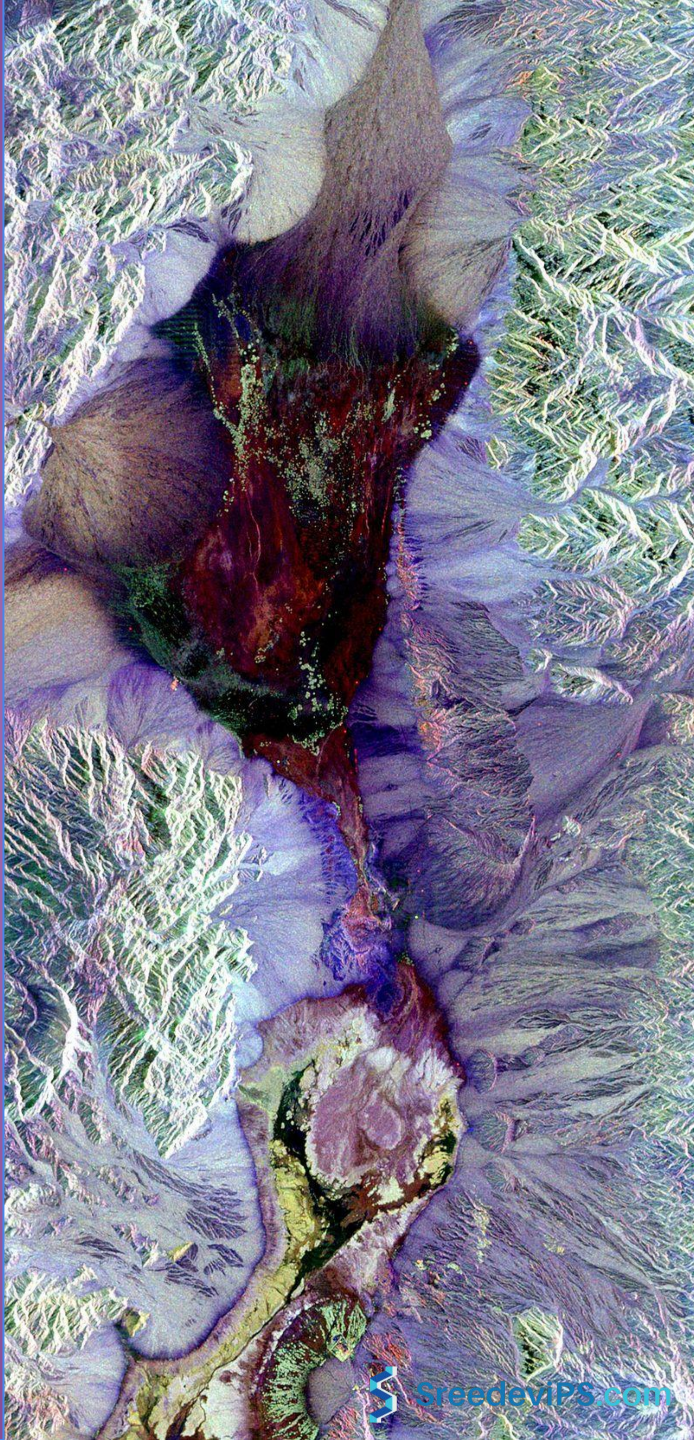
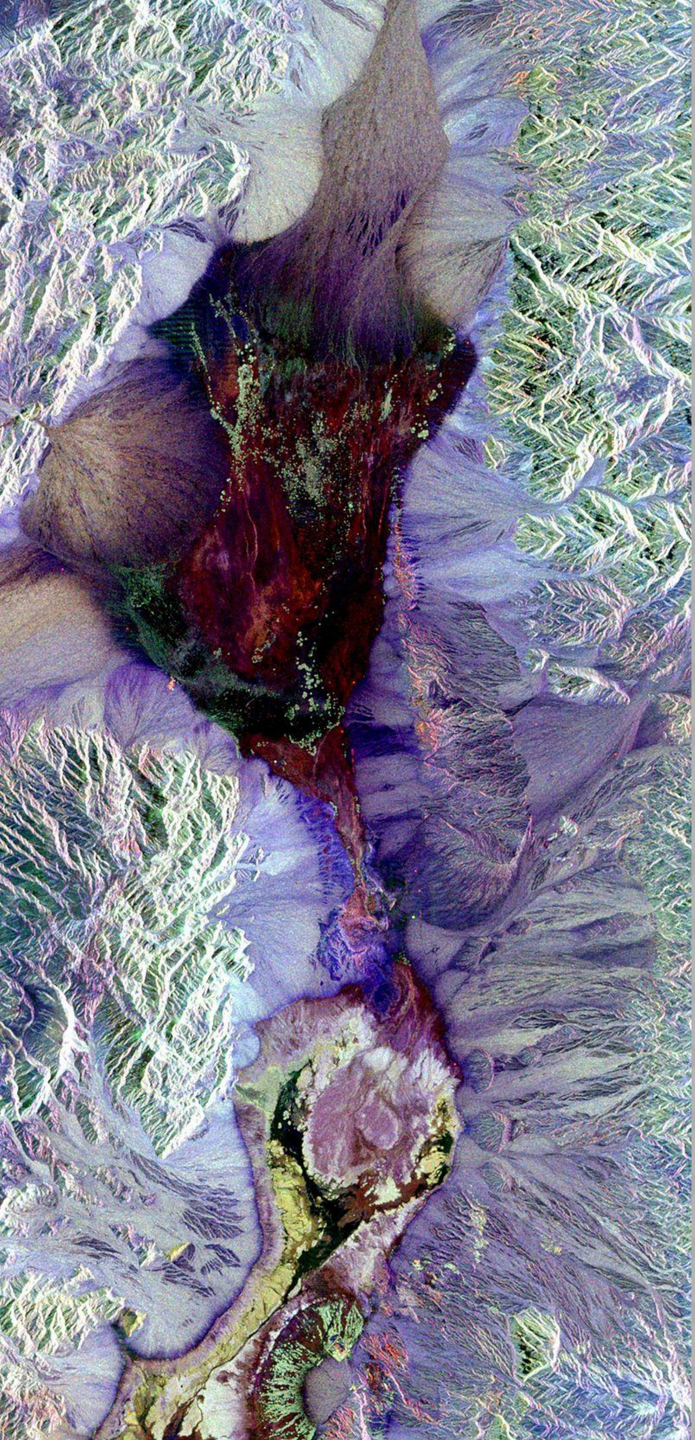
REMOTE SENSING

