



NTOU

National Taiwan Ocean University

---

# *Principle of Remote Sensing*

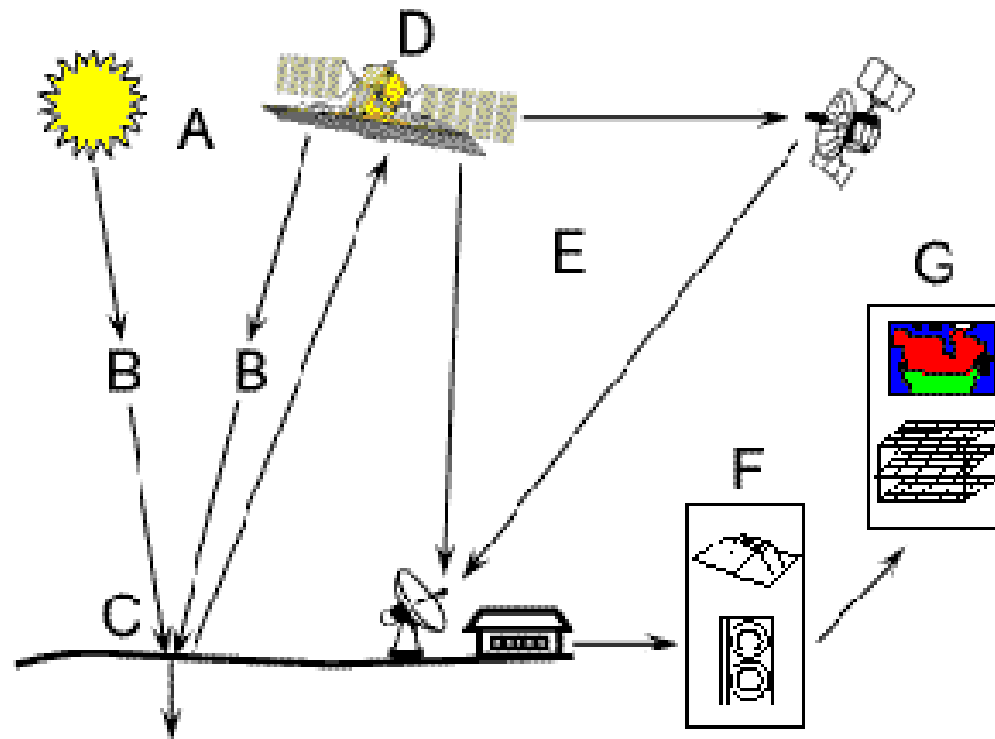
*Chung-Ru Ho*

*National Taiwan Ocean University  
Department of Marine Environmental Informatics  
Keelung, Chinese Taipei*

# What is Remote Sensing?

- *According to the definition of Canada Centre for Remote Sensing*
  - *Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.*

# Remote Sensing Process



© CCRS / CCT

# Remote Sensing Process

- Energy Source or Illumination (A) - the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
- Radiation and the Atmosphere (B) - as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.
- Interaction with the Target (C) - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
- Recording of Energy by the Sensor (D) - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

# Remote Sensing Process

- Transmission, Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).
- Interpretation and Analysis (F) - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.
- Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

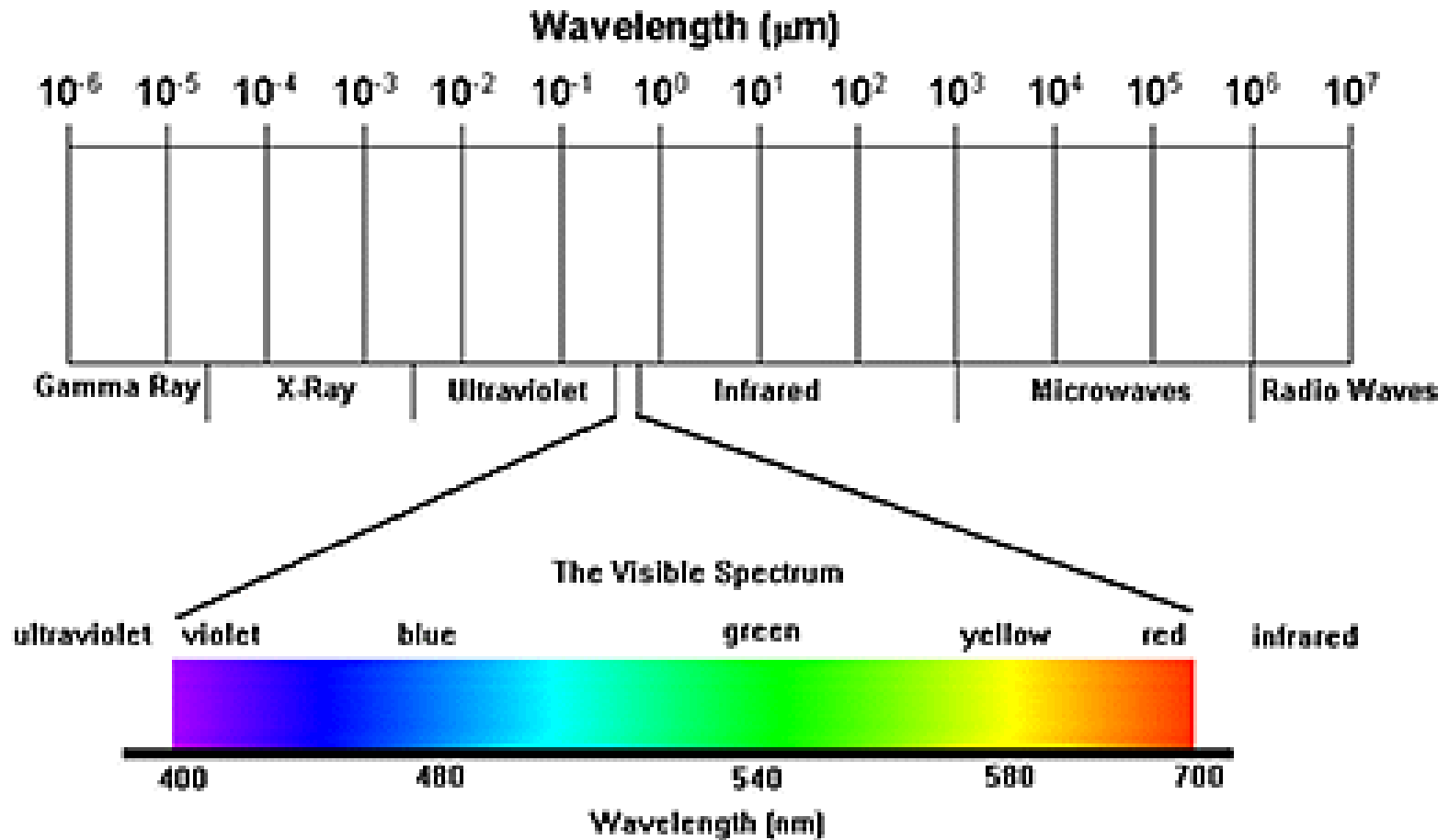
# Electromagnetic Waves

- Electromagnetic waves are energy transported through space in the form of periodic disturbances of electric and magnetic fields. All electromagnetic waves travel through space at the same speed,  $c = 2.99792458 \times 10^8$  m/s, commonly known as the **speed of light**. An electromagnetic wave is characterized by a **frequency** and a **wavelength**. These two quantities are related to the speed of light by the equation,
- **speed of light = frequency x wavelength ( $c = f \times \lambda$ )**
- The frequency (and hence, the wavelength) of an electromagnetic wave depends on its source. There is a wide range of frequency encountered in our physical world, ranging from the low frequency of the electric waves generated by the power transmission lines to the very high frequency of the gamma rays originating from the atomic nuclei. This wide frequency range of electromagnetic waves constitute the **Electromagnetic Spectrum**.

