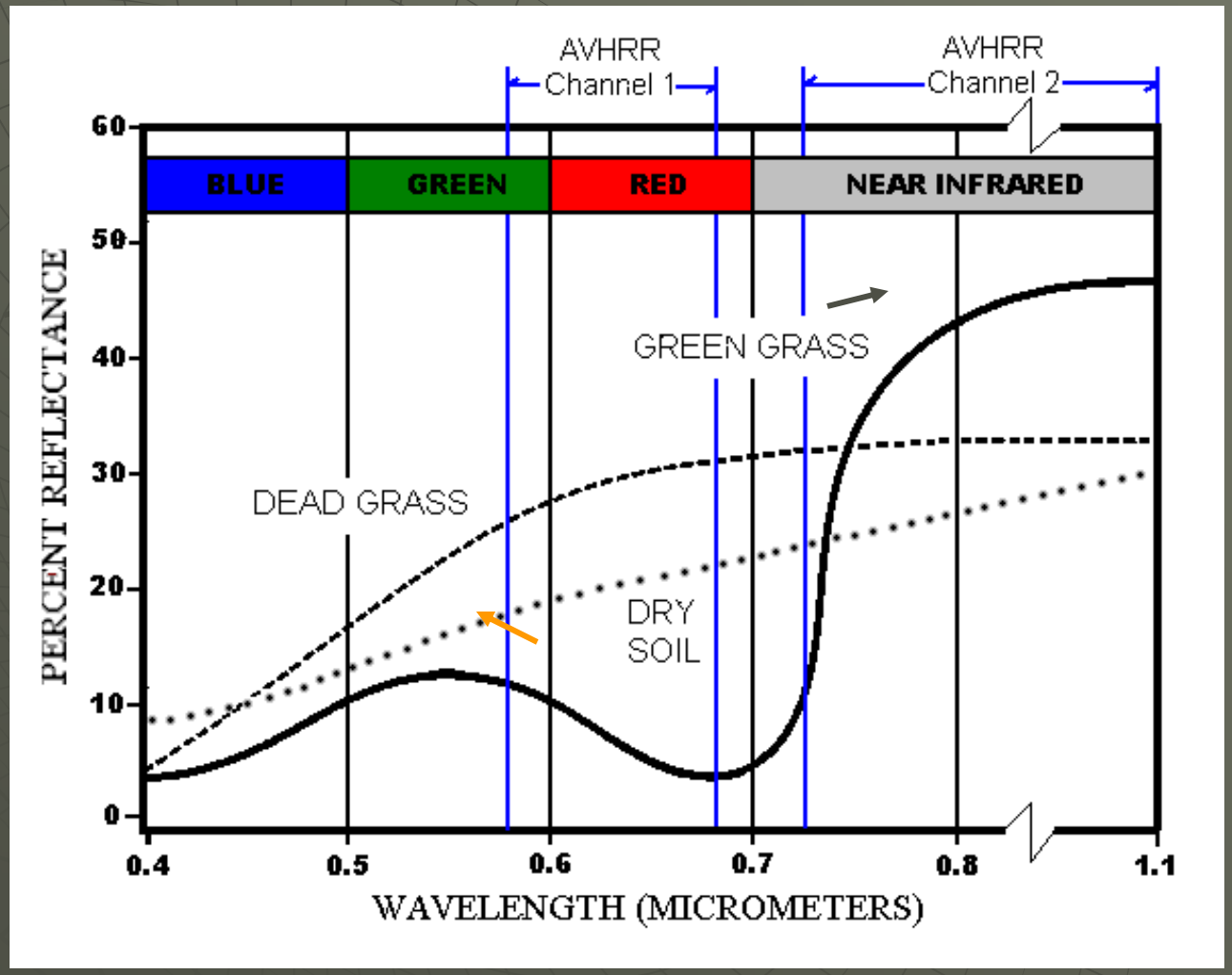
The Electromagnetic Spectrum


Electromagnetic Spectrum
0.4 0.5 0.6 0.7 (μm)
UV
blue
green
red
Near infrared
Visible
Wavelength (μm)
10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9
Wavelength (μm)
Cosmic rays
gamma rays
X rays
Microwave
Television &Radio
Ultraviolet (UV)
Visible
Near-IR
Mid-IR
Thermal IR

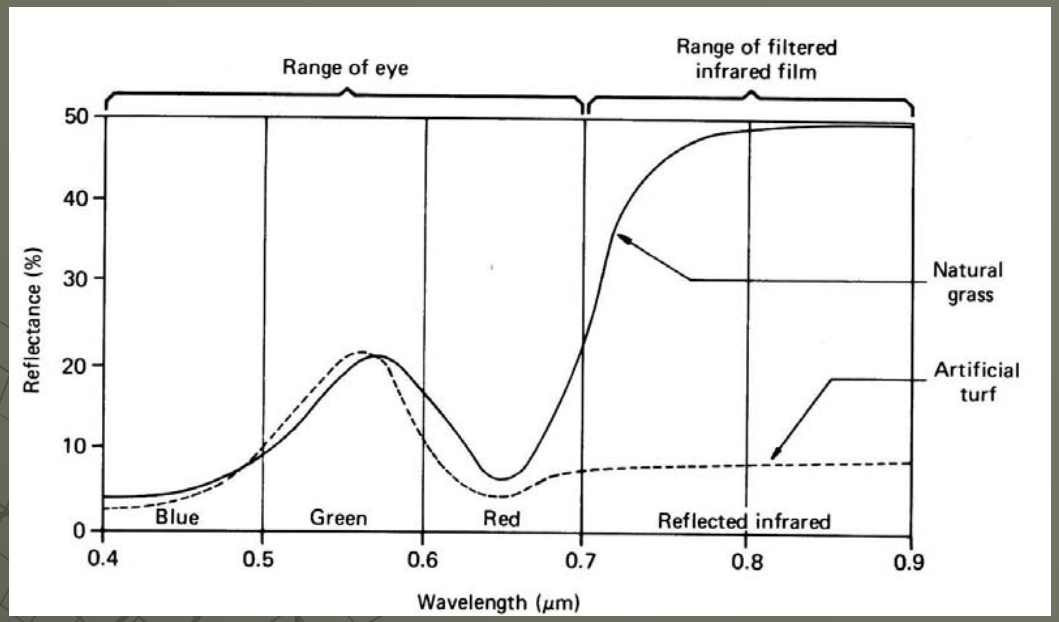
Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

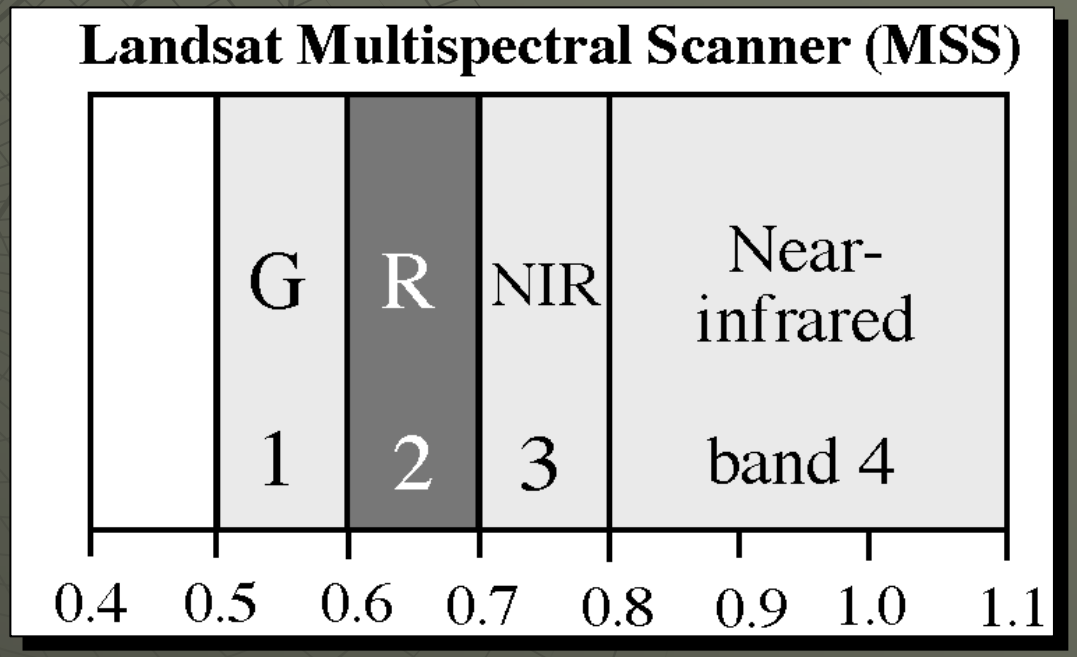


Visible and Infrared wavelengths are critical to monitoring the land surface.