KTU/CE 307





MODULE V

REMOTE SENSING

SYLLABUS

- Remote Sensing : Definition- Electromagnetic spectrum-Energy interactions with atmosphere and earth surface features-spectral reflectance of vegetation, soil and water- Classification of sensors-Active and Passive, Resolution-spatial, spectral radiometric and Temporal resolution, Multi spectral scanning-Along track and across track scanning

REMOTE SENSING - DEFINITION

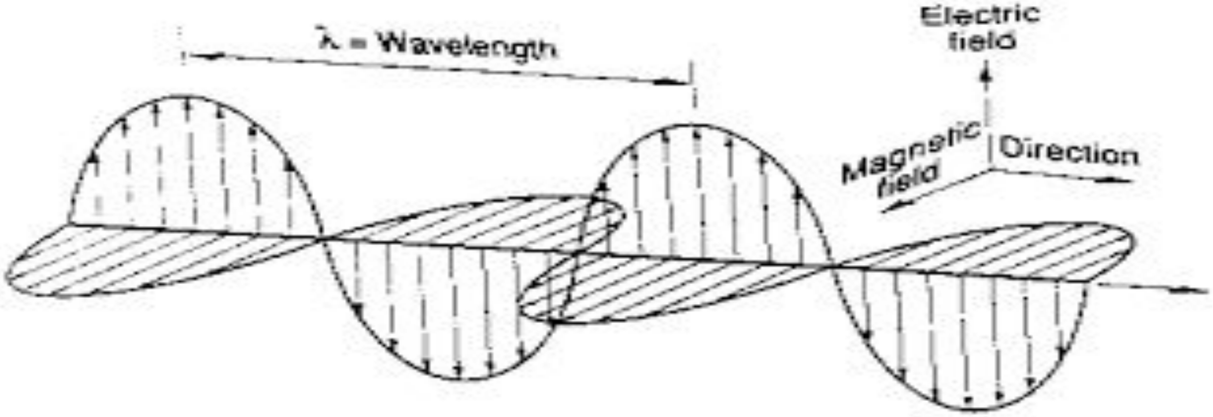
- Science and art of obtaining information about an object, area or phenomenon through an analysis of data acquired by a device that is not in direct contact with the area, object or phenomenon under investigation.

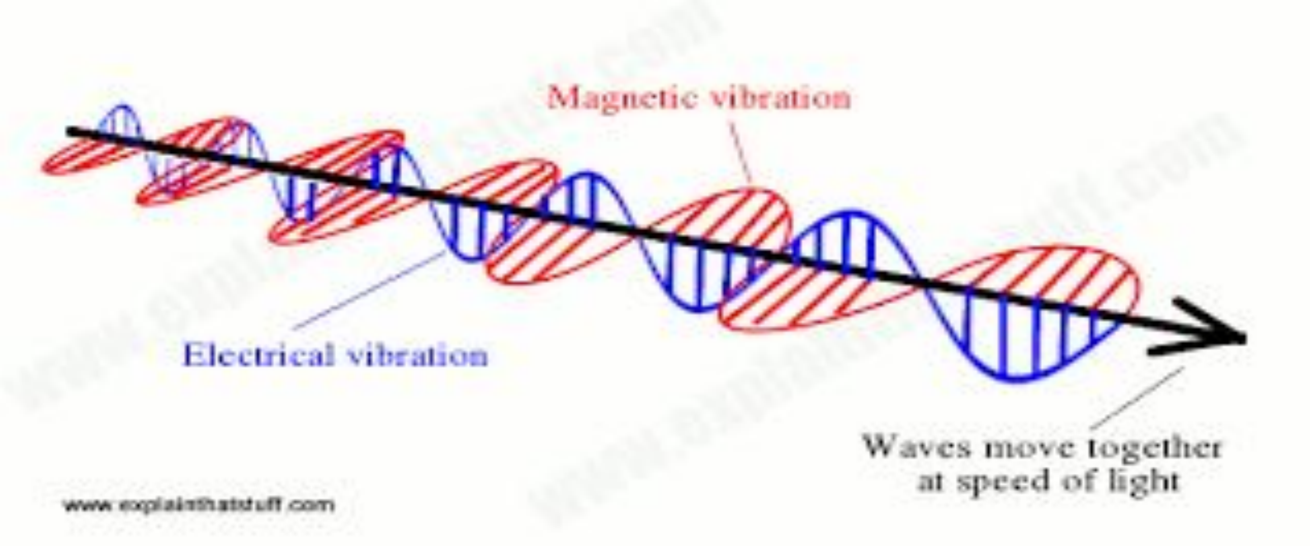
ELECTROMAGNETIC SPECTRUM

- The electromagnetic spectrum is the complete spectrum or continuum of light including radio waves, infrared, visible light, ultraviolet light, X-rays and gamma rays
- An electromagnetic wave consists of electric and magnetic fields which vibrates thus making waves.