# Electromagnetic Spectrum

- The electromagnetic spectrum can be divided into several wavelength (frequency) regions, among which only a narrow band from about 400 to 700 nm is visible to the human eyes. Note that there is no sharp boundary between these regions. The boundaries shown in the above figures are approximate and there are overlaps between two adjacent regions.
- **Wavelength units: 1 mm = 1000  $\mu\text{m}$ ; 1  $\mu\text{m}$  = 1000 nm.**

# Electromagnetic Spectrum





# Electromagnetic Spectrum

- **Microwaves:** 1 mm to 1 m wavelength. The microwaves are further divided into different frequency (wavelength) bands: (1 GHz =  $10^9$  Hz)
  - **P band:** 0.3 - 1 GHz (30 - 100 cm)
  - **L band:** 1 - 2 GHz (15 - 30 cm)
  - **S band:** 2 - 4 GHz (7.5 - 15 cm)
  - **C band:** 4 - 8 GHz (3.8 - 7.5 cm)
  - **X band:** 8 - 12.5 GHz (2.4 - 3.8 cm)
  - **Ku band:** 12.5 - 18 GHz (1.7 - 2.4 cm)
  - **K band:** 18 - 26.5 GHz (1.1 - 1.7 cm)
  - **Ka band:** 26.5 - 40 GHz (0.75 - 1.1 cm)

# Electromagnetic Spectrum

- **Infrared:** 0.7 to 300  $\mu\text{m}$  wavelength. This region is further divided into the following bands:
  - **Near Infrared (NIR):** 0.7 to 1.5  $\mu\text{m}$ .
  - **Short Wavelength Infrared (SWIR):** 1.5 to 3  $\mu\text{m}$ .
  - **Mid Wavelength Infrared (MWIR):** 3 to 8  $\mu\text{m}$ .
  - **Long Wavelength Infrared (LWIR):** 8 to 15  $\mu\text{m}$ .
  - **Far Infrared (FIR):** longer than 15  $\mu\text{m}$ .
- The NIR and SWIR are also known as the **Reflected Infrared**, referring to the main infrared component of the solar radiation reflected from the earth's surface. The MWIR and LWIR are the **Thermal Infrared**.

# Electromagnetic Spectrum

- **Visible Light:** This narrow band of electromagnetic radiation extends from about 400 nm (violet) to about 700 nm (red). The various color components of the visible spectrum fall roughly within the following wavelength regions:
  - **Red:** 610 - 700 nm
  - **Orange:** 590 - 610 nm
  - **Yellow:** 570 - 590 nm
  - **Green:** 500 - 570 nm
  - **Blue:** 450 - 500 nm
  - **Indigo:** 430 - 450 nm
  - **Violet:** 400 - 430 nm
- **Ultraviolet:** 3 to 400 nm
- **X-Rays and Gamma Rays**

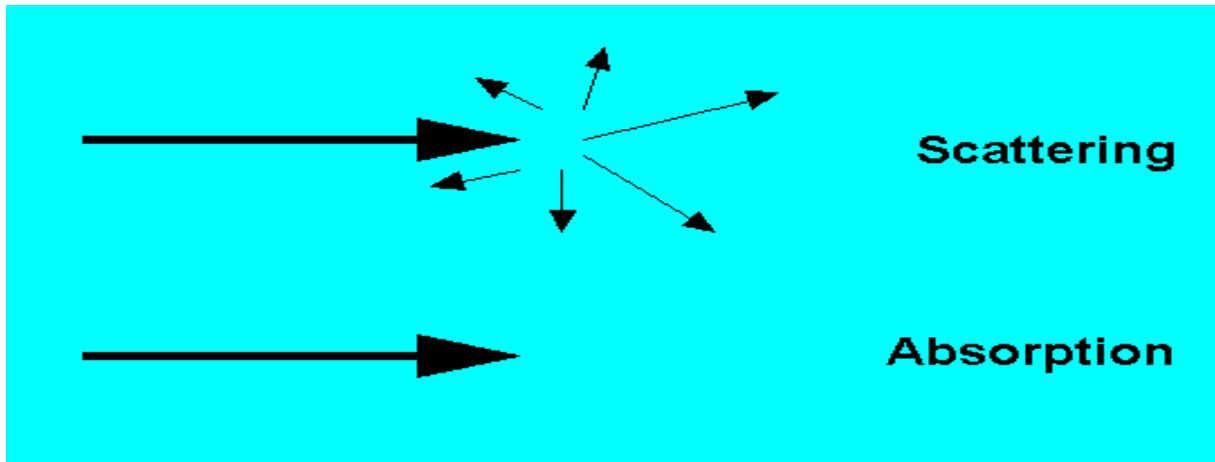
# Photons

- According to quantum physics, the energy of an electromagnetic wave is quantized, i.e. it can only exist in discrete amount. The basic unit of energy for an electromagnetic wave is called a **photon**. The energy  $Q$  of a photon is proportional to the wave frequency  $f$ ,

$$Q = h f$$

where the constant of proportionality  $h$  is the **Planck's Constant**,  $h = 6.626 \times 10^{-34}$  J s.

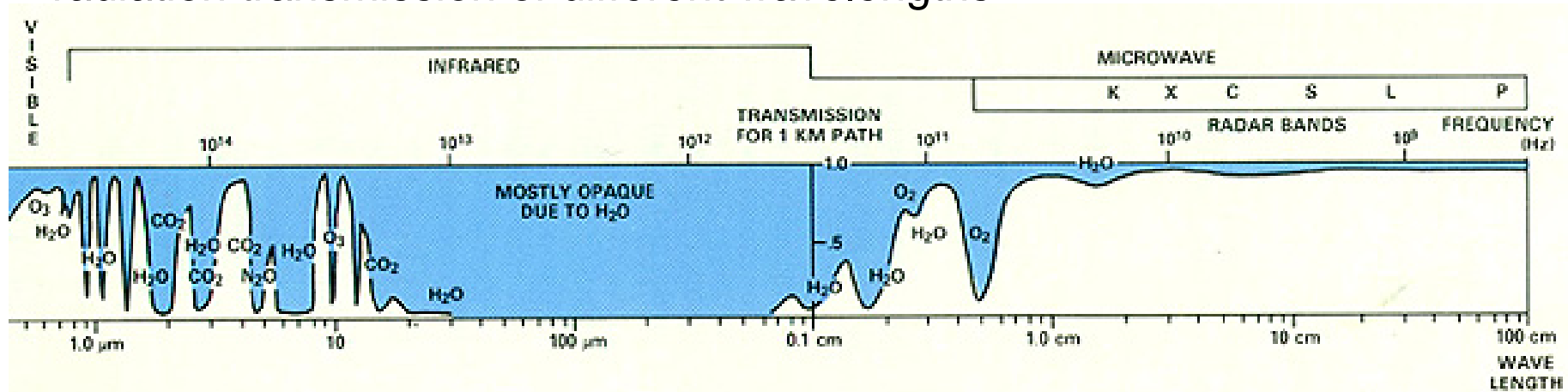
# Atmospheric Effects



When electromagnetic radiation travels through the atmosphere, it may be **absorbed** or **scattered** by the constituent particles of the atmosphere. Molecular absorption converts the radiation energy into excitation energy of the molecules. Scattering redistributes the energy of the incident beam to all directions. The overall effect is the removal of energy from the incident radiation.

# Atmospheric Window

Most remote sensing is conducted above the Earth either within or above the atmosphere. The gases in the atmosphere interact with solar irradiation and with radiation from the Earth's surface. The atmosphere itself is excited by EMR so as to become another source of released photons. Here is a generalized diagram showing relative atmospheric radiation transmission of different wavelengths.

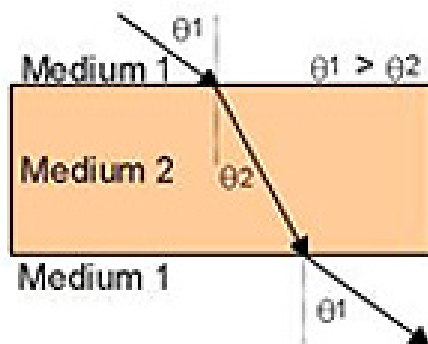


Blue zones (absorption bands) mark minimal passage of incoming and/or outgoing radiation, whereas, white areas (transmission peaks) denote atmospheric windows, in which the radiation doesn't interact much with air molecules and hence, isn't absorbed.

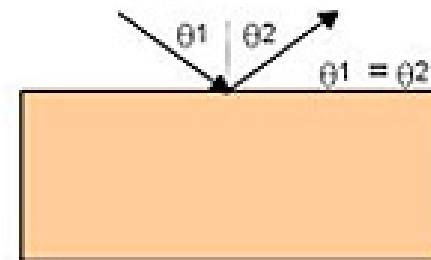
# Interaction with Target

Any beam of photons from some source passing through medium 1 (usually air) that impinges upon an object or target (medium 2) will experience one or more reactions.