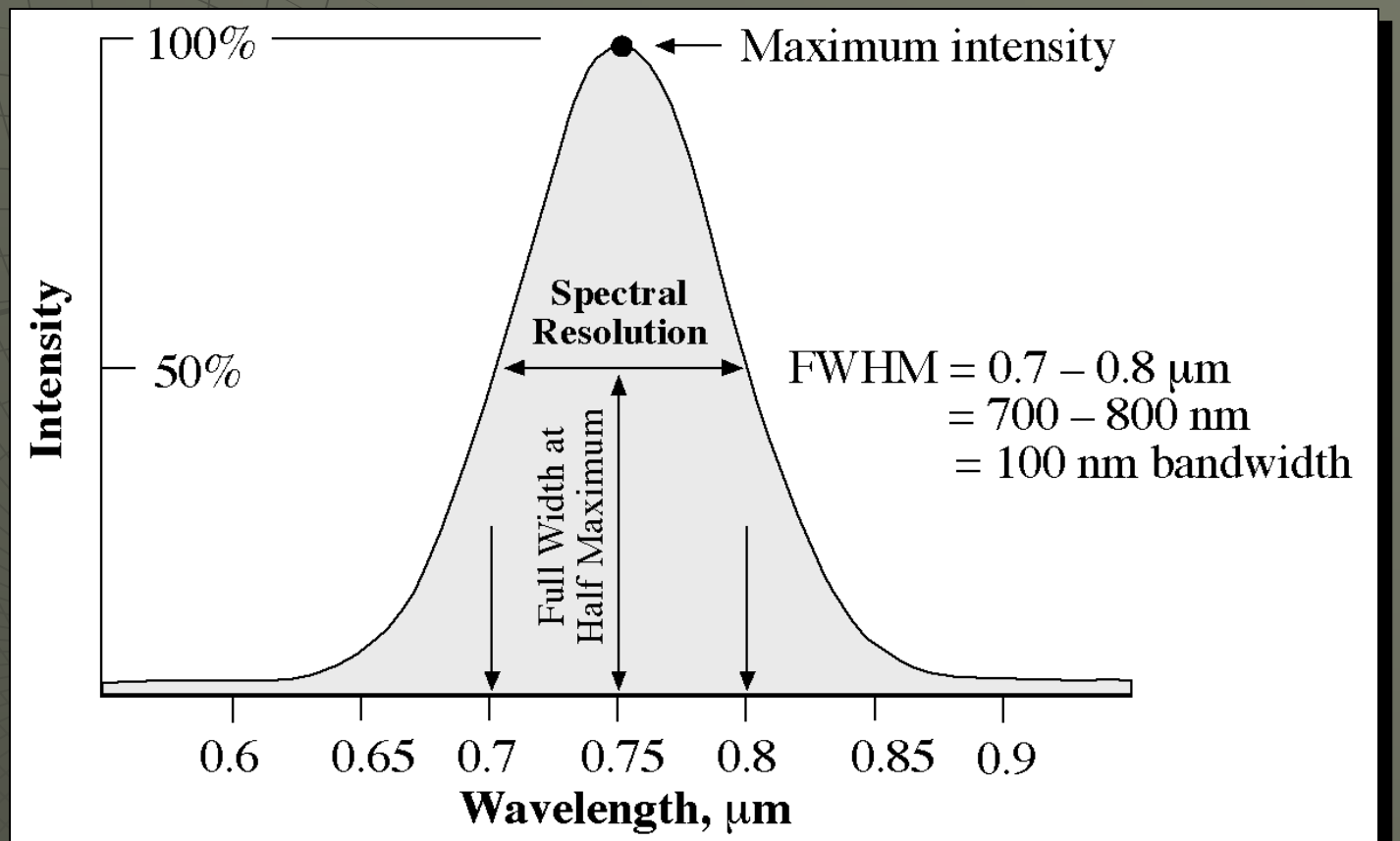


Landsat MSS Wavebands



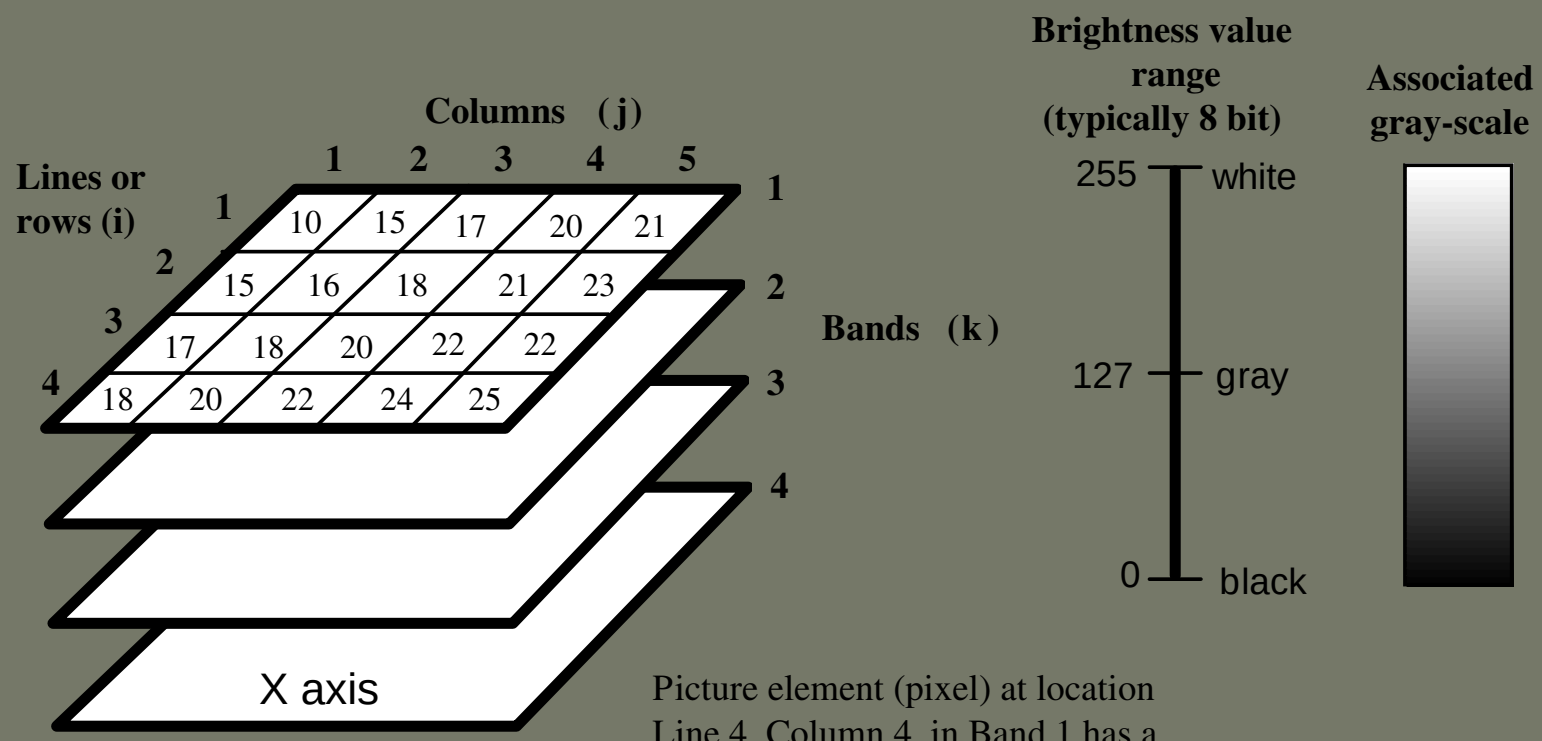


Spectral Resolution



b. Precise bandpass measurement of a detector based on Full Width at Half Maximum (FWHM) criteria

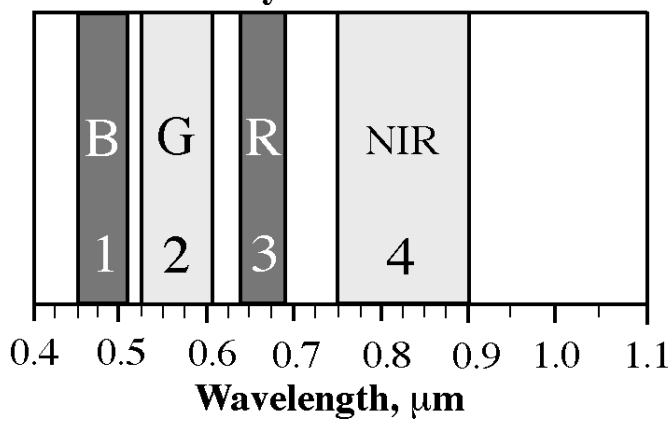
Remote Sensing Raster Data Format



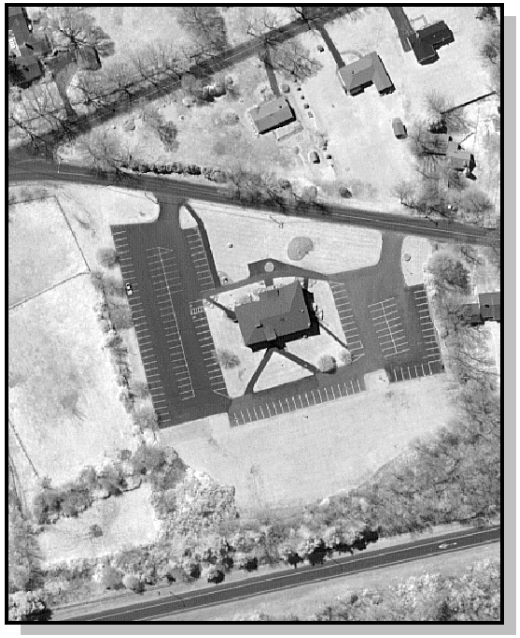
Picture element (pixel) at location Line 4, Column 4, in Band 1 has a Brightness Value of 24, i.e., $BV_{4,4,1} = 24$.

Jensen, 2000

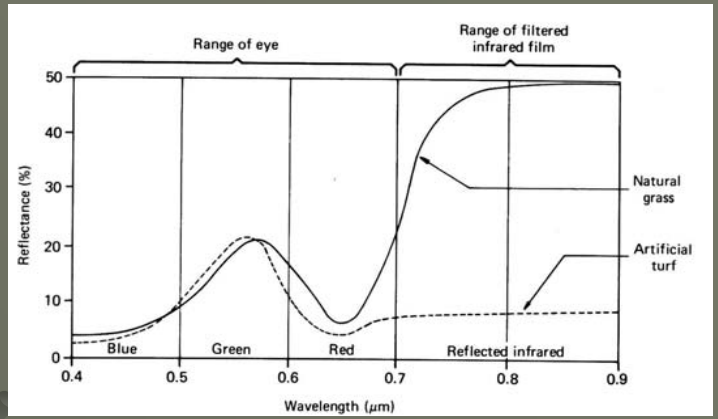
Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

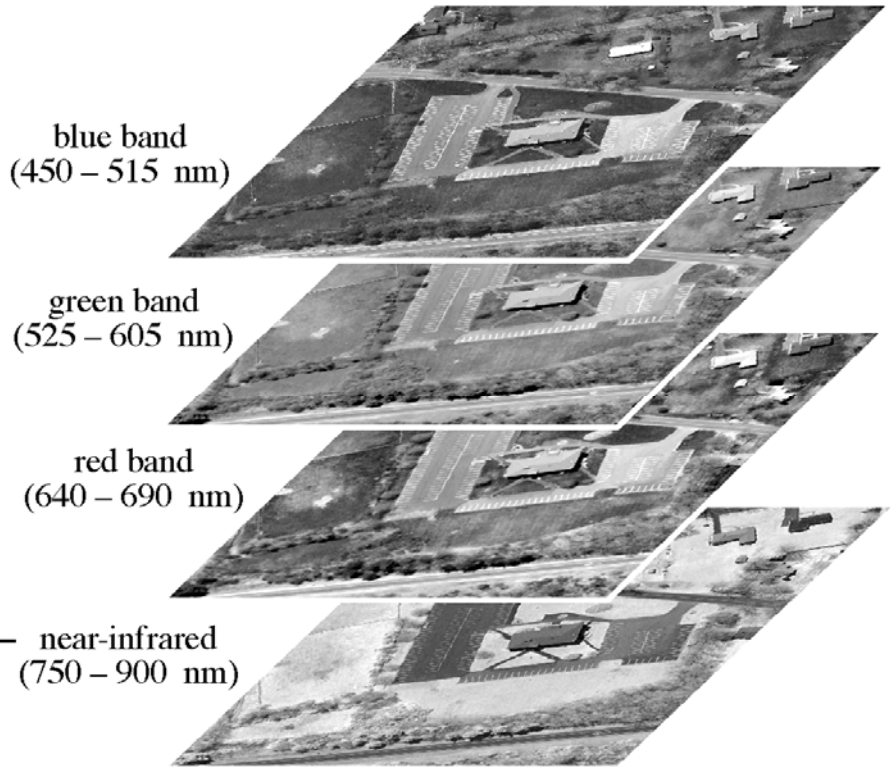


a. Nominal spectral resolution of the Landsat Multispectral Scanner and Positive Systems ADAR 5500 digital frame camera.



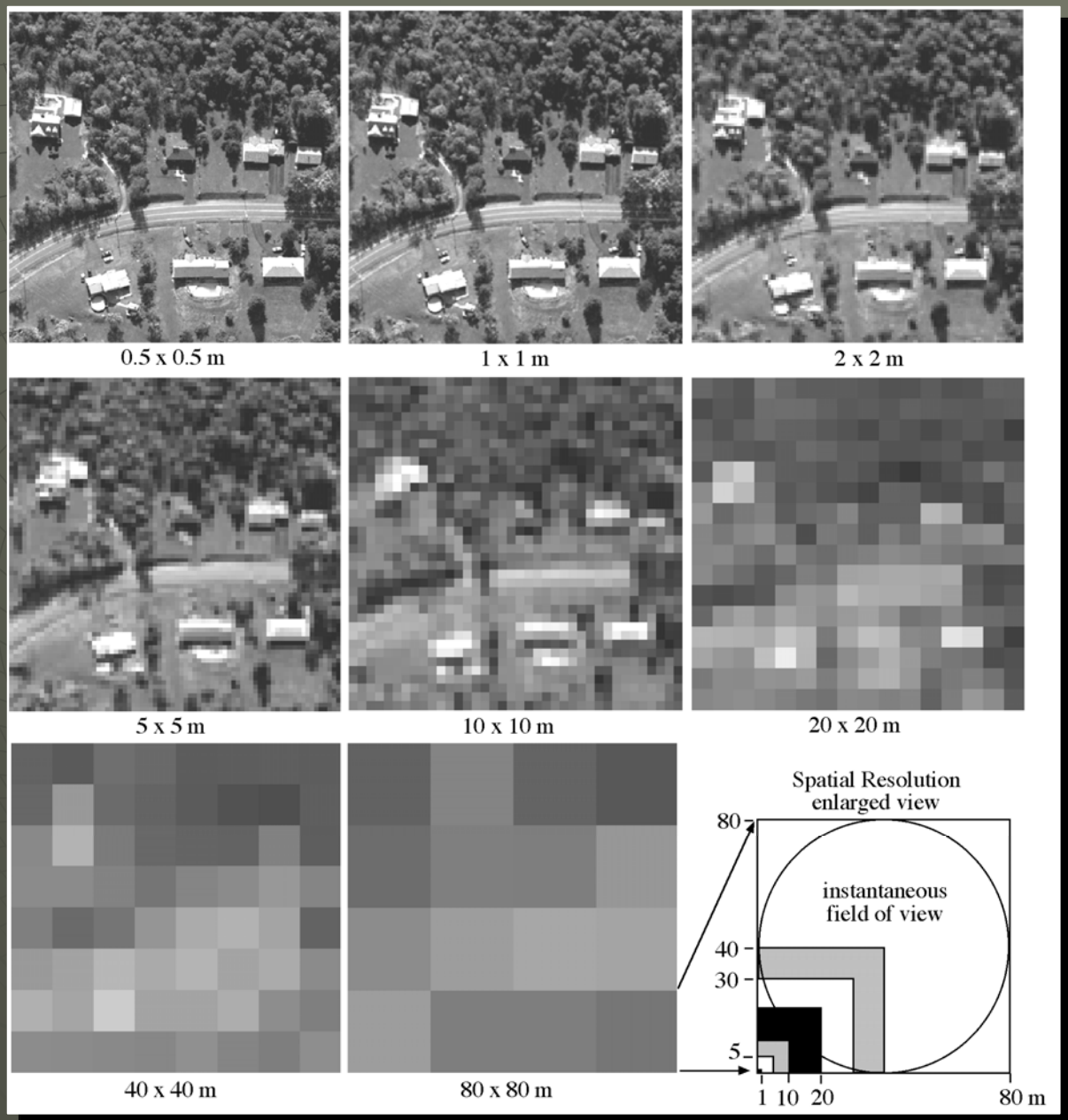
c. Single band of ADAR 5500 data





d. Multispectral remote sensing

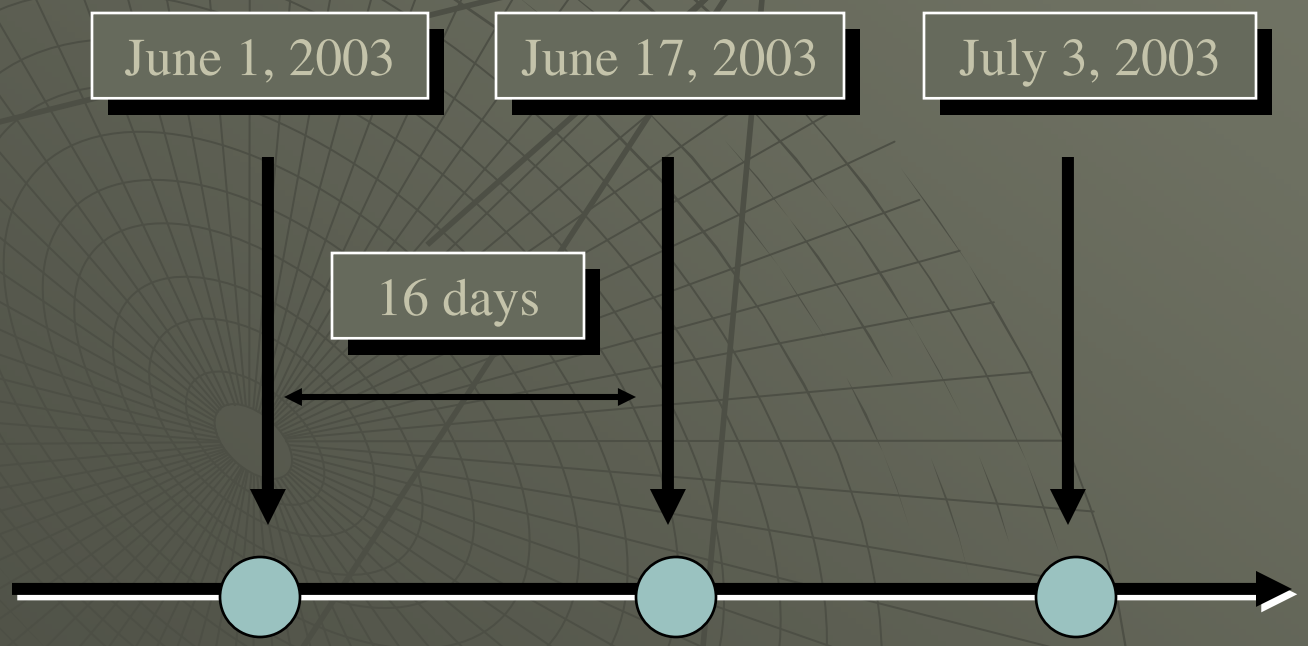
Spatial Resolution



Jensen, 2000

Temporal Resolution

Remote Sensor Data Acquisition



Jensen, 2000

Radiometric Resolution (precision)