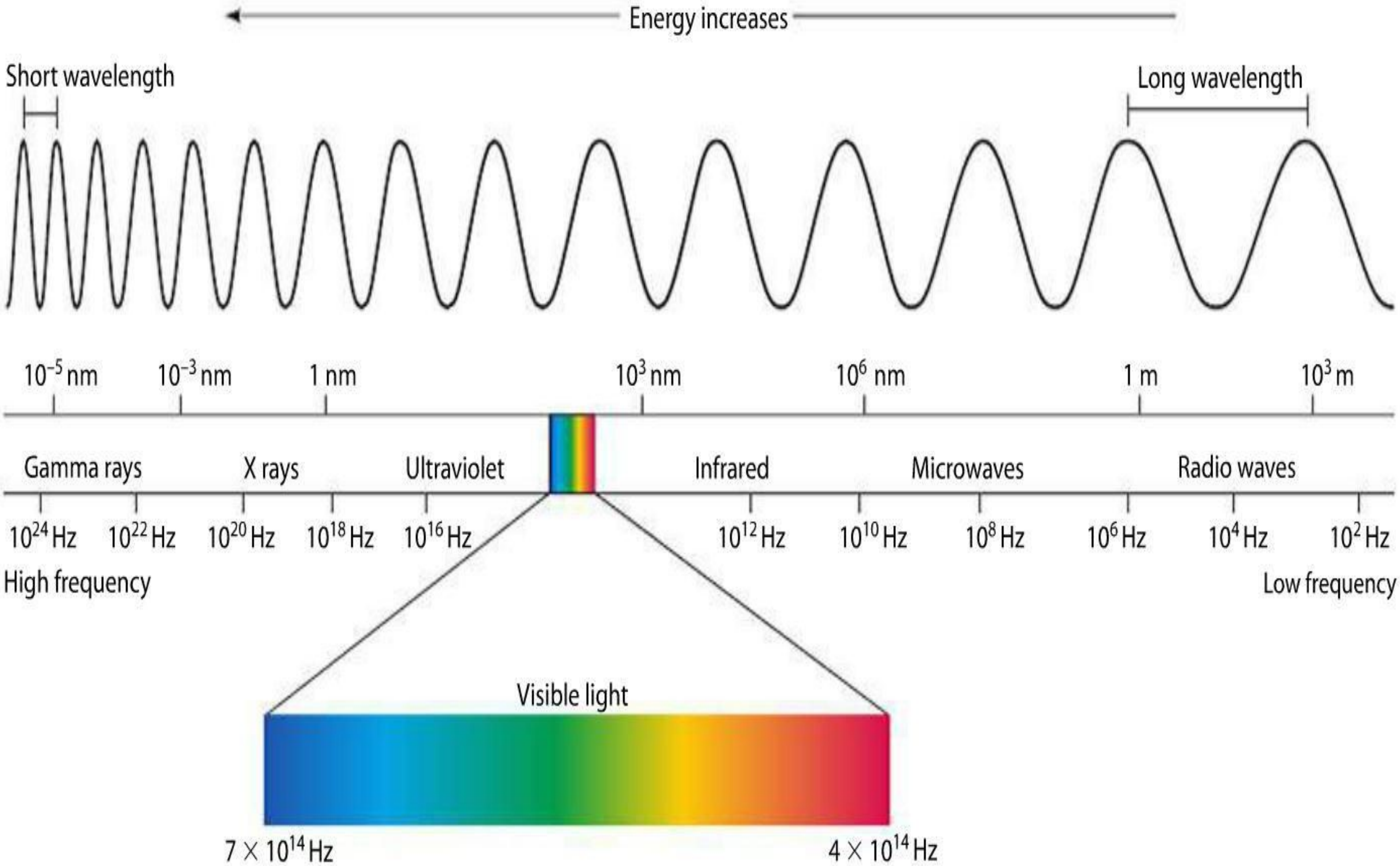
WAVES

- Properties of waves include speed, frequency and wavelength
- $c = \lambda \times f$
- c = speed, 3×10^8 m/s
- λ = wave length
- f = frequency