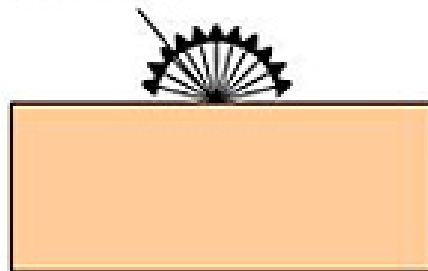
Transmission



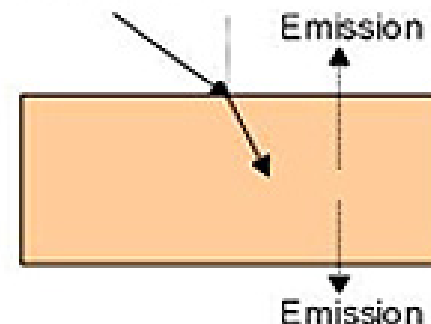
Reflection



Scattering

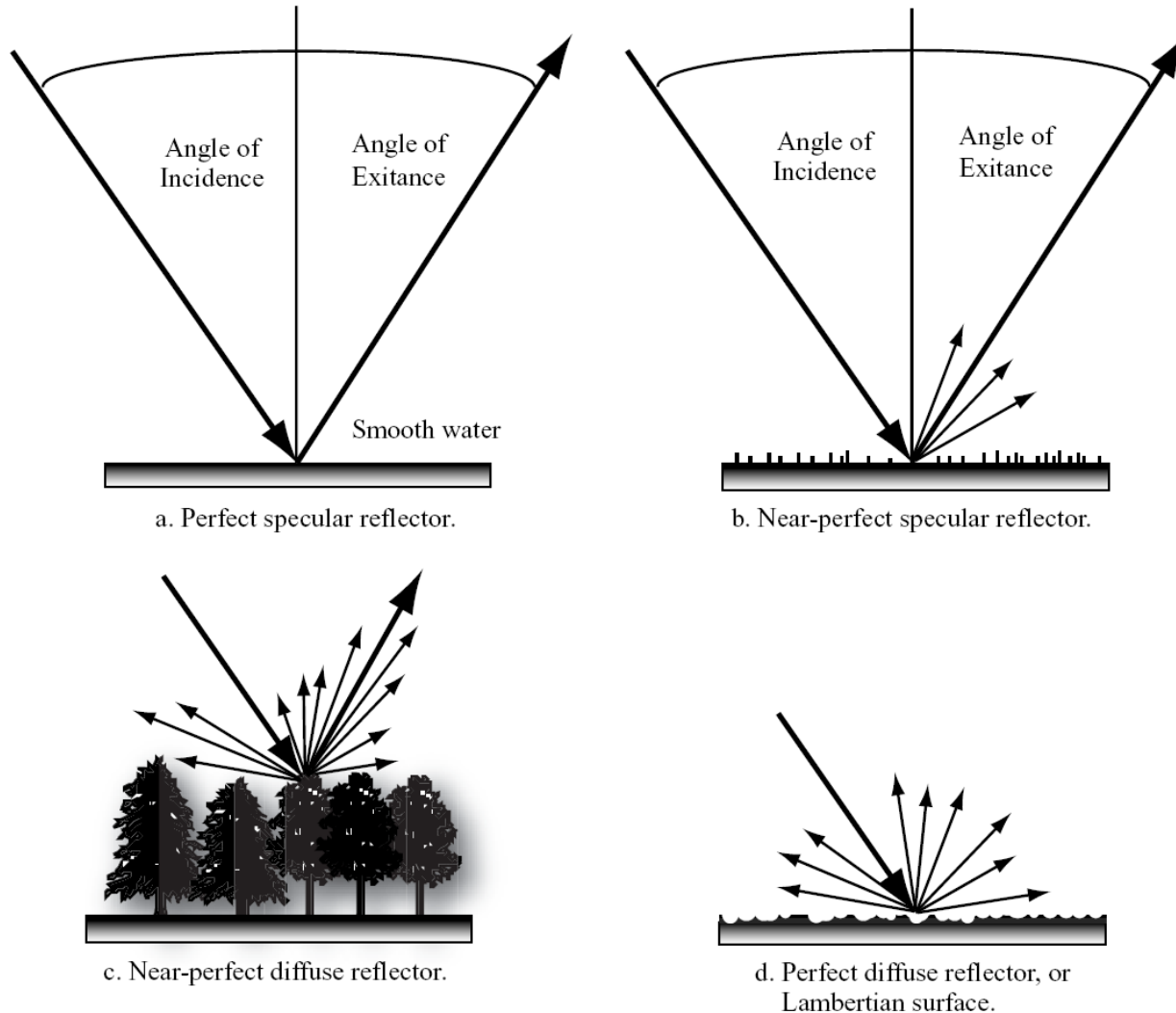


Absorption



# Interaction with Target

## Specular versus Diffuse Reflectance





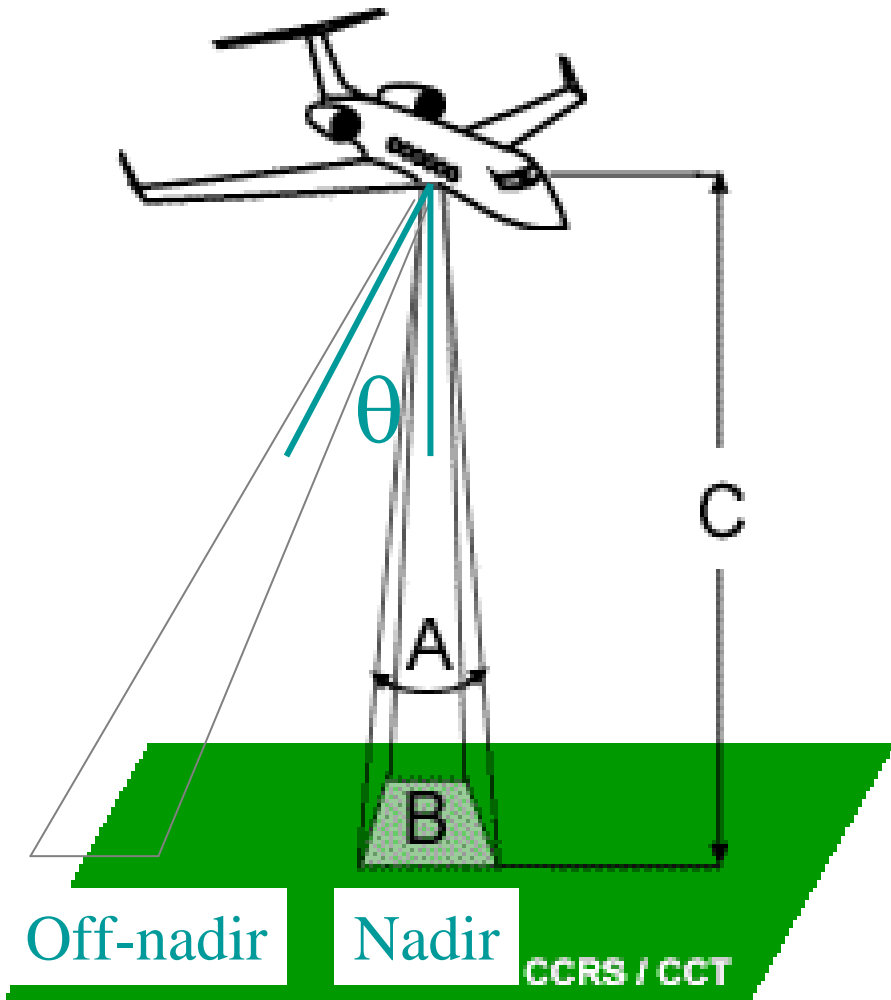
# Sensor Characteristics

- Sensed: Active vs. Passive
- Angle: Nadir vs. Off-nadir
- Motion: Scanning vs. Non-scanning
- Type: Imaging vs. Non-imaging

# Active vs. Passive

- Passive sensors detect naturally produced radiation (by the sun, earth, or atmosphere)
  - Emitted – thermal infrared, passive microwave
  - Reflected (solar) – visible, near infrared
- Active sensors produce their own radiation and detect reflection or backscatter
  - Lasers (visible)
  - Radars (microwave)
  - Altimeters (visible or microwave)

# Nadir vs. Off-nadir



Off-nadir viewing results in a larger IFOV  $\rightarrow$  lower spatial resolution.