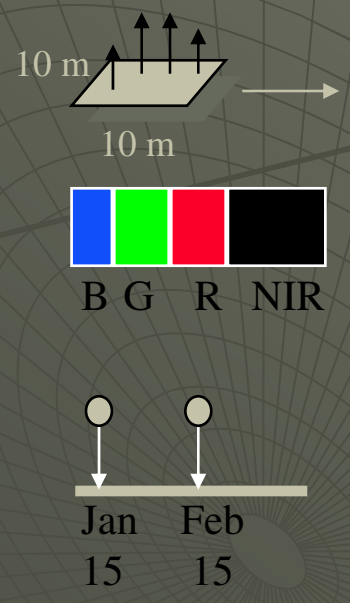
0 → 8-bit (0 - 255)

0 → 9-bit (0 - 511)

0 → 10-bit (0 - 1023)

Jensen, 2000

Remote Sensor Resolution



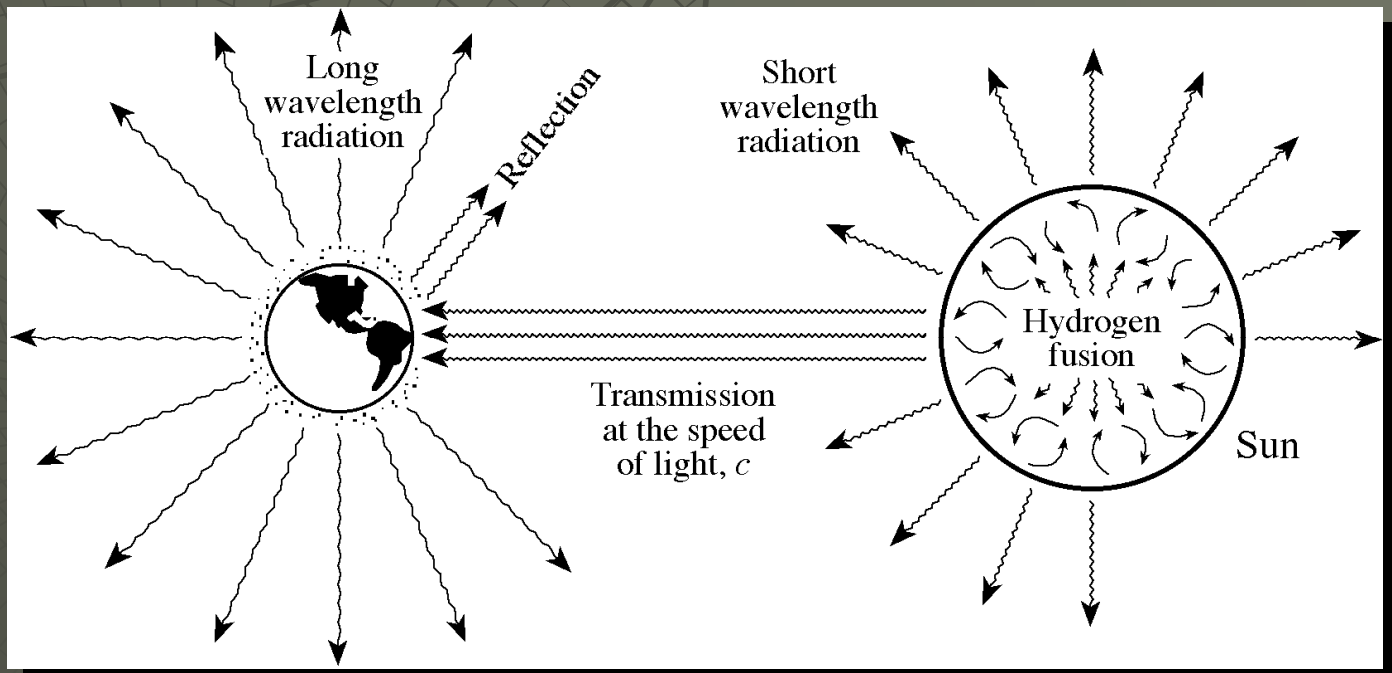
00101101

- Spatial - the size of the field-of-view, e.g. 10 x 10 m.
- Spectral - the number and size of spectral regions the sensor records data in, e.g. blue, green, red, near-infrared thermal infrared, microwave (radar).
- Temporal - how often the sensor acquires data, e.g. every 30 days.
- Radiometric - the sensitivity of detectors to small differences in electromagnetic energy.

Jensen, 2000

Earth – Sun Interactions

- Solar spectrum peaks in the visible spectrum
- Earth (terrestrial) spectrum peaks in the thermal infrared



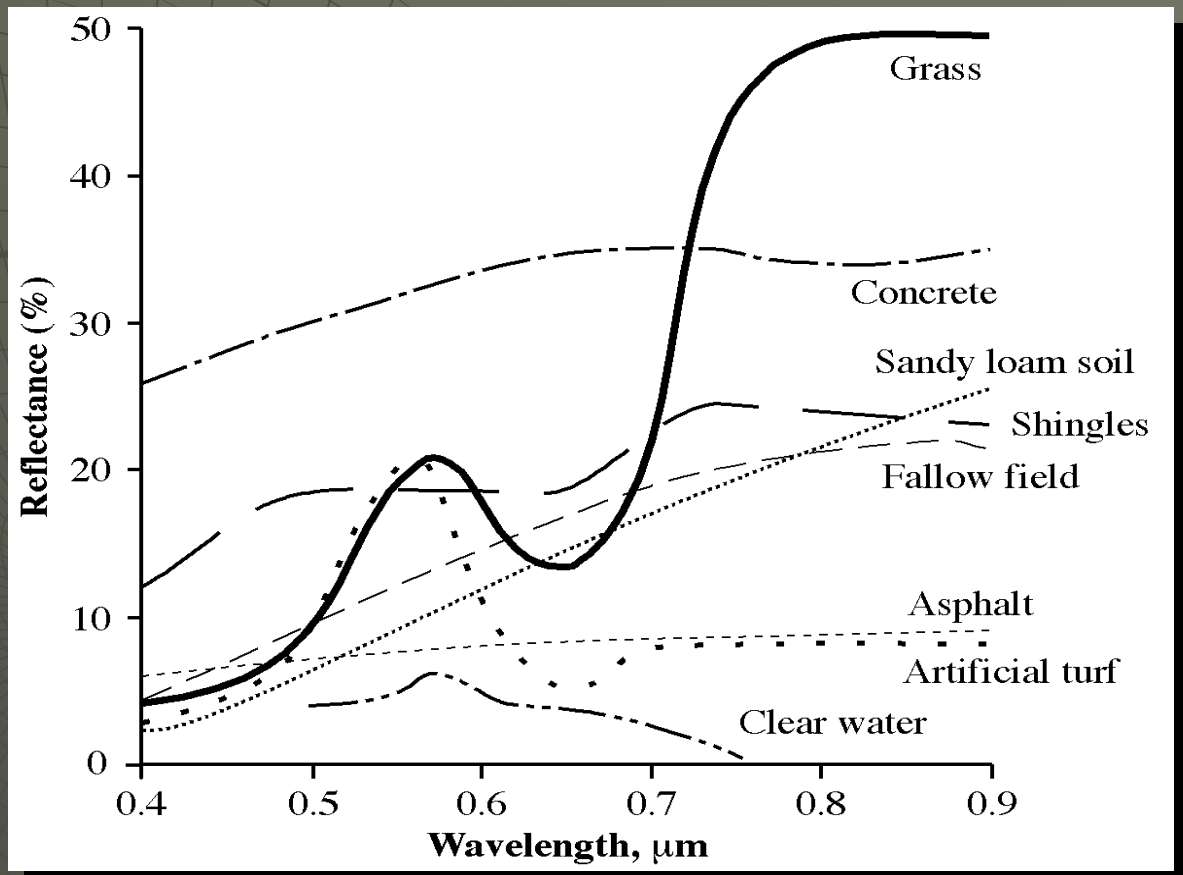
Spectral Properties of Objects

- The ***spectral properties*** of an object describe how the object's reflectance, transmittance and absorptance properties change with wavelength.
- These changes are due the material (chemical) and structural (shape) properties of the object.
- Therefore, by remotely observing reflected or emitted ***spectra*** from the Earth's surface, we can infer material and structural properties of surface features.

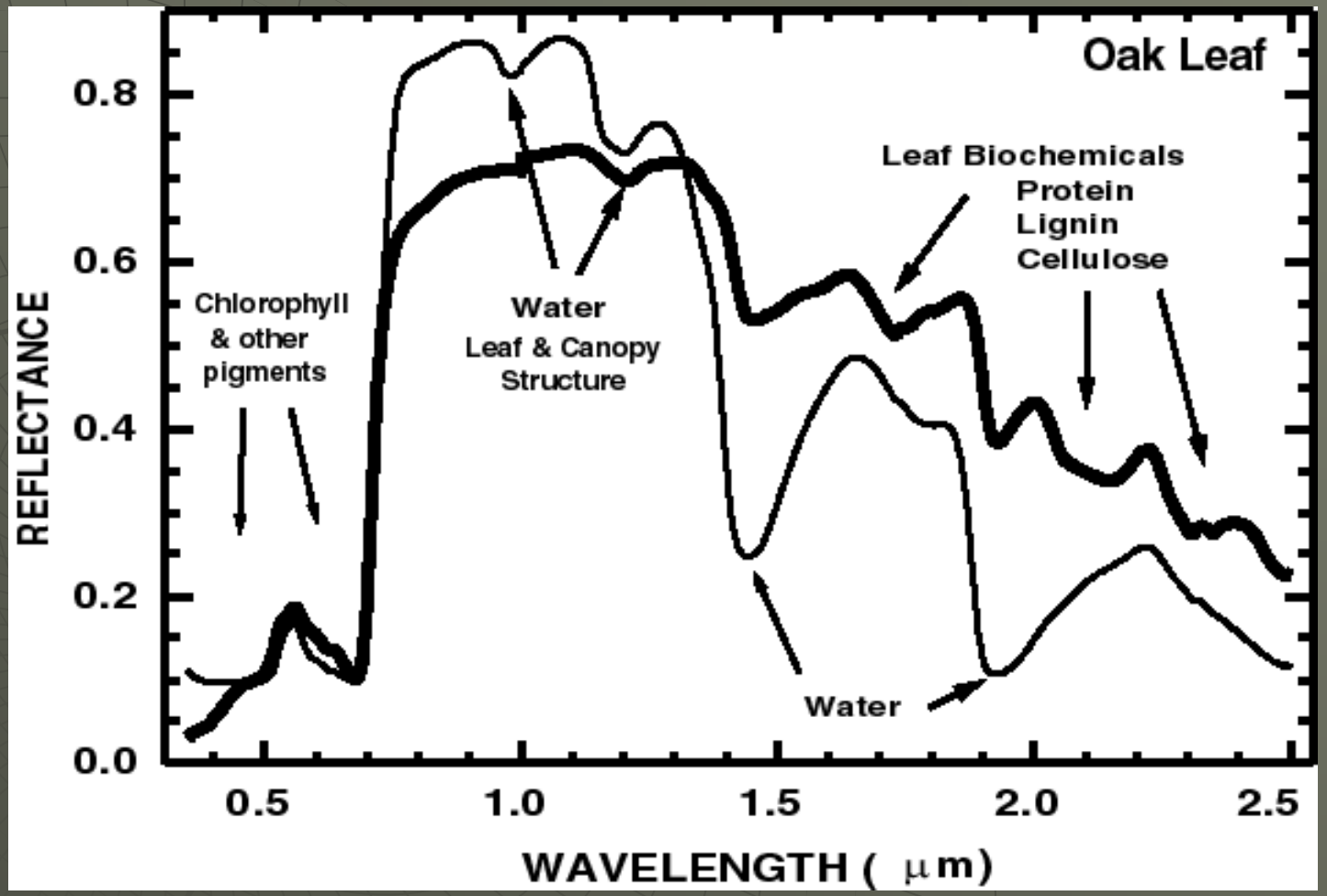
Types of Spectra

- Emission, transmission and absorption spectra
  - Used mostly for astronomy, atmospheric science, lab material analysis
  - Emission spectra plays a role in terrestrial remote sensing
- Reflectance spectra
  - The dominant “workhorse” for the type of passive remote sensing done for earth applications