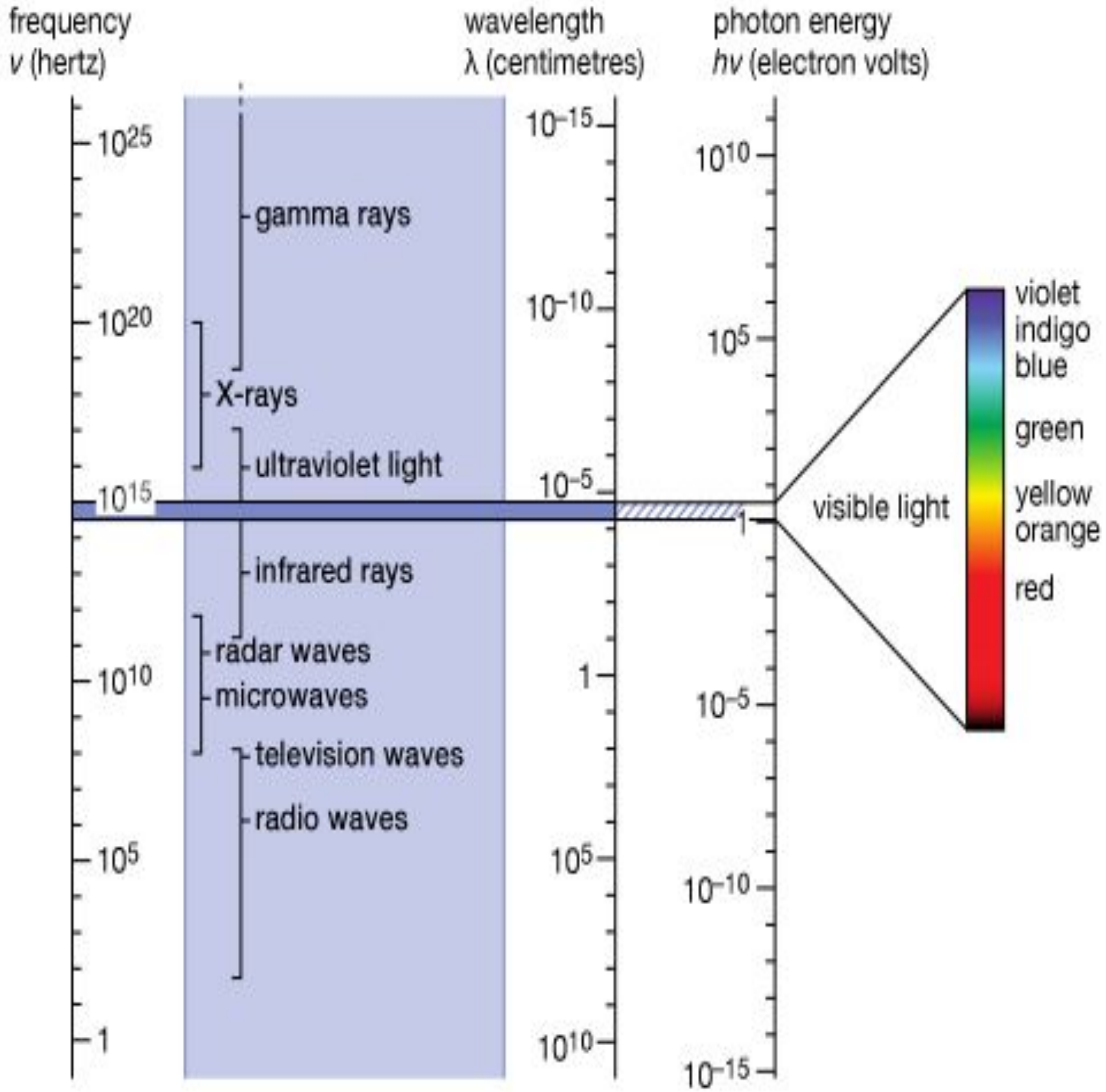

λ = Wavelength
Electric field
Magnetic field
Direction

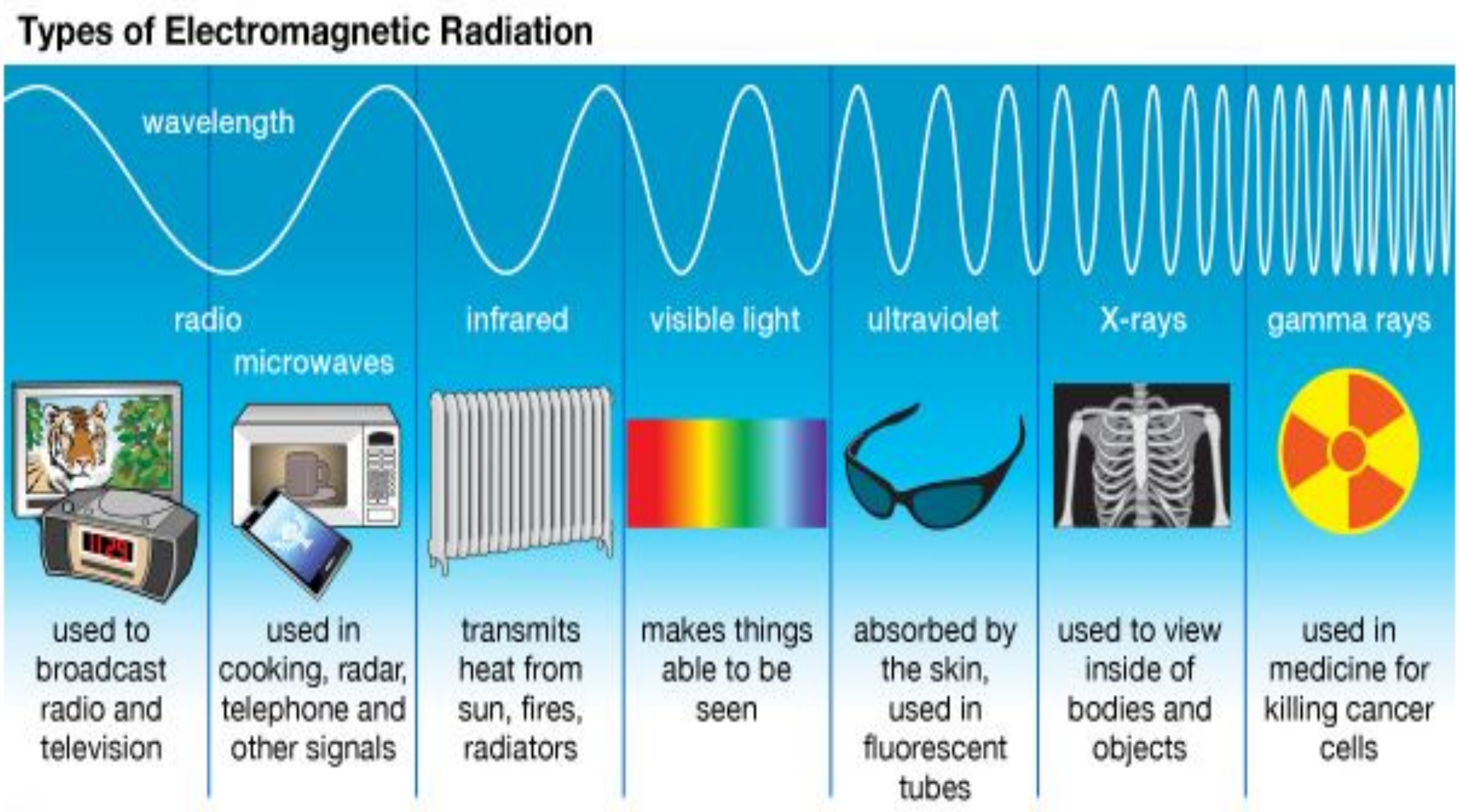

Magnetic vibration
Electrical vibration
Waves move together at speed of light
www.explainthatstuff.com