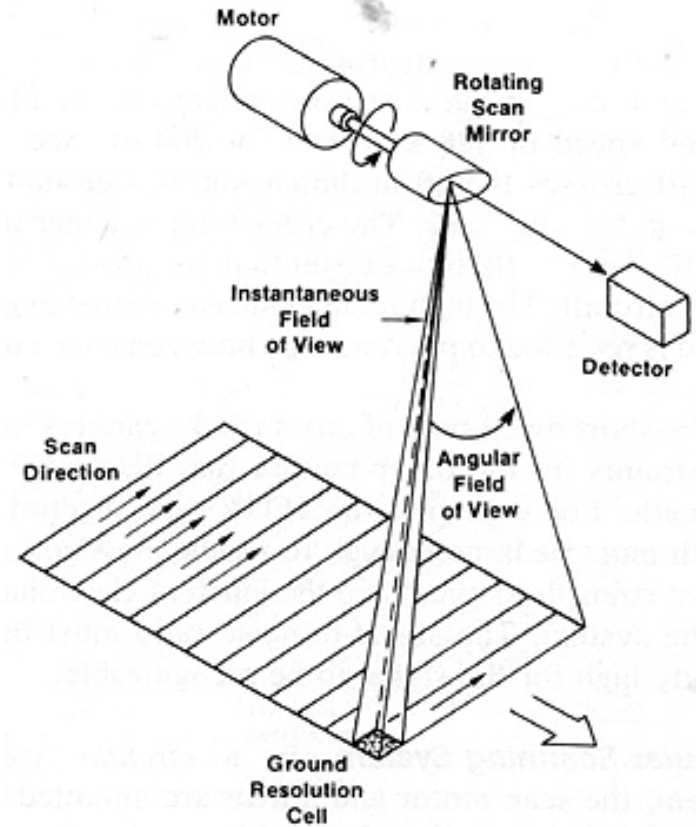
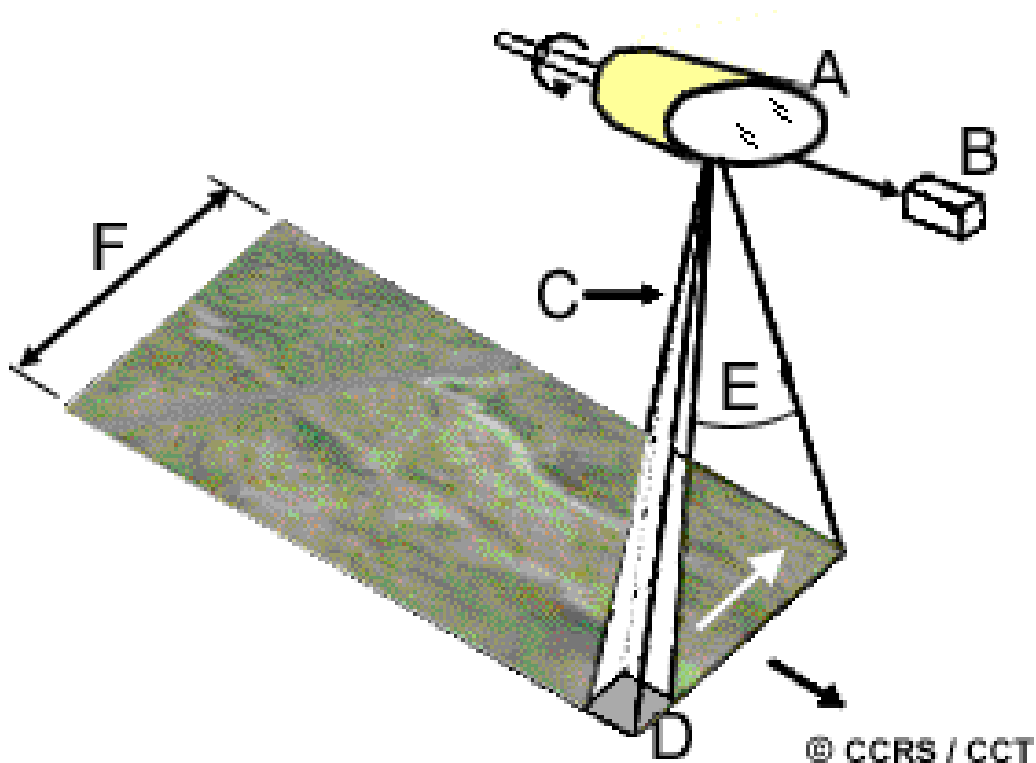
$\theta$  = sensor angle (or “view angle” or “look angle”)

$\theta = 0$  for nadir (directly above surface)

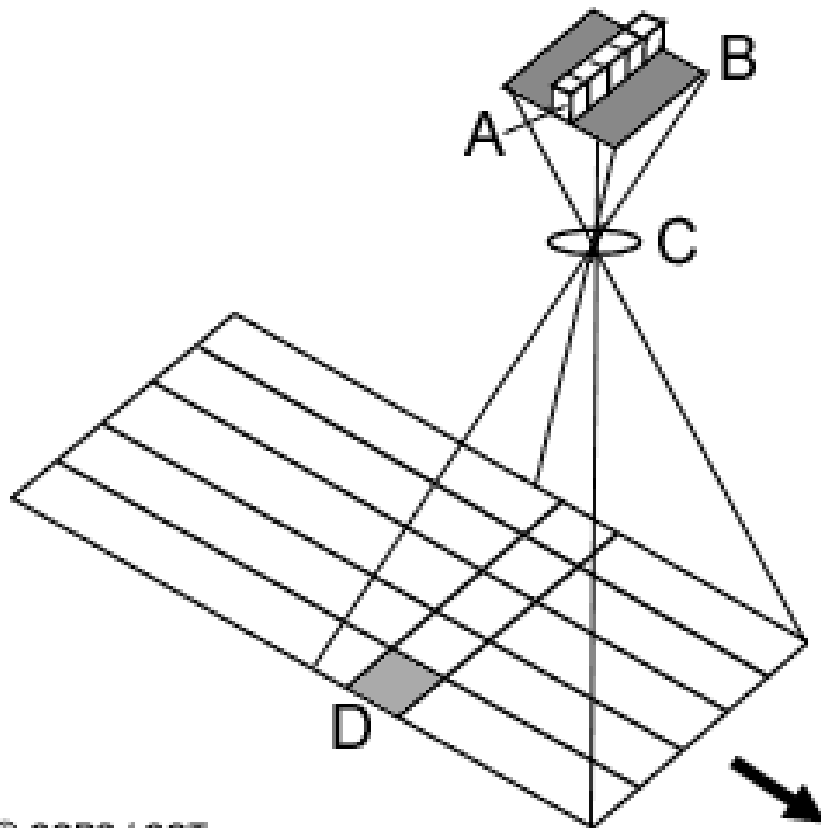
# Scanning vs. Framing

- Framing (non-scanning) instruments sense at a specific, constant sensor angle
  - Instantaneously measures radiation from entire scene all at once
- Scanning instruments sense at variable angles – sweep across a range of angles
  - Scans point-by-point across scene
  - For scanning instruments, swath width (and hence revisit period) are a function of the range of sensor angles

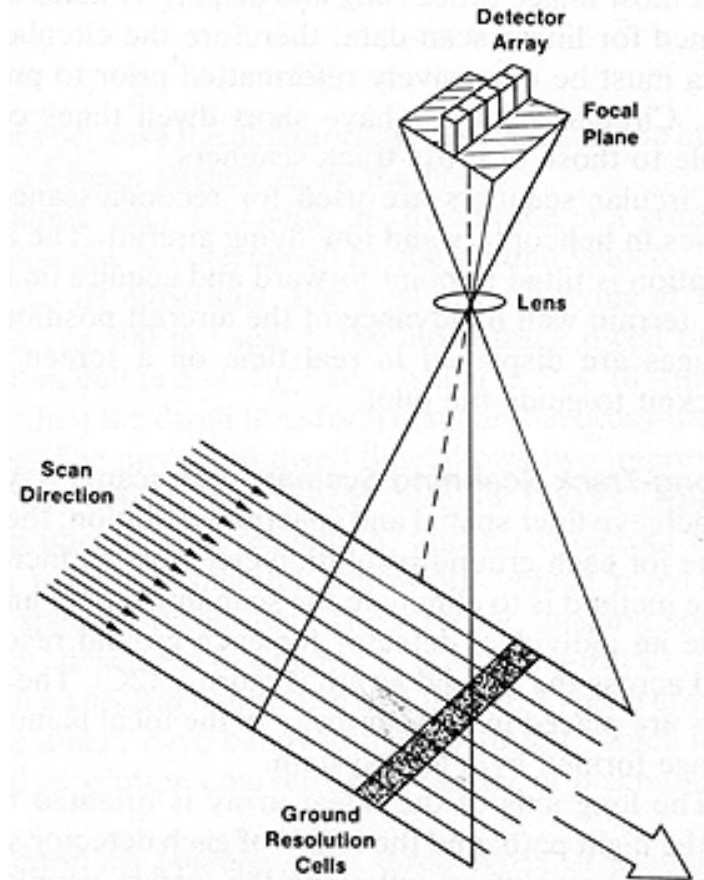
# Cross-Track Scanners



# Along-Track Scanners (Pushbroom)



© CCRS / CCT



# Imaging vs. Non-imaging

- Imaging
  - Photons impinge onto a sensitive surface
    - film negative (cameras)
    - cathode ray tube (tv),
    - charged coupled device (CCD) (digital cameras)
- Non-imaging
  - Measures EMR from all points in IFOV and integrates to get one value, based on signal strength
    - sea surface height
    - sea surface wind