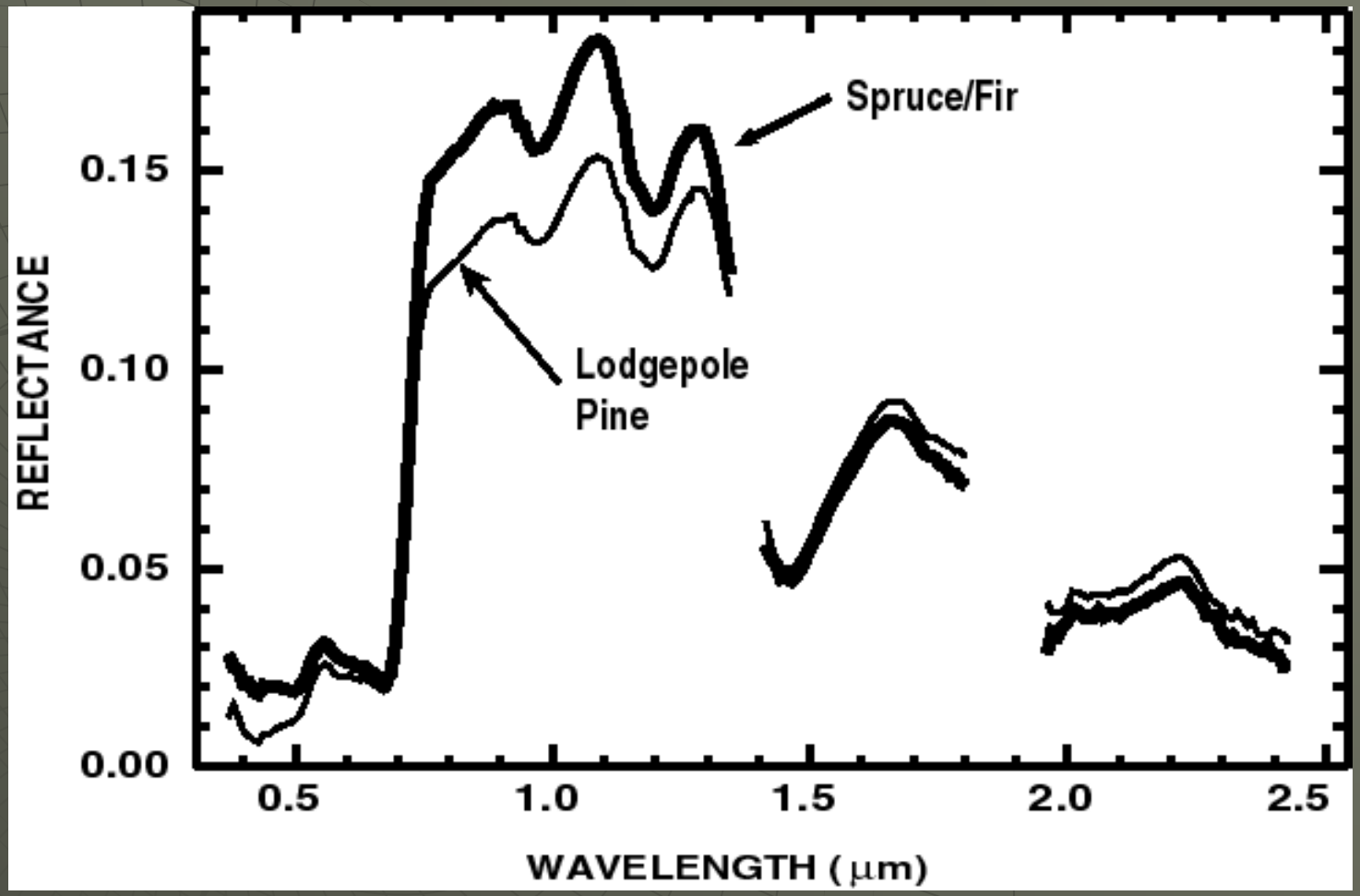
Reflectance spectra of typical Earth surface features



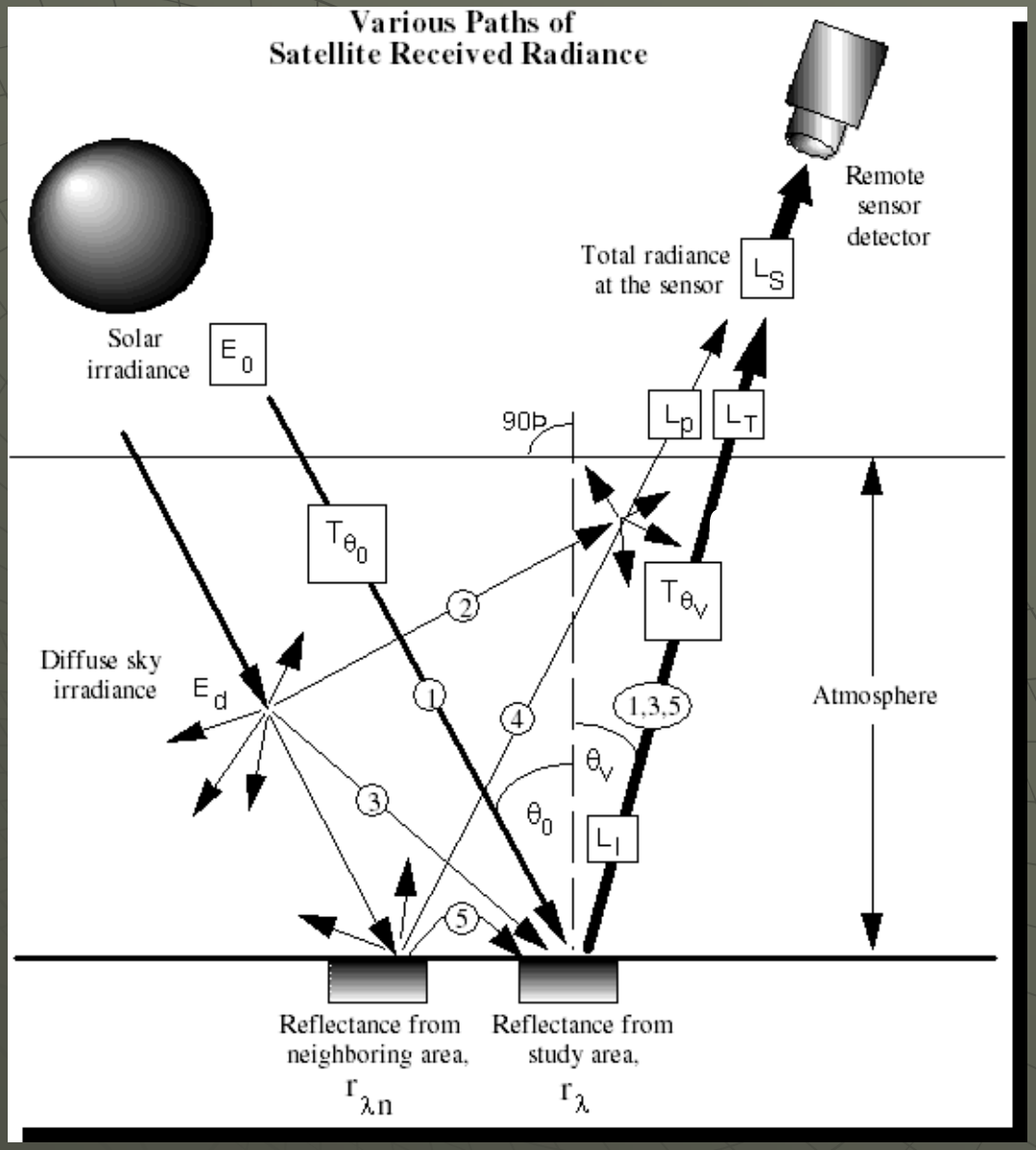
Vegetation Spectral Features



Spectra for different tree species



Observing through the atmosphere



Electromagnetic Radiation (EMR)

1 – EMR scattered & absorbed out of the illumination path

2 – EMR scattered into the observation path

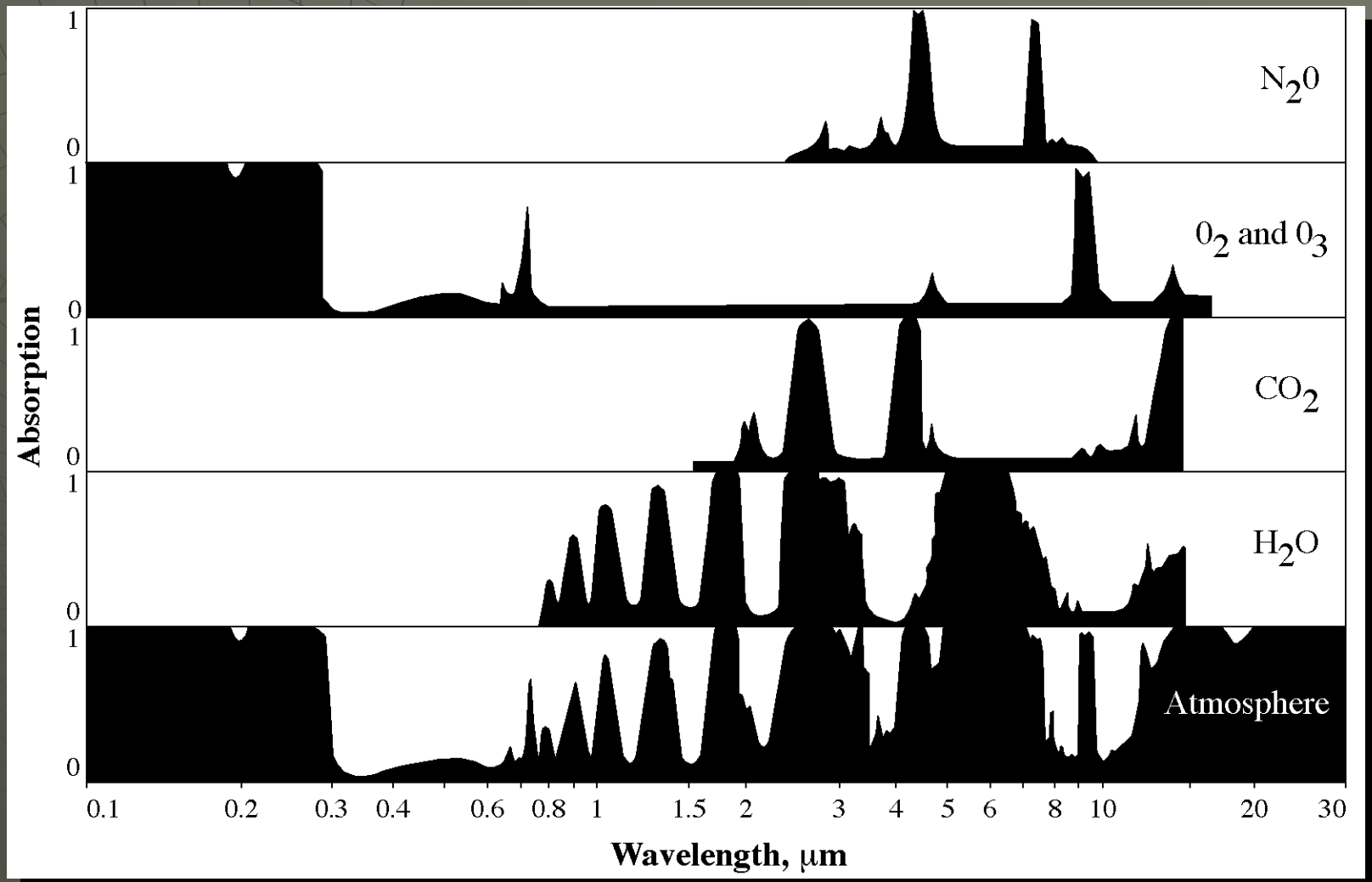
3 – EMR scattered into the illumination path