- Since all light travels at the same speed, wavelength and frequency have an indirect relationship.
- Light with a short wavelength will have a high frequency and light with a long wavelength will have a low frequency.
- Light with short wavelengths has high energy and long wavelength has low energy



Energy increases
Short wavelength
Long wavelength
10⁻⁵ nm
10⁻³ nm
1 nm
10³ nm
10⁶ nm
1 m
10³ m
Gamma rays
X rays
Ultraviolet
Infrared
Microwaves
Radio waves
10²⁴ Hz
10²² Hz
10²⁰ Hz
10¹⁸ Hz
10¹⁶ Hz
10¹² Hz
10¹⁰ Hz
10⁸ Hz
10⁶ Hz
10⁴ Hz
10² Hz
High frequency
Low frequency
Visible light
7 × 10¹⁴ Hz
4 × 10¹⁴ Hz


frequency
ν (hertz)
wavelength
λ (centimetres)
photon energy
hν (electron volts)
10^25
10^20
10^15
10^10
10^5
1
gamma rays
X-rays
ultraviolet light
infrared rays
radar waves
microwaves
television waves
radio waves
10^−15
10^−10
10^−5
1
10^5
10^10
10^10
10^5
1
10^−5
10^−10
10^−15
visible light
violet
indigo
blue
green
yellow
orange
red

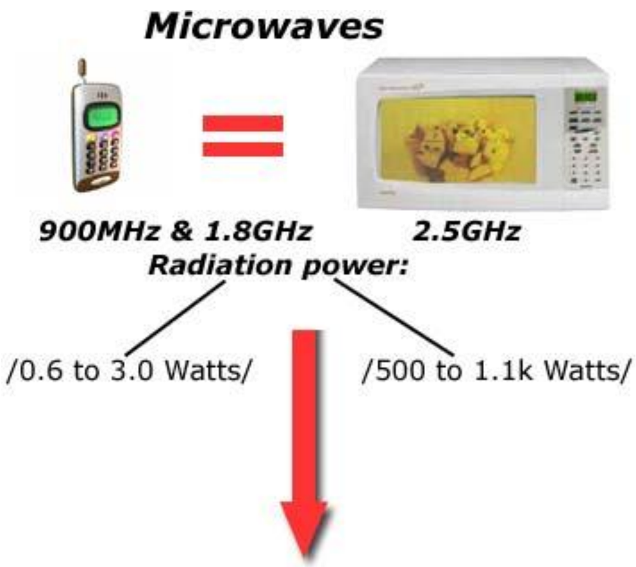

Types of Electromagnetic Radiation
wavelength
radio
microwaves
infrared
visible light
ultraviolet
X-rays
gamma rays
used to broadcast radio and television
used in cooking, radar, telephone and other signals
transmits heat from sun, fires, radiators
makes things able to be seen
absorbed by the skin, used in fluorescent tubes
used to view inside of bodies and objects
used in medicine for killing cancer cells

RADIO WAVES

- Low energy waves with long wavelengths
- Includes FM, AM, radar and TV waves
- Wavelengths of 10^{-1}m and longer
- Low frequency
- Used in many devices such as remote control items, cell phones, wireless devices, etc.

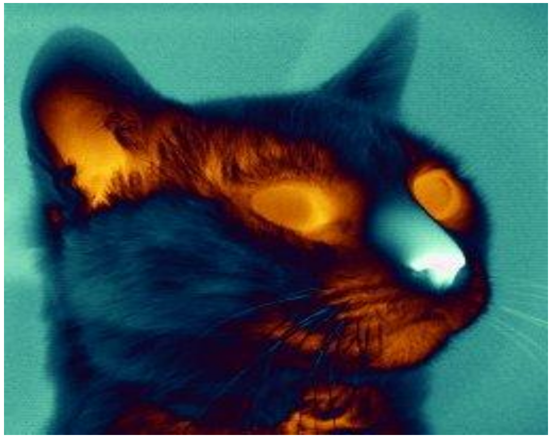
MICROWAVES

- Longer than radio, shorter than light and infrared
- Wavelength 1 x 10^{-4} m to 1 x 10^{-1} m
- First used in radar, now used in communication, medicine and consumer use (microwave ovens)



INFRARED WAVES

- Invisible electromagnetic waves that are detected as heat
- Can be detected with special devices such as night goggles
- Used in heat lamps
- Higher energy than microwaves but lower than visible light



VISIBLE LIGHT

- The portion of the electromagnetic spectrum that human eyes can detect
- ROY G BIV (red, orange, yellow, green, blue, indigo, violet)
- Red is the lowest frequency and violet is the highest frequency

ULTRAVIOLET WAVES

- Higher energy than light waves
- Can cause skin cancer and blindness in humans
- Used in tanning beds and sterilizing equipment