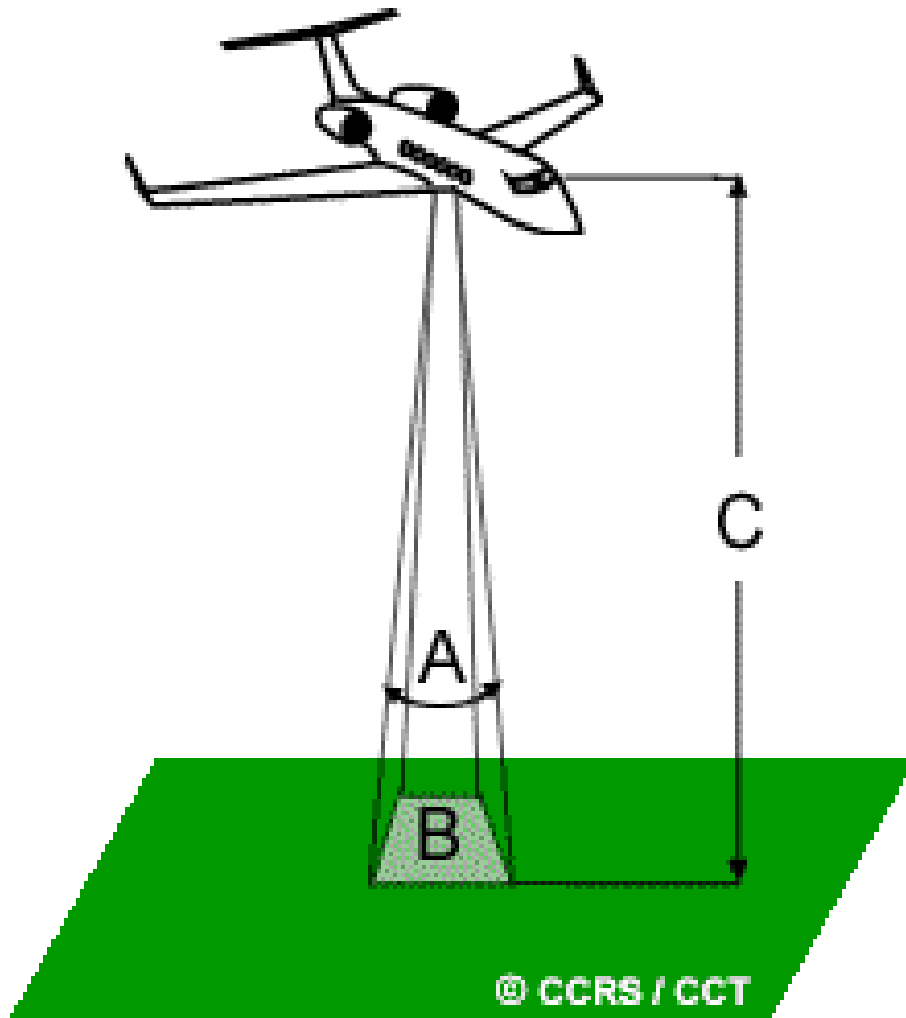
# Sensor Resolutions

- Spatial - the size of the instantaneous 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).
- Radiometric - the sensitivity of detectors to small differences in electromagnetic energy.
- Temporal - how often the sensor acquires data, e.g. every 30 days.

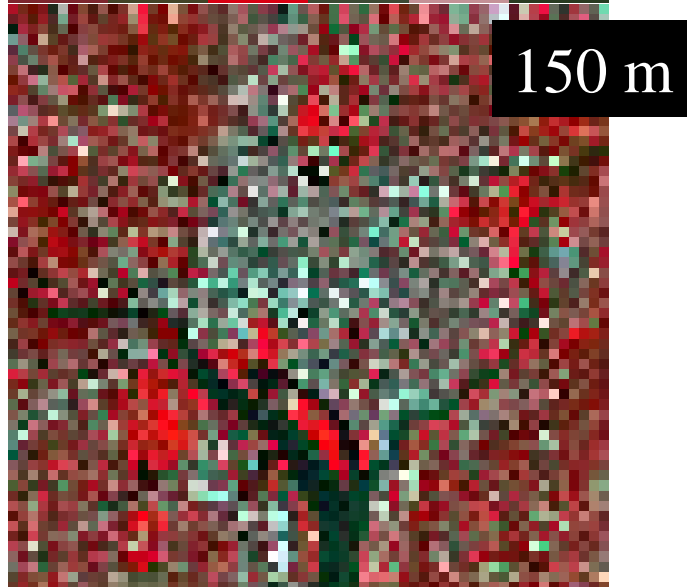
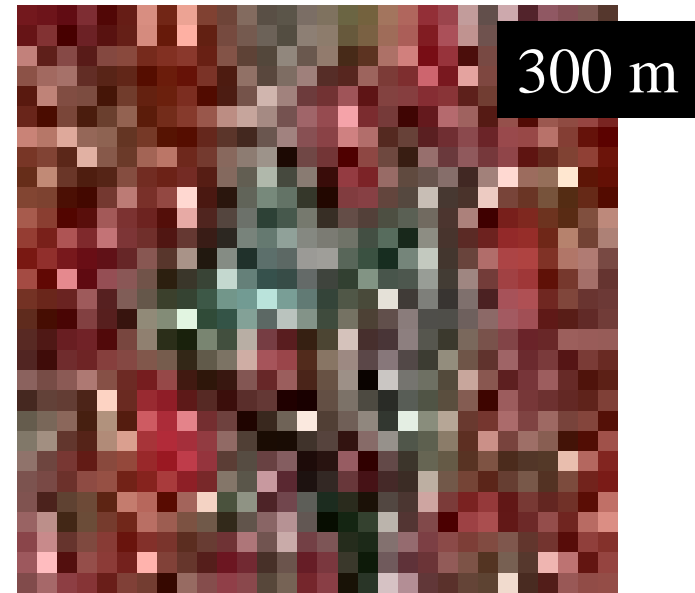
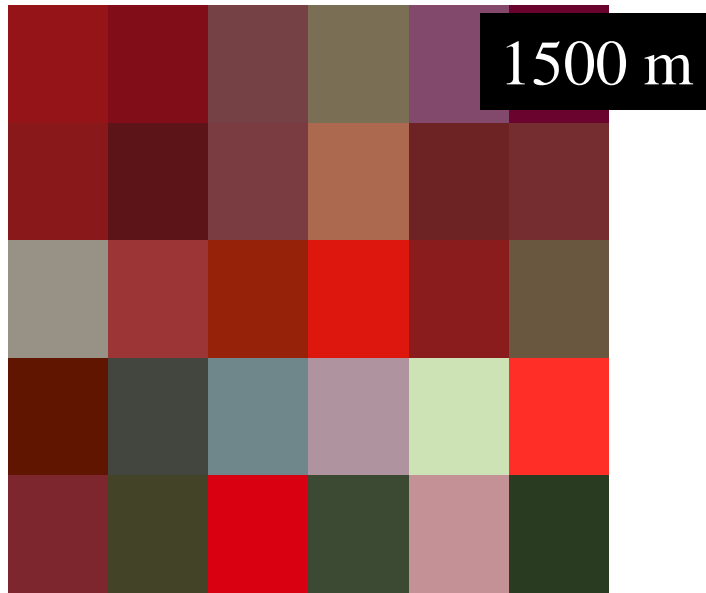


# Sensor Resolutions

Instantaneous  
Field of View



# Spatial Resolution



## Imagery of Harbor Town in Hilton Head, SC, at Various Nominal Spatial Resolutions

# Spatial Resolution



a. 0.5 x 0.5 m.



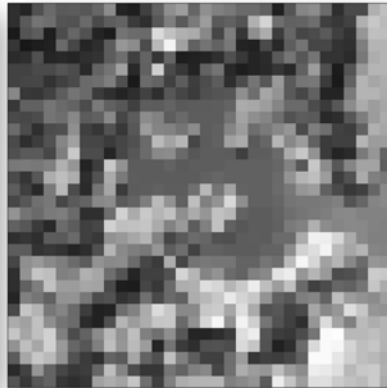
b. 1 x 1 m.



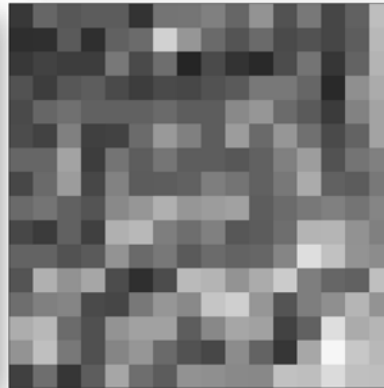
c. 2.5 x 2.5 m.