4 – EMR from adjacent area scattered into the observation path

5 – EMR from adjacent area scattered into the illumination path

6 – EMR scattered & absorbed out of the observation path

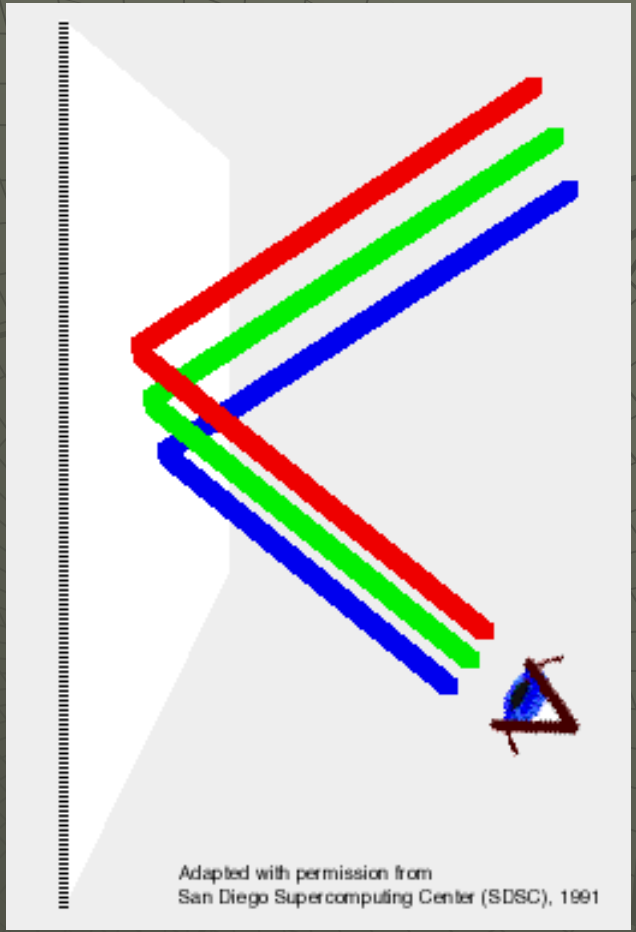
Observing through the atmosphere - absorption

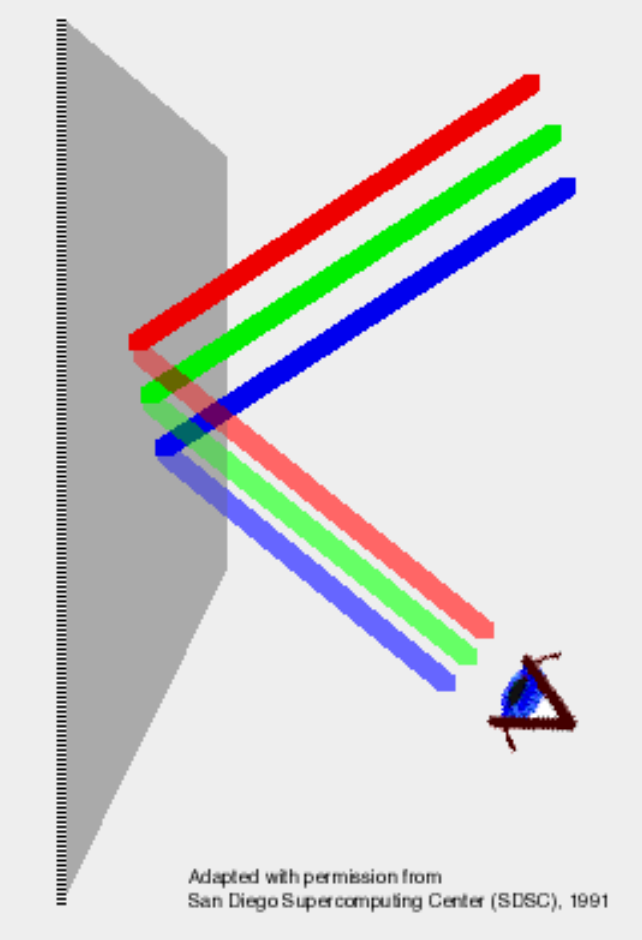


Detecting EMR

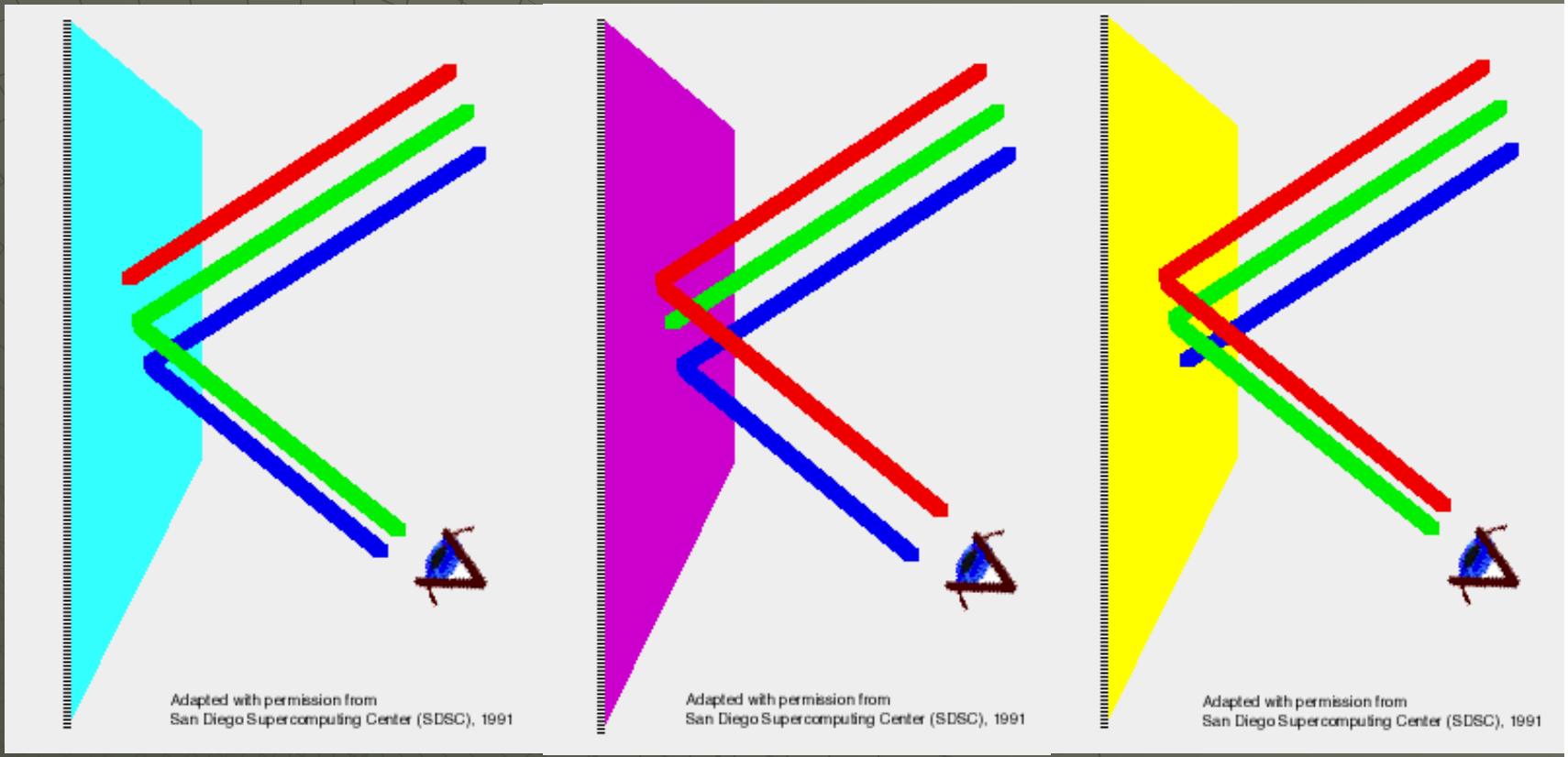
- Eyes
  - limited (by definition) to visible light
  - highly adaptable (focus, dynamic range, wide field)
  - connected to a brain that influences observations
    - optical illusions, etc.
- Cameras
  - Not limited to visible
  - Not as adaptable
  - More quantitative
  - Doesn’t complain sitting in cold space

Color Vision – Reflective RGB





Color Vision – Reflective RGB (CMY)



subtracting RGB components through absorption yields CMY components

What about non-visible "colors"?

red

green

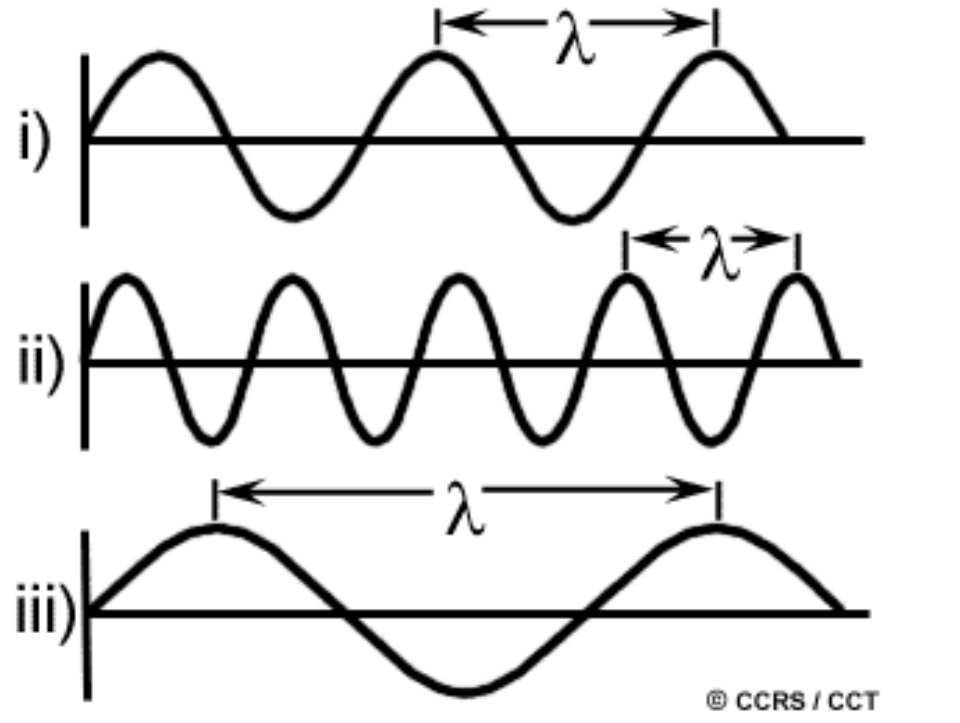
blue

near-infrared

"true color"
R = red
G = green
B = blue

"false color"
R = near IR
G = red
B = green

Color Infrared – “false color”

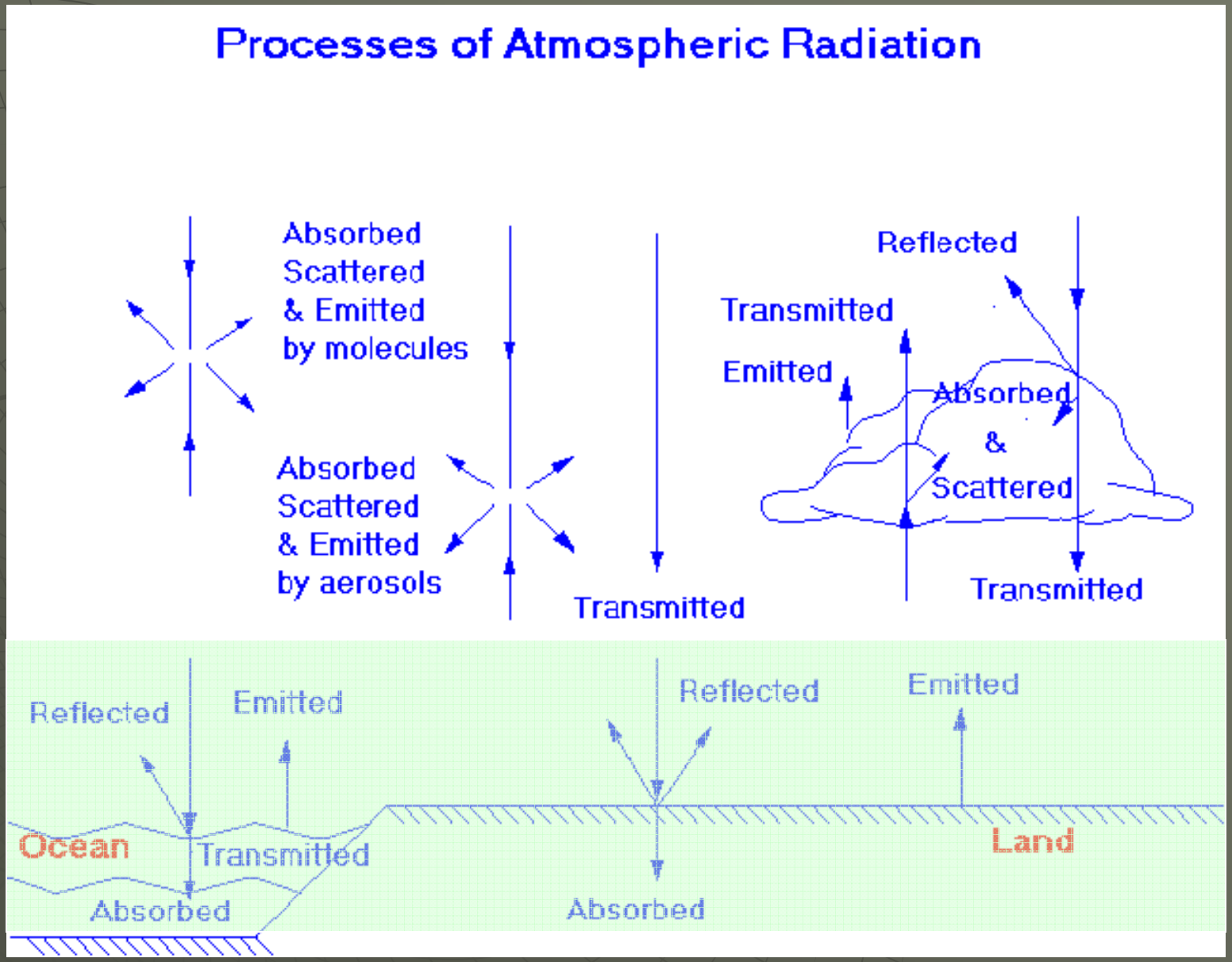


Wavelength and frequency are related by the following formula:

$$c = \lambda\nu$$

Where
c = speed of light (m s^{-1})
λ= wavelength (m)
ν = frequency s^{-1}

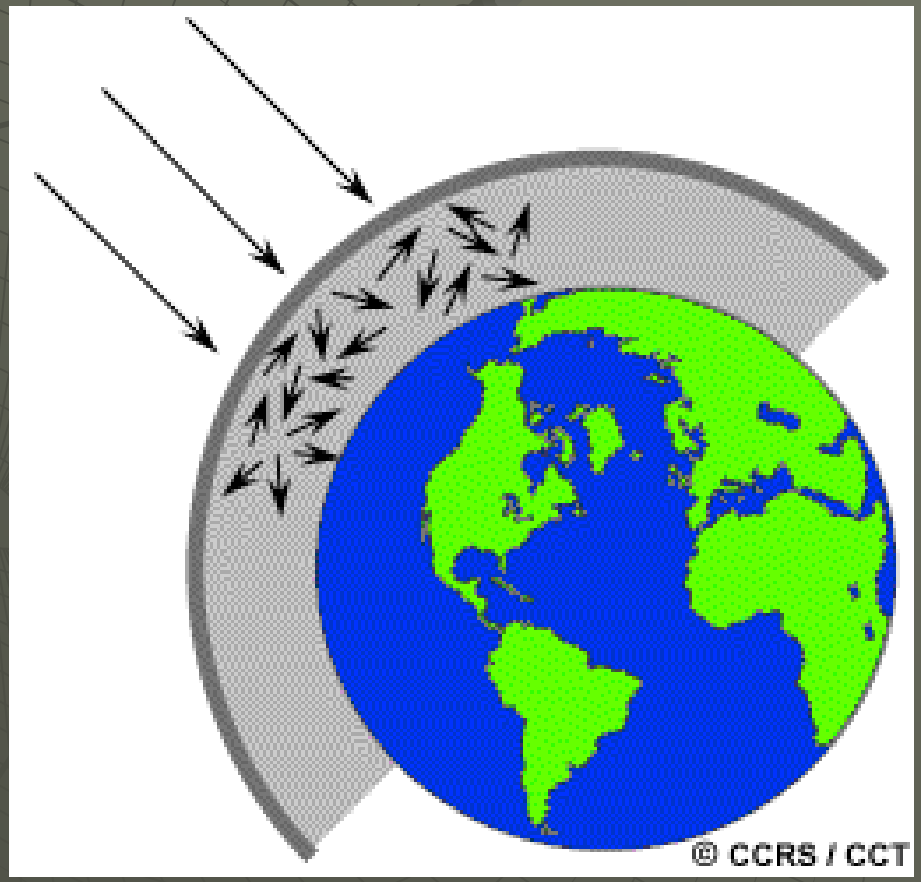
Radiation interactions with the atmosphere



Observing through the atmosphere - scattering

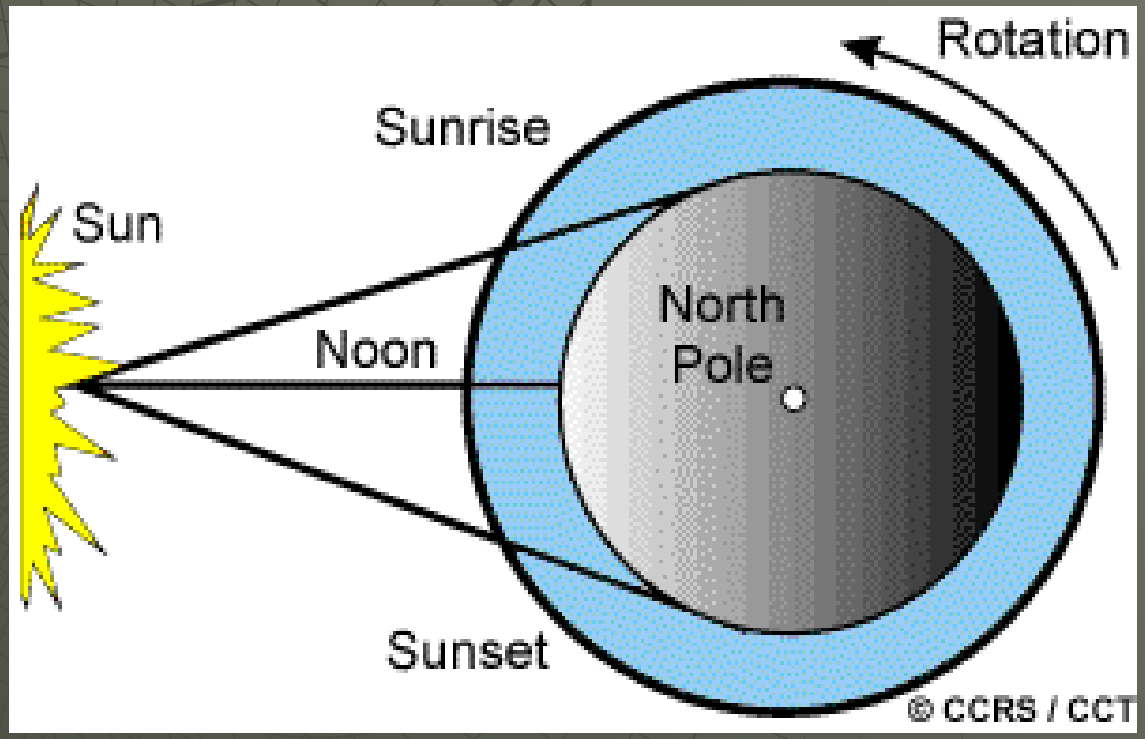
- Molecules and particles in the atmosphere scatter (transmit + reflect) light
  - scatters light out of a path (red sunsets)
    - with atmospheric absorption, this is called “extinction”
  - scatters light into a path (blue skies)
- Type of scatters
  - Rayleigh – due to molecules (small compared to wavelength)
    - much greater effect at shorter wavelengths
  - Mie – due to objects approximately the same size as the scattered EMR wavelength
  - Geometric Optics (or non-selective) – objects large compared to wavelength, like water DROPLETS – anything easily modeled using ray tracing or similar algorithms

Scattering: “depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere.”

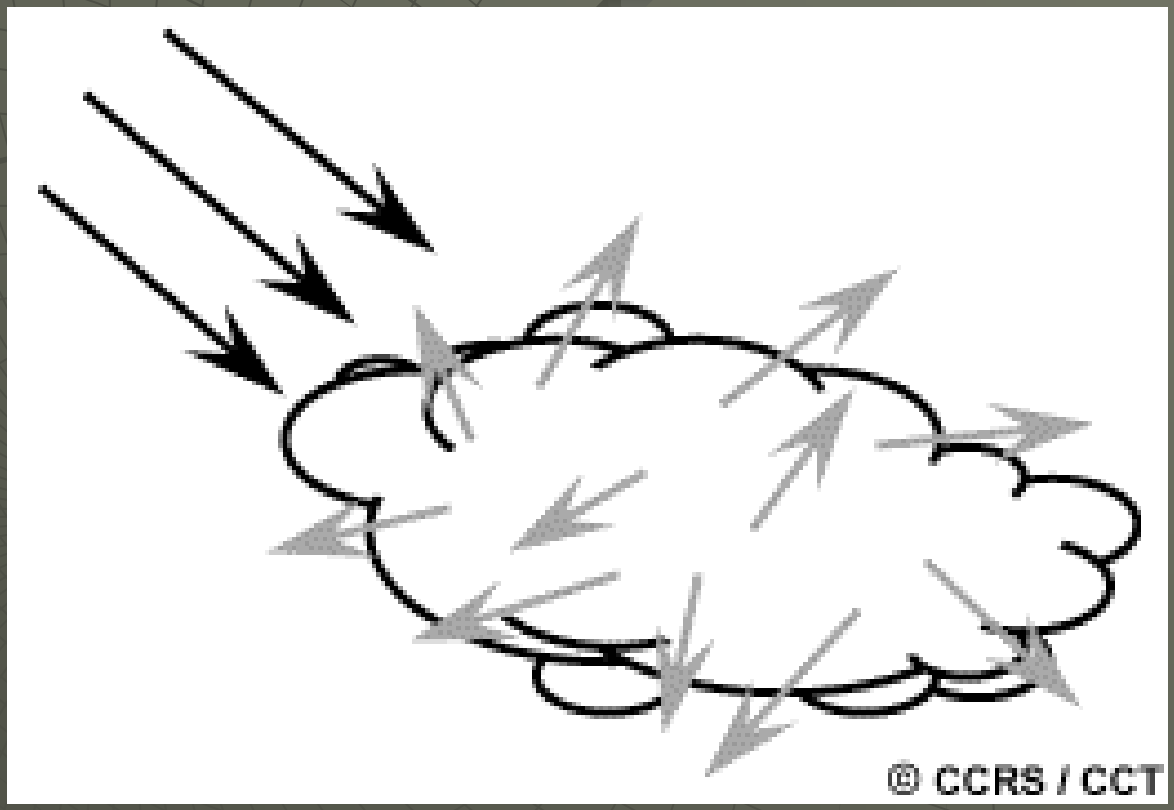


"Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation.

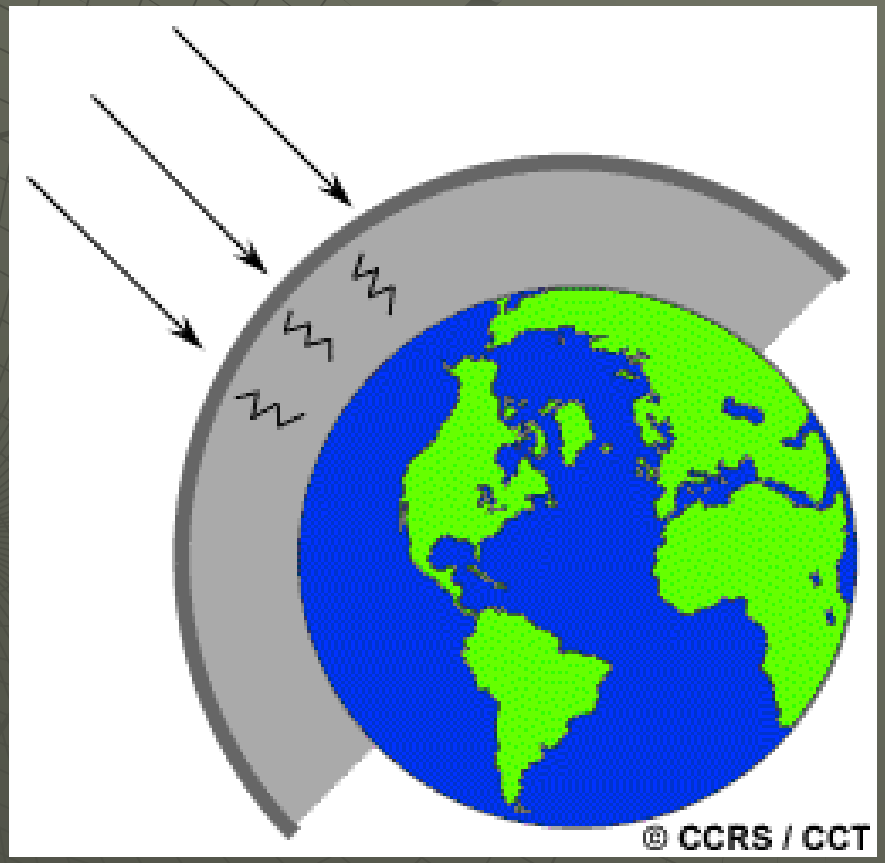
As sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At **sunrise and sunset** the light has to travel farther through the atmosphere than at midday and the scattering of the shorter wavelengths is more complete"



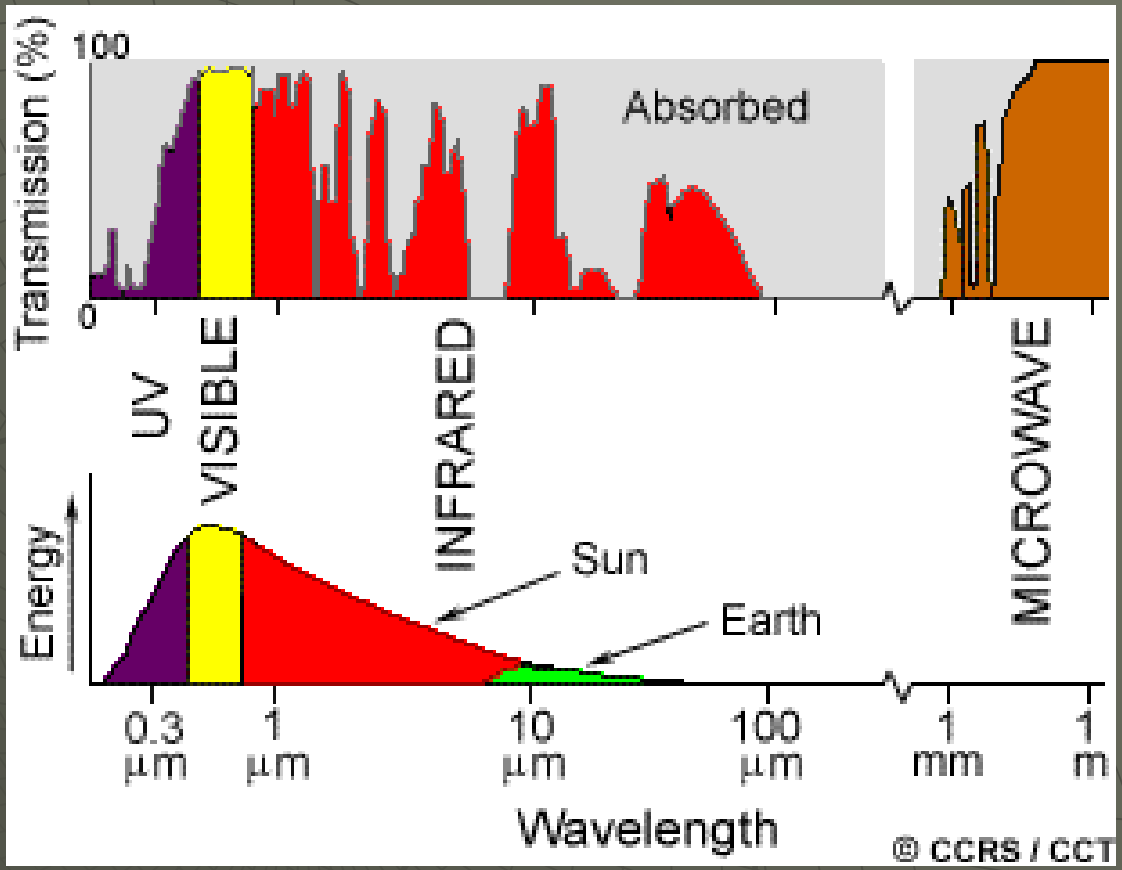
"**Mie scattering** occurs when the particles are just about the same size as the wavelength of the radiation."