X-RAYS

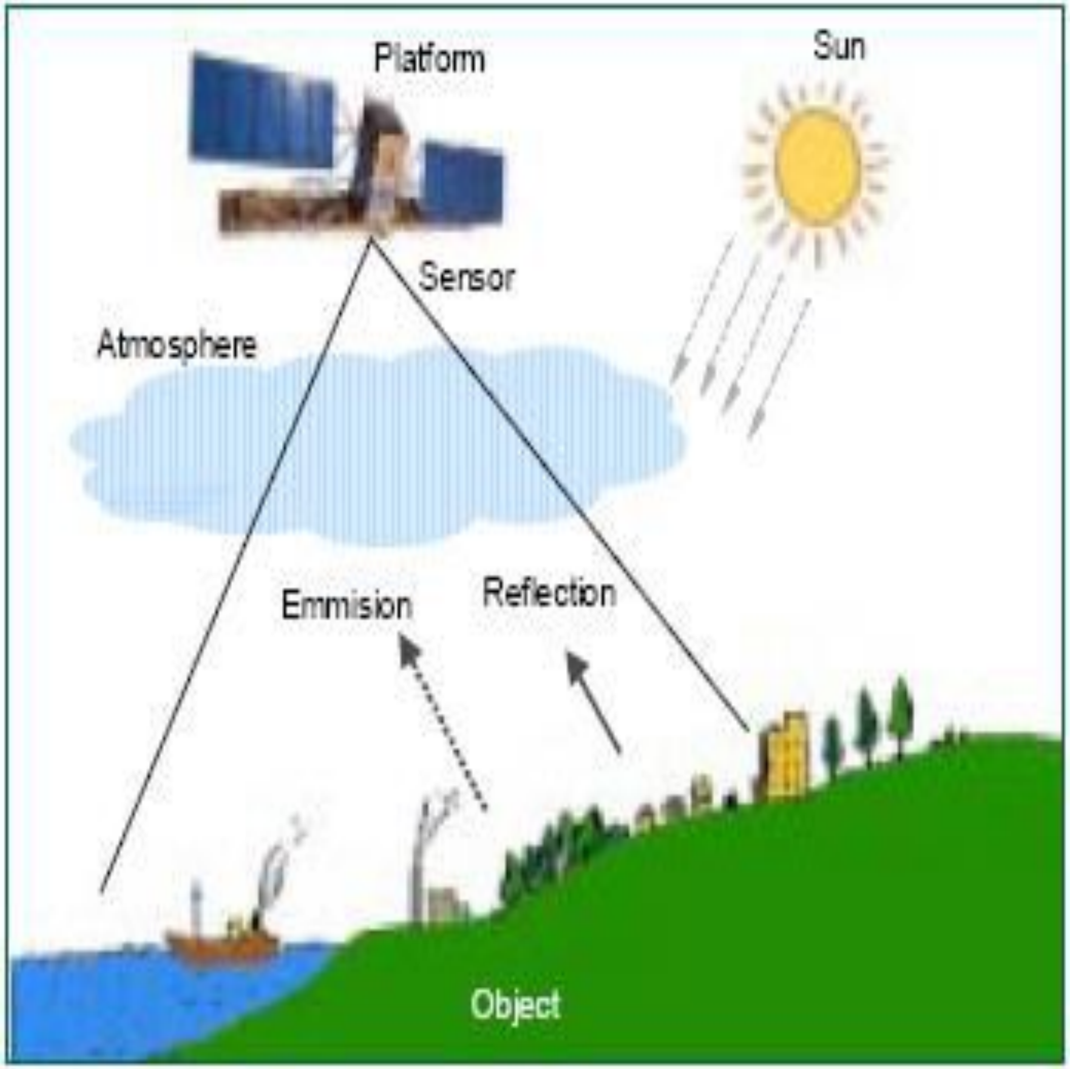
- High energy waves
- First discovered by Roentgen
- Used in medicine, industry and astronomy
- Can cause cancer

GAMMA RAYS

- Highest energy
- Blocked from Earth's surface by atmosphere

BASIC CONCEPTS OF REMOTE SENSING

- remote sensing is the process of inferring surface parameters from measurements of the electromagnetic radiation (EMR) from the Earth's surface
- EMR can either be reflected or emitted from the Earth's surface
- remote sensing is detecting and measuring electromagnetic (EM) energy emanating or reflected from distant objects made of various materials, so that we can identify and categorize these objects by class or type,


Platform
Sun
Sensor
Atmosphere
Emmision
Reflection
Object

PRINCIPLE OF REMOTE SENSING

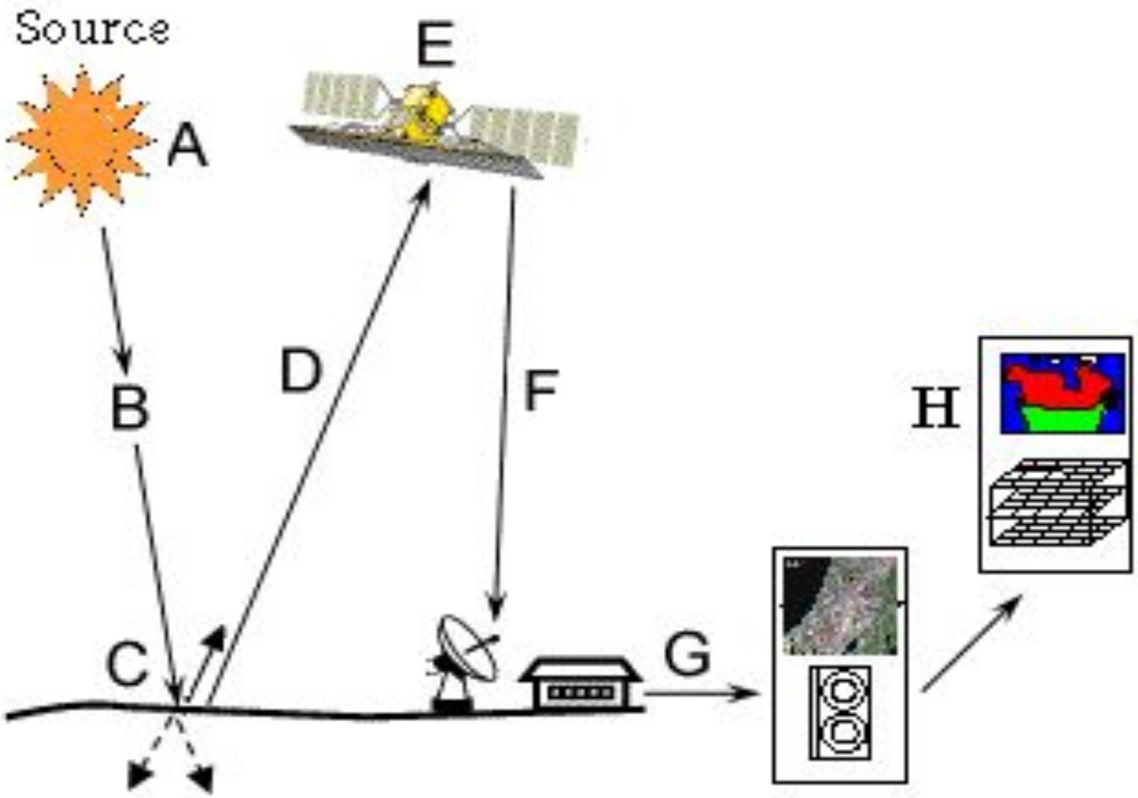
- Different objects reflect or emit different amounts of energy in different bands of the electromagnetic spectrum.
- The amount of energy reflected or emitted depends on the properties of both the material and the incident energy (angle of incidence, intensity and wavelength).