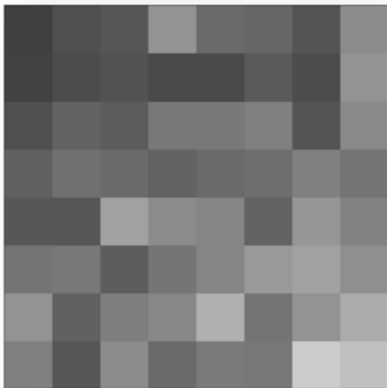
d. 5 x 5 m.



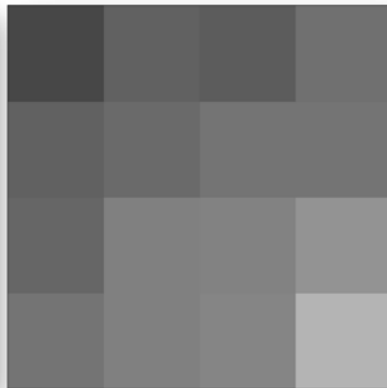
e. 10 x 10 m.



f. 20 x 20 m.

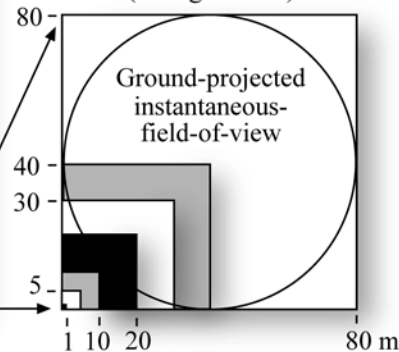


g. 40 x 40 m.



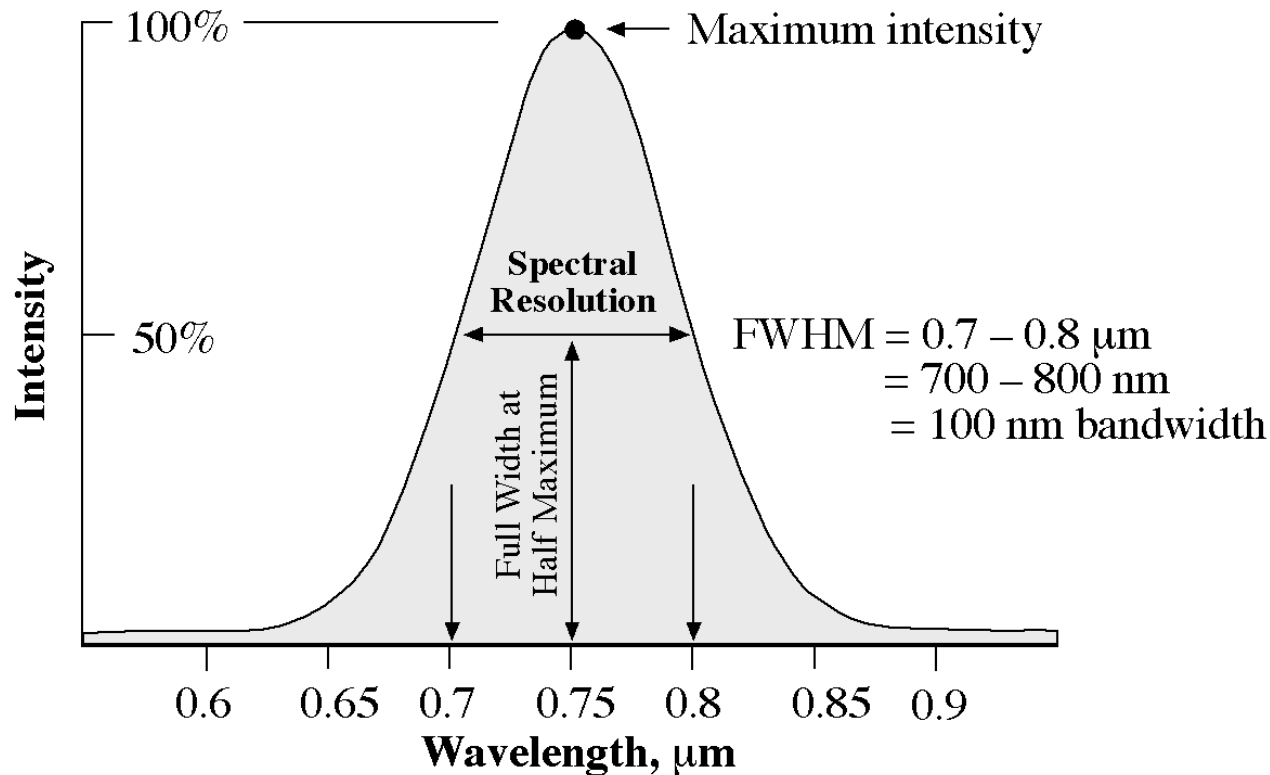
h. 80 x 80 m.

**Nominal Spatial Resolution**  
(enlarged view)

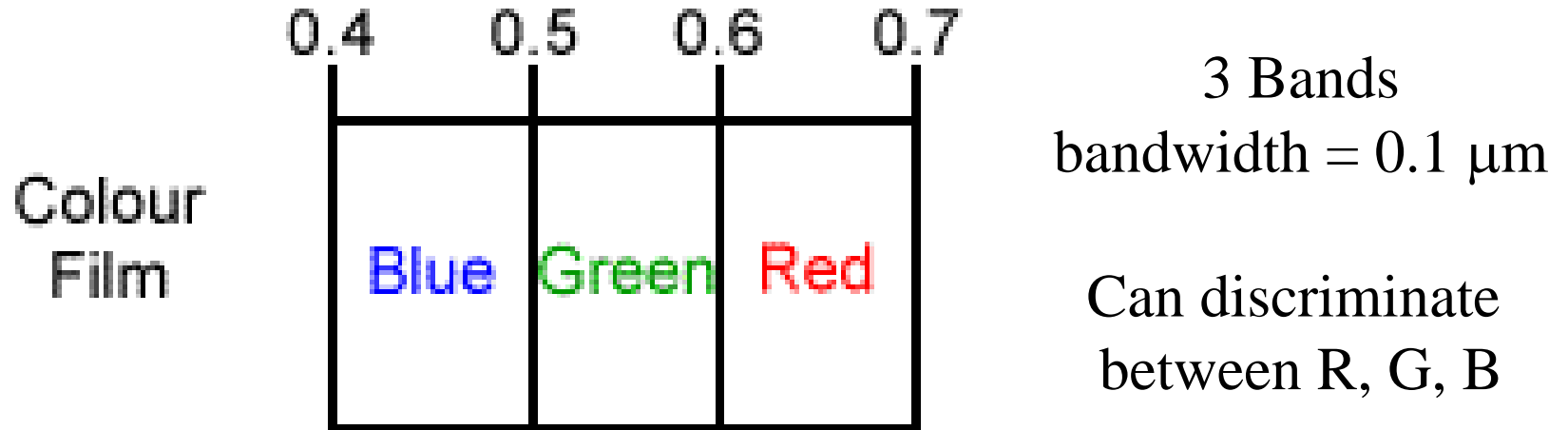
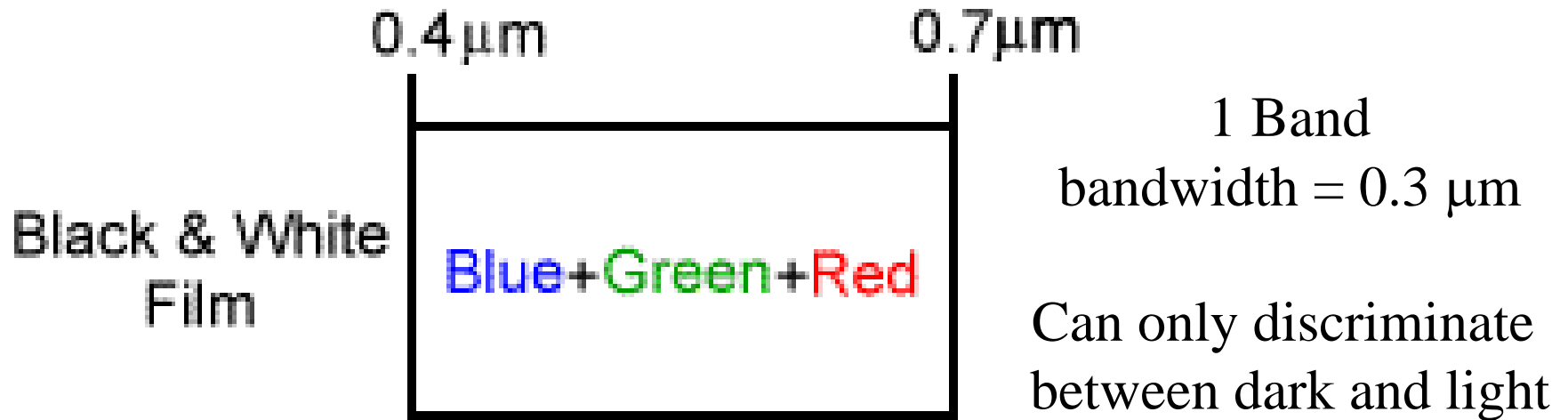


# Spectral Resolution - Bandwidth

The usual method of specifying spectral bandwidth is the full width at half maximum.