"Absorption.. causes molecules in the atmosphere to absorb energy at various wavelengths." Ozone, Carbon Dioxide, and water vapor are primary atmospheric absorbers.

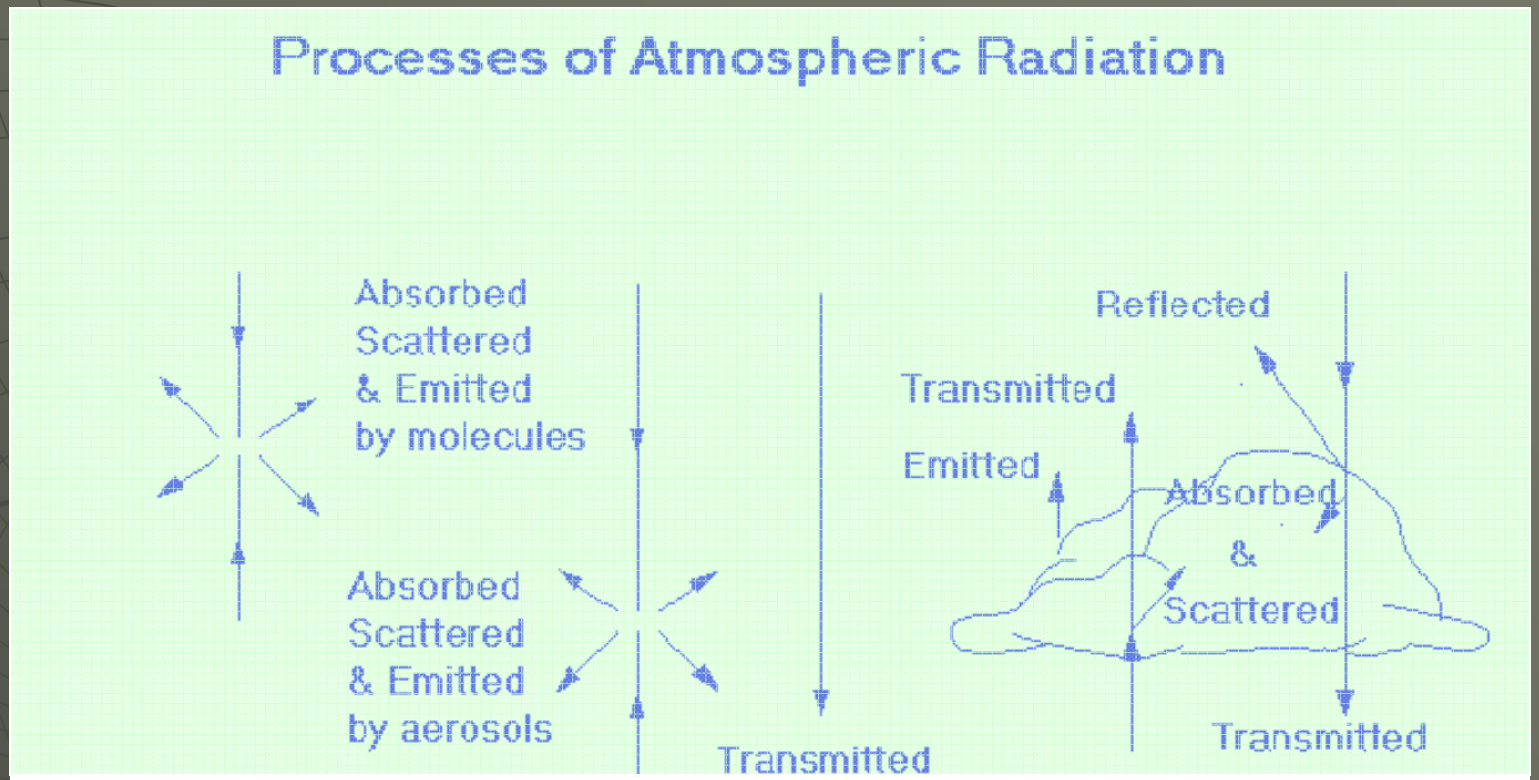


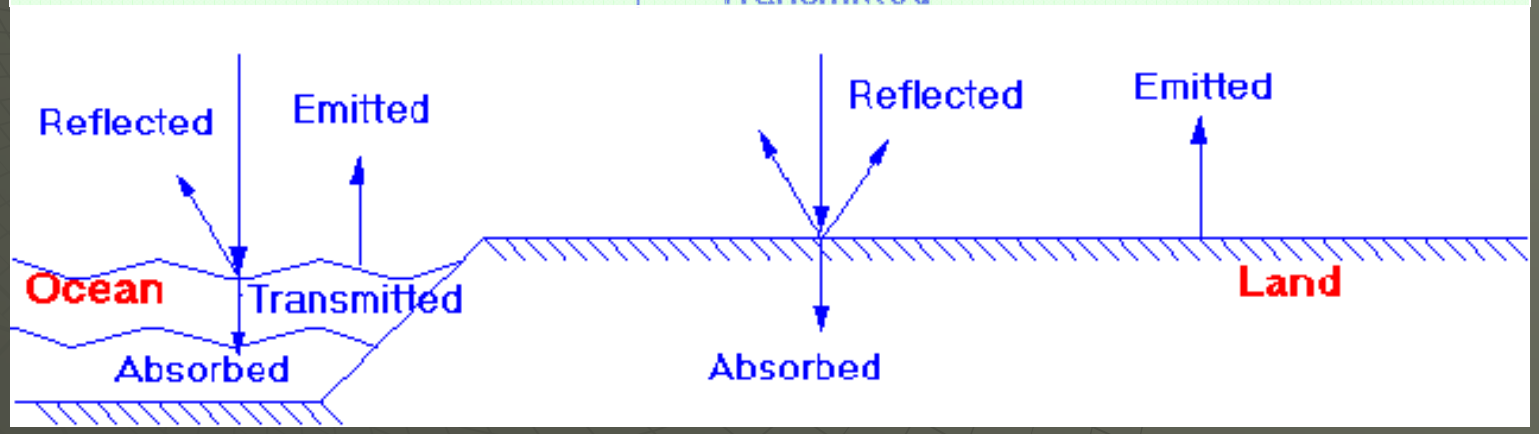
Atmospheric Windows



"Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors"

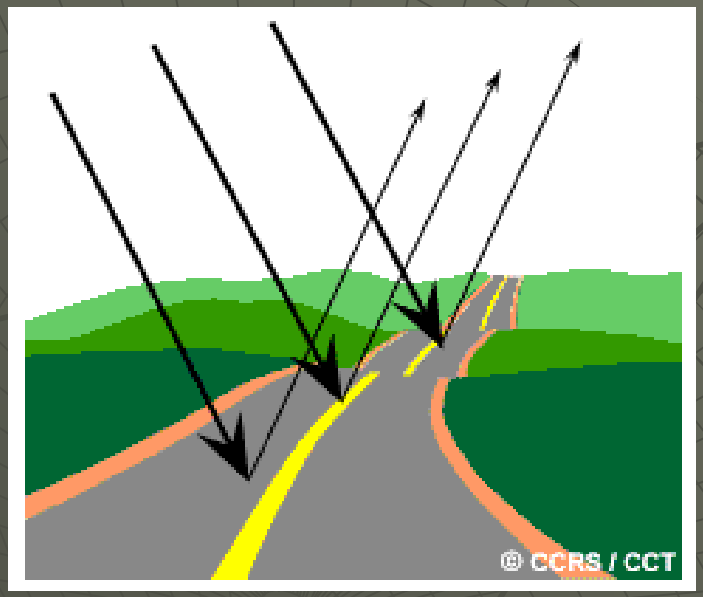
Radiation interactions with the surface



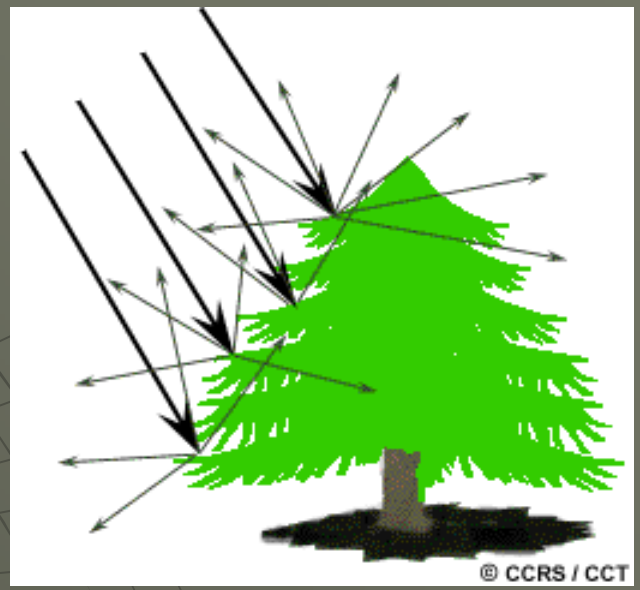


Energy incident (I) upon the surface is either **absorbed (A)**; **transmitted (T)**; and/or **reflected (R)**.

Reflectance Types



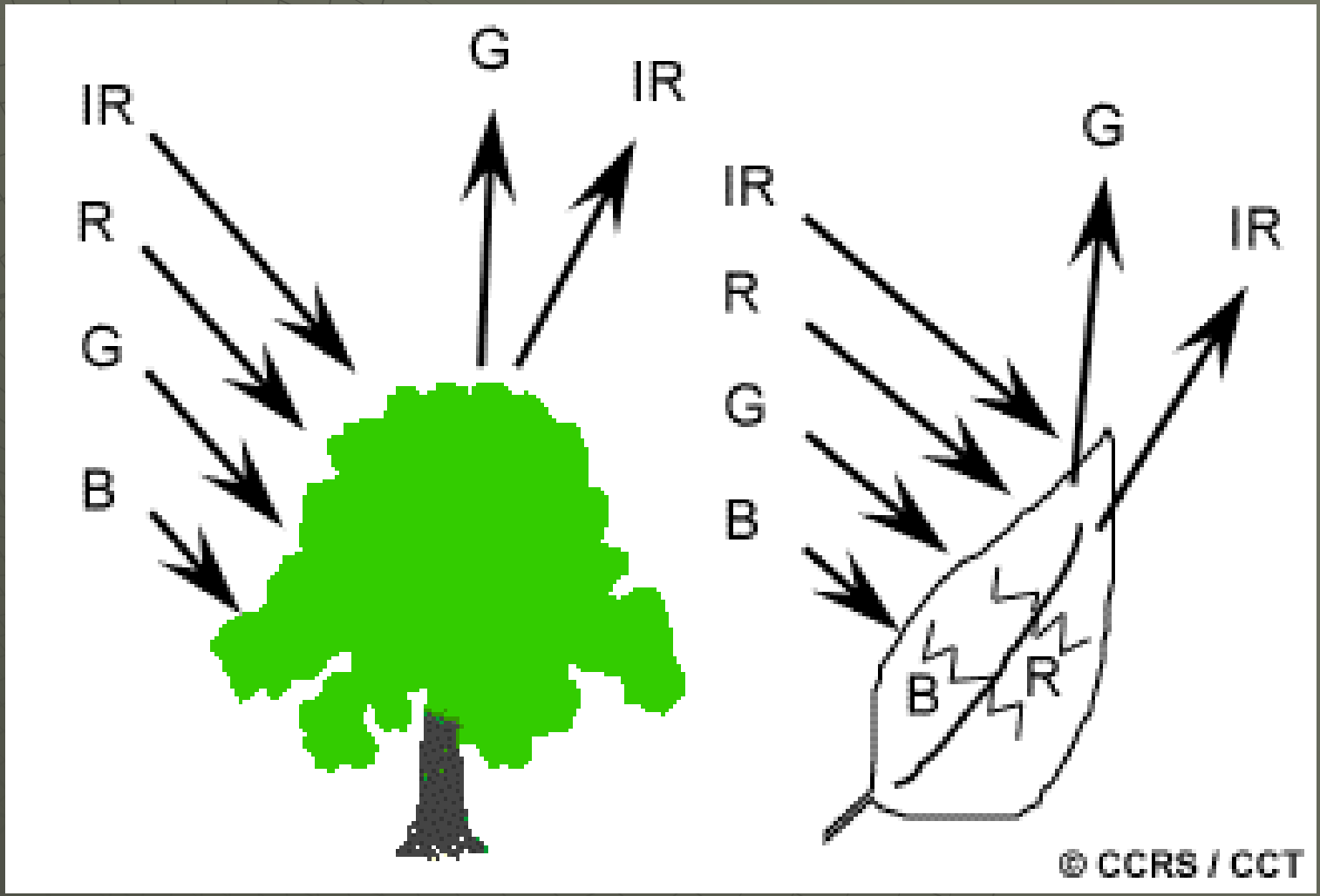
When surface is smooth we get **specular** reflectance.