- A device to detect this reflected or emitted electro-magnetic radiation from an object is called a “sensor” (e.g., cameras and scanners).
- A vehicle used to carry the sensor is called a “platform” (e.g., aircrafts and satellites).

Main stages in remote sensing

- A. Emission of electromagnetic radiation
  - The Sun or an EMR source located on the platform
- B. Transmission of energy from the source to the object
  - Absorption and scattering of the EMR while transmission
- C. Interaction of EMR with the object and subsequent reflection and emission

- D. Transmission of energy from the object to the sensor
- E. Recording of energy by the sensor
  - Photographic or non-photographic sensors
- F. Transmission of the recorded information to the ground station
- G. Processing of the data into digital or hard copy image
- H. Analysis of data


Source
A
E
B
D
F
H
C
G

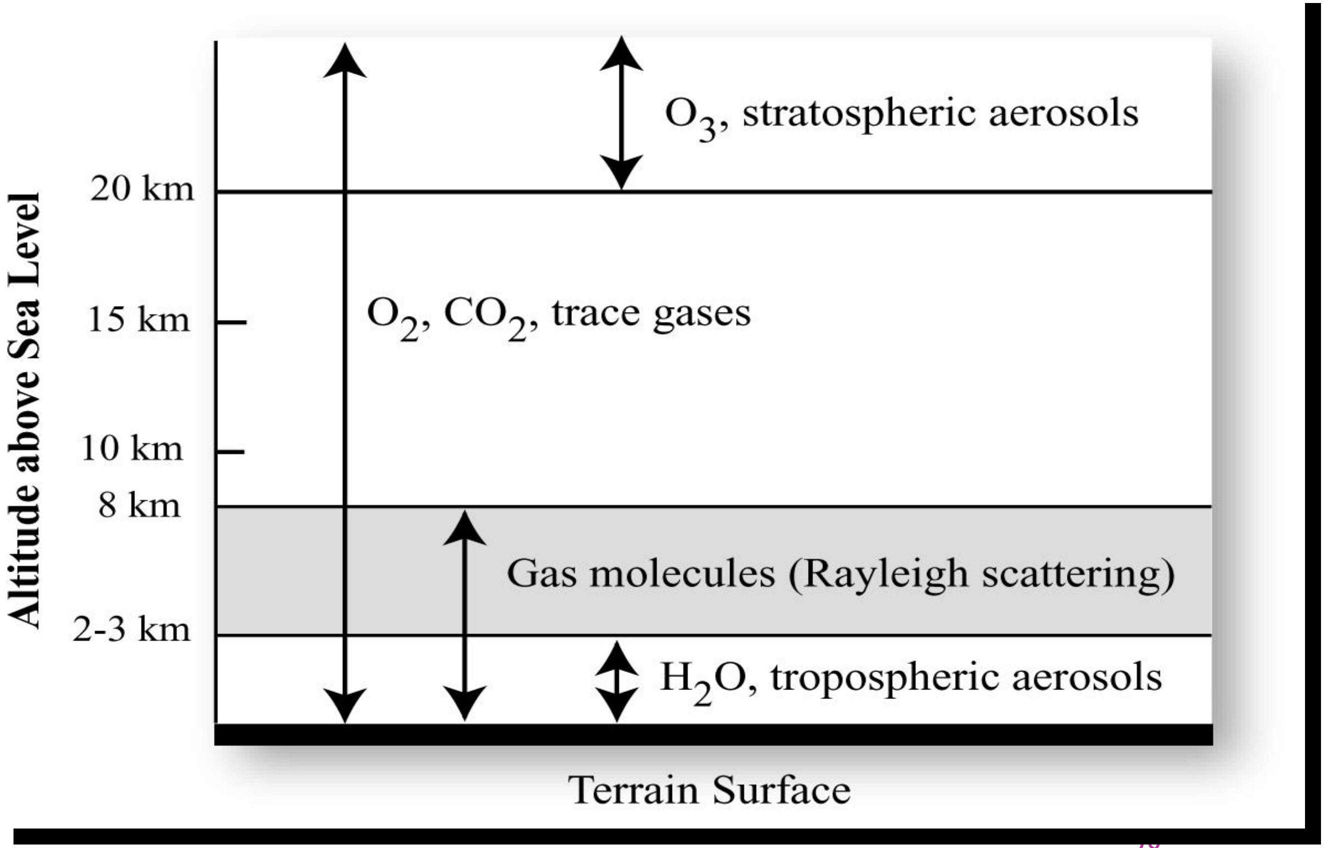
Energy interactions with atmosphere

- The composition of the atmosphere influences both the incoming solar radiation and the outgoing terrestrial radiation
- The radiance (the energy reflected by the surface) received at a satellite is a result of electromagnetic radiation that undergoes several processes which are wavelength dependent