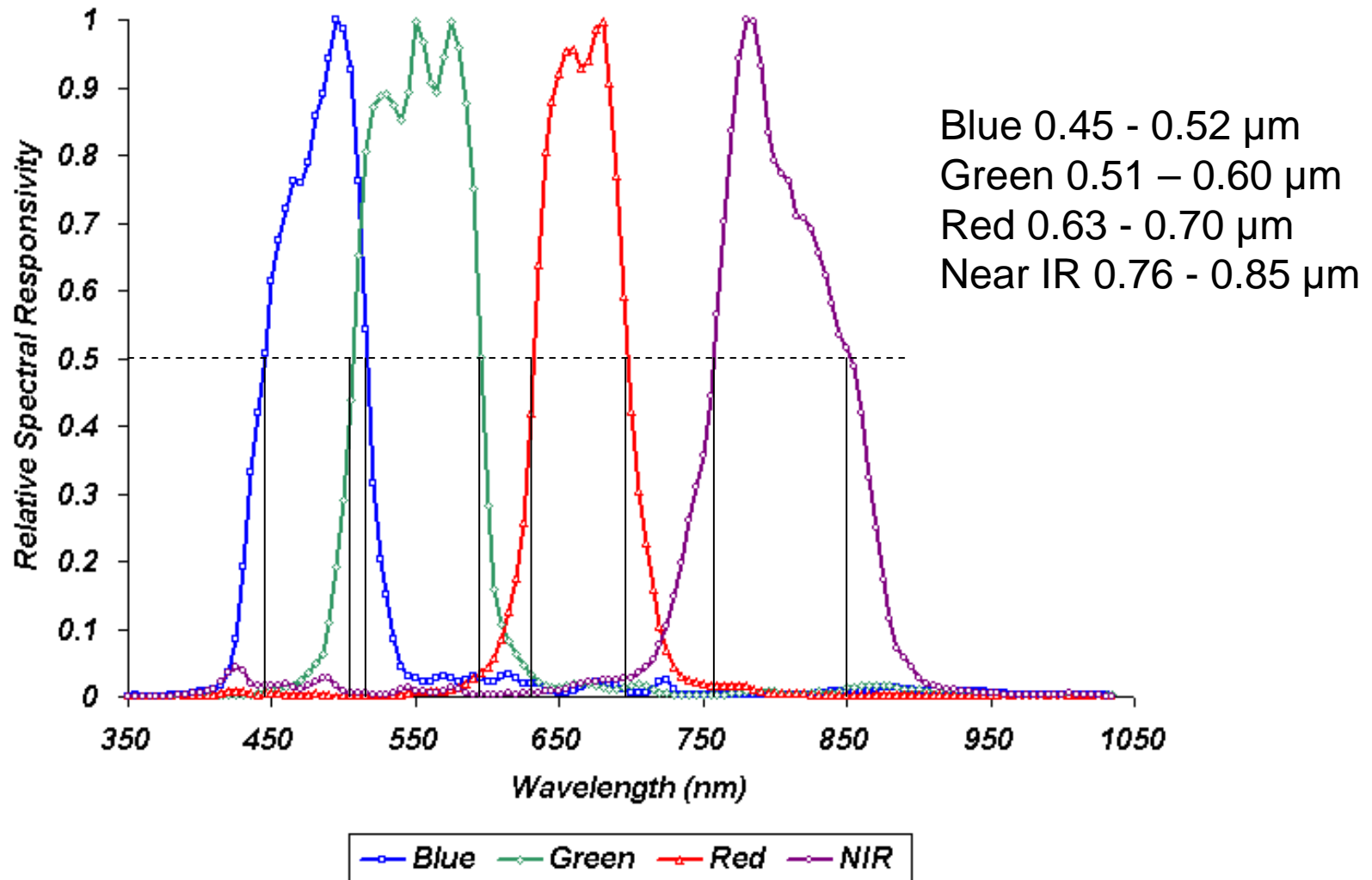


# B&W (1-band) vs. Color (3-band)



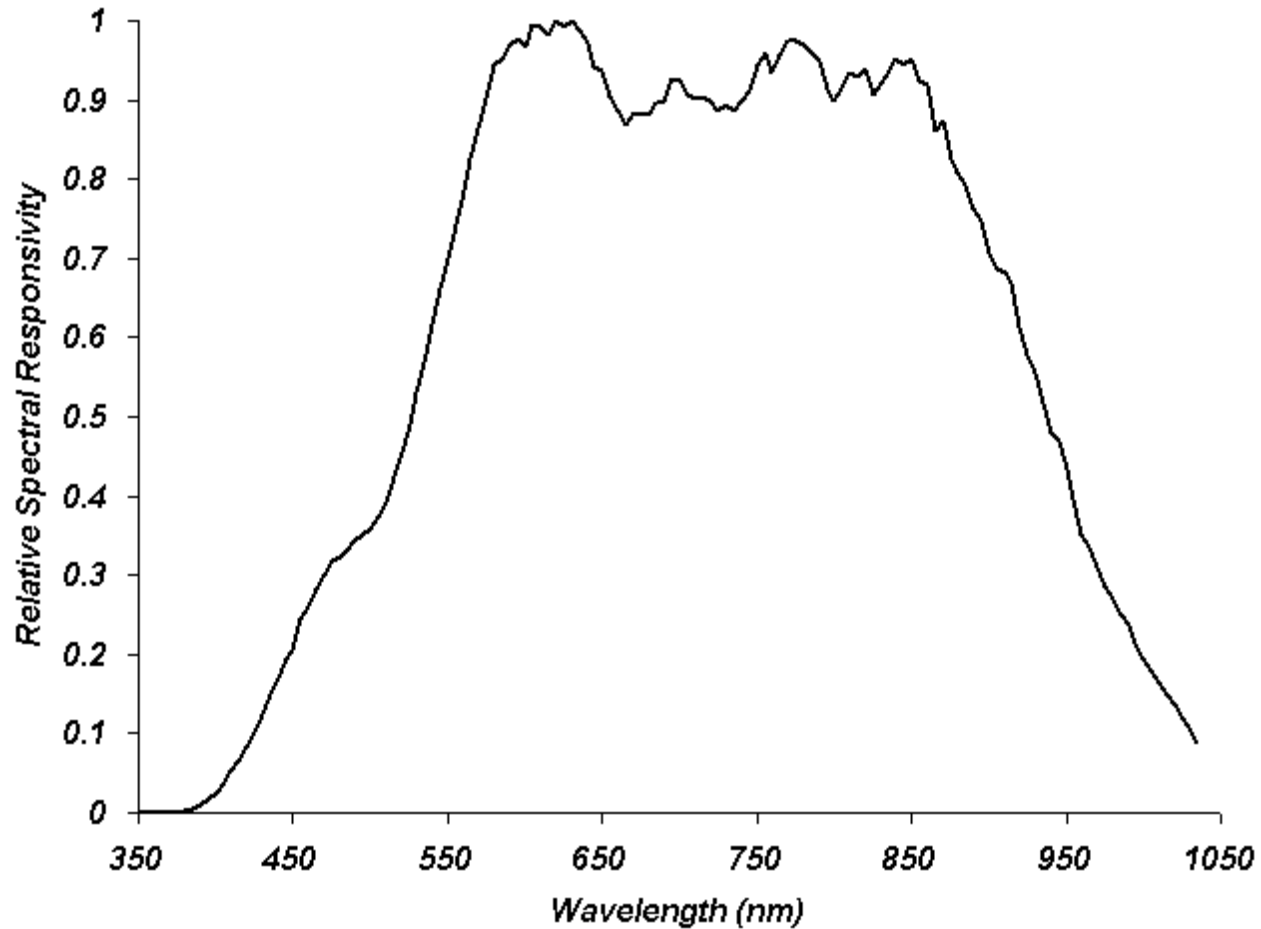
© CCRS / CCT

# Spectral Bandwidth



IKONOS multi-spectral bandwidth

# Spectral Bandwidth



IKONOS panchromatic bandwidth

# Radiometric Resolution

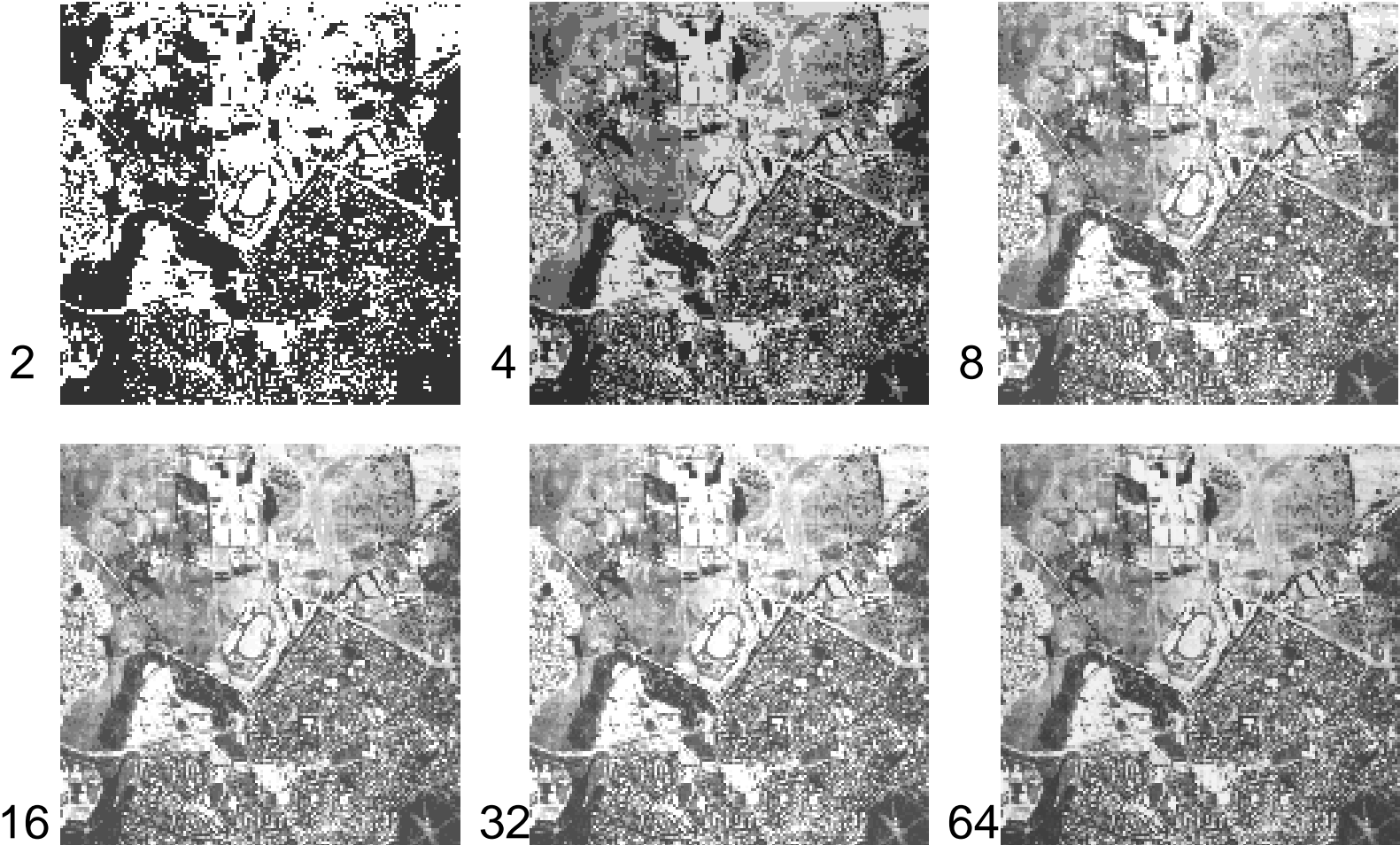
Radiometric resolution in remotely sensed data is defined as the amount of energy required to increase a pixel value by one quantization level or 'count'. In image processing, quantization levels are usually referred to as Digital Numbers (DN).

$$2^{\text{number of bits}} = \text{number of quantisation levels}$$

| Number of bits | Number of quantisation levels | Range of quantisation levels |
|----------------|-------------------------------|------------------------------|
| 1              | 2                             | 0-1                          |
| 2              | 4                             | 0-3                          |
| 3              | 8                             | 0-7                          |
| 4              | 16                            | 0-15                         |