When surface is rough we get **diffuse** reflectance.

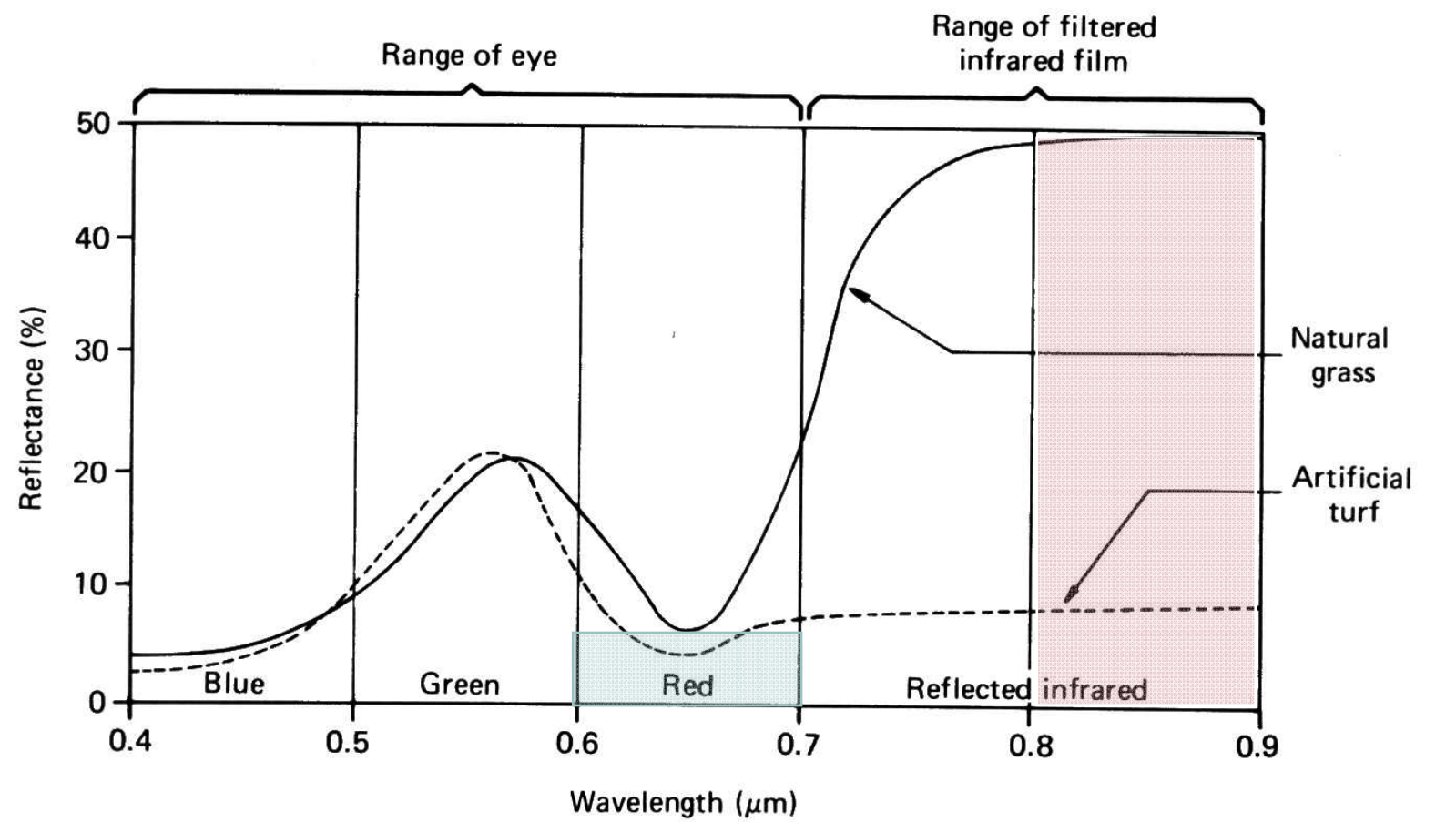
Radiation interactions with vegetation…

Note red and blue light *absorbed* by plant leaf.



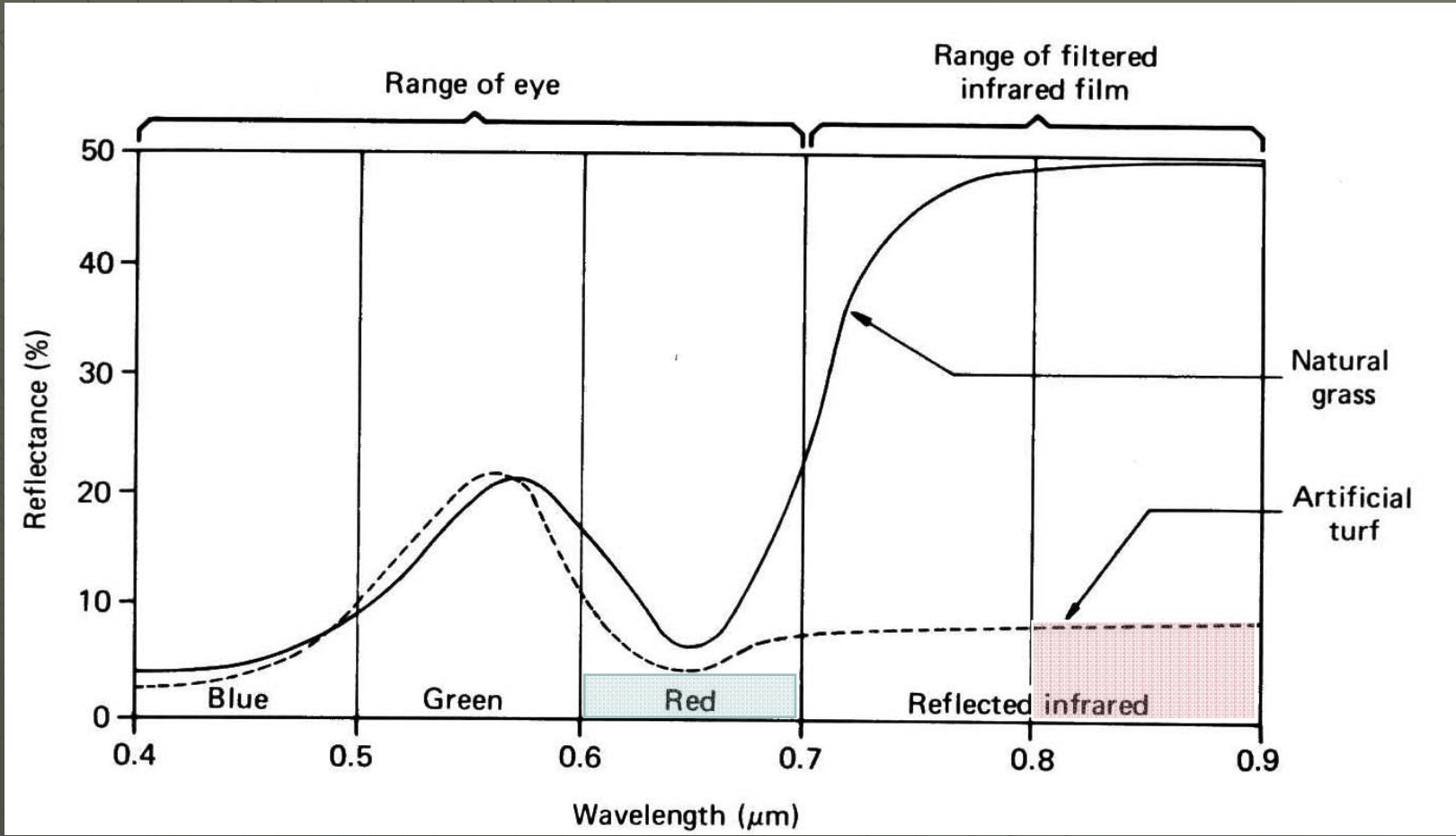
Normalized Difference Vegetation Index

NDVI = (Near IR – Red)/(Near IR + Red)
Range = -1 to +1
NDVI (grass = (50-5)/(50+5) = 0.82



Normalized Difference Vegetation Index

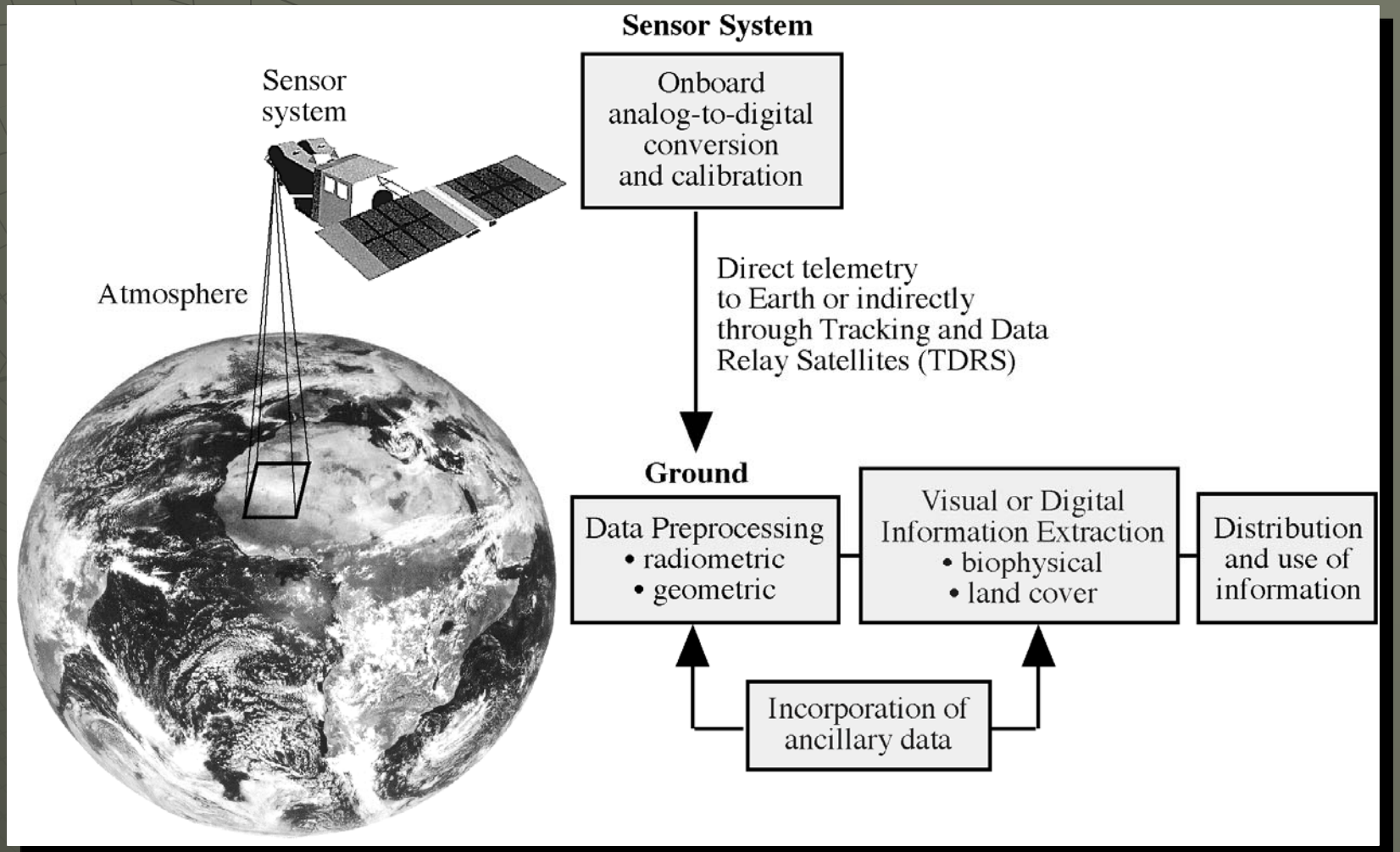
NDVI = (Near IR – Red)/(Near IR + Red)
NDVI (turf = (6-4)/(6+4) = 0.20)



Applications of Coarse to High Resolution Satellite Imagery for Land Productivity Assessment & Management

Plate II Oblique normal color **(a)** and color infrared **(b)** aerial photographs showing a portion of the University of Wisconsin-Madison campus, June 27, 1968, 11:00 A.M. The football field has artificial turf with low infrared reflectance. (For major discussion, see Section 2.9.)

Remote Sensing Processing Overview



Jensen, 2000