| 5              | 32                            | 0-31                         |
| 6              | 64                            | 0-63                         |
| 7              | 128                           | 0-127                        |
| 8              | 256                           | 0-255                        |
| 9              | 512                           | 0-511                        |
| 10             | 1024                          | 0-1023                       |



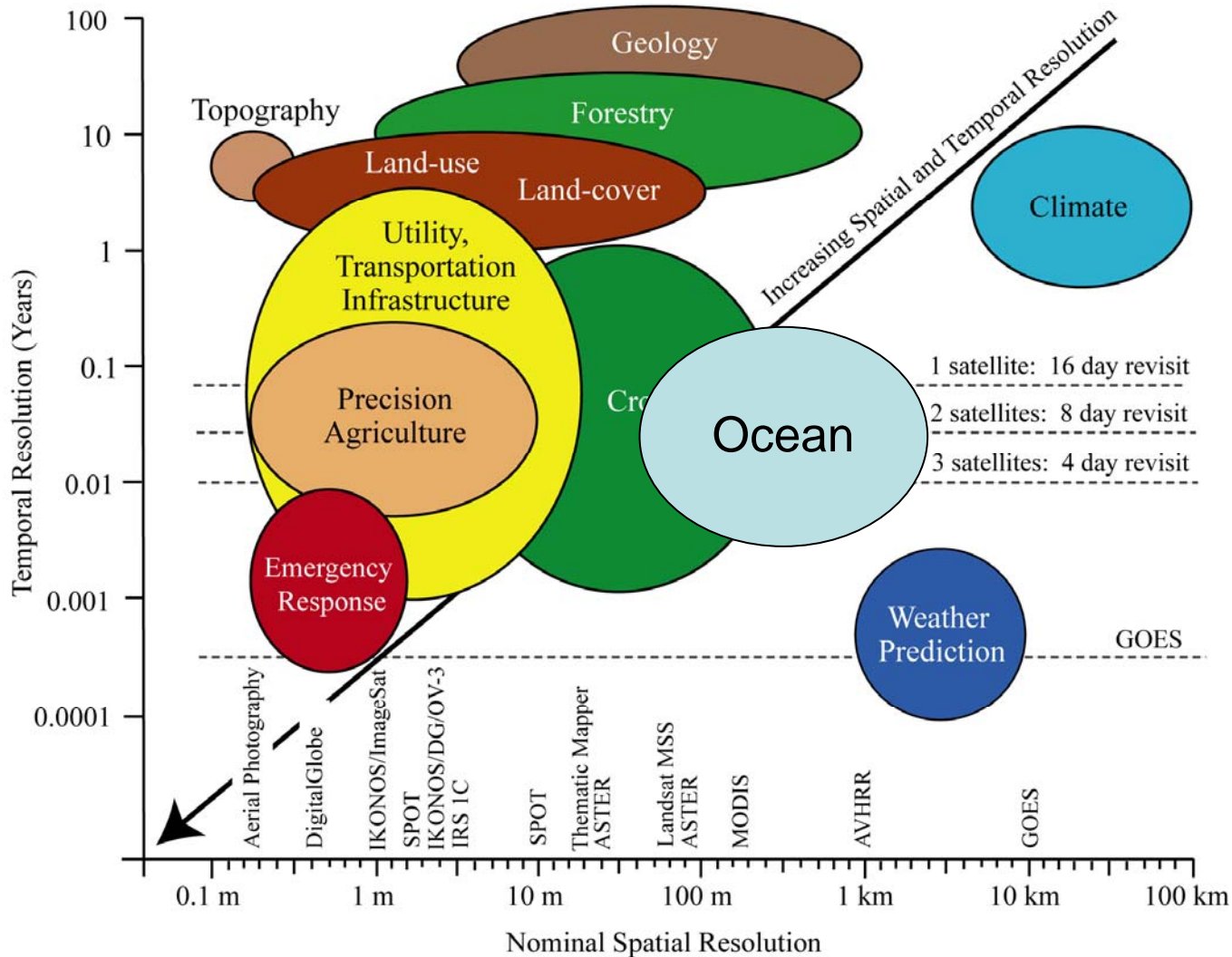
# Radiometric Resolution



Effect of changes in radiometric resolution on image feature contrast



## Spatial and Temporal Resolution for Selected Applications



There are spatial and temporal resolution considerations that must be made for certain remote sensing applications.

# Oceanographic Applications

- Visible wavelength "ocean color" sensors
- Sea surface temperature from infrared scanning radiometers
- Passive microwave radiometers
- Satellite altimetry of sea surface topography
- Active microwave sensing of sea-surface roughness