- Scattering
- Absorption

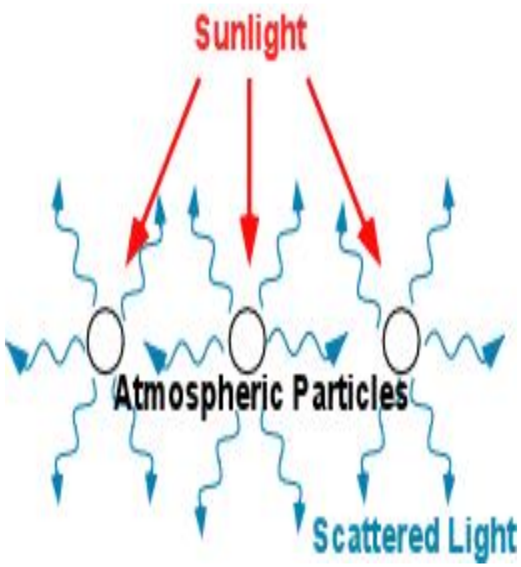
ATMOSPHERIC LAYERS AND CONSTITUENTS

- Major subdivisions of the atmosphere and the types of molecules and aerosols found in each layer.



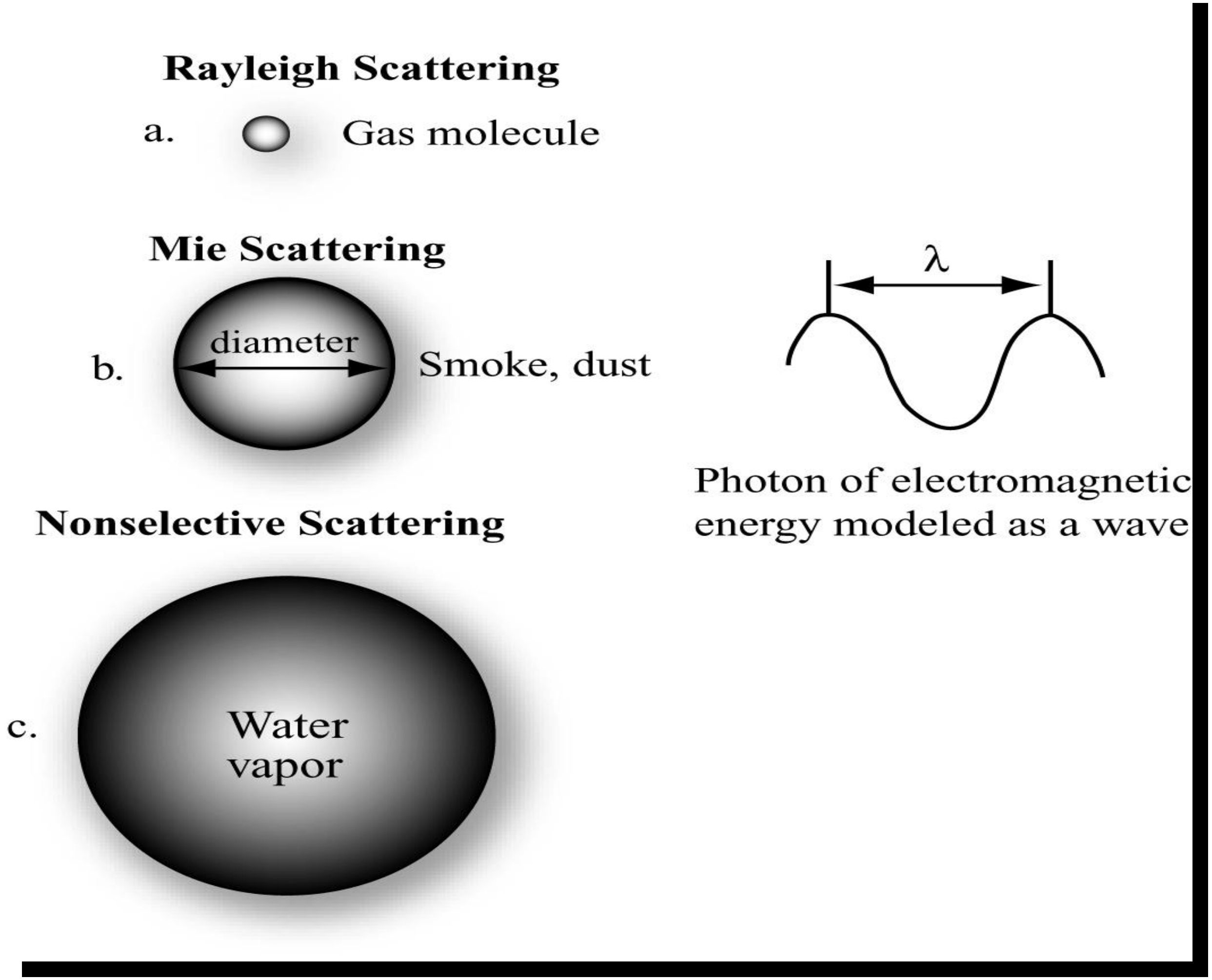
SCATTERING

- The redirection of EM energy by particles suspended in the atmosphere or large molecules of atmospheric gases



TYPES OF SCATTERING

- Rayleigh scattering
- Mie scattering
- Nonselective scattering



Rayleigh Scattering
a.
Gas molecule
Mie Scattering
b.
diameter
Smoke, dust
Nonselective Scattering
c.
Water
vapor
λ
Photon of electromagnetic
energy modeled as a wave

EFFECTS OF SCATTERING

- It causes haze in remotely sensed images
- It decreases the spatial detail on the images
- It also decreases the contrast of the images

ABSORPTION

- Absorption is the process by which radiant energy is absorbed and converted into other forms of energy
- An absorption band is a range of wavelengths (or frequencies) in the electromagnetic spectrum within which radiant energy is absorbed by substances such as water (H_2O), carbon dioxide (CO_2), oxygen (O_2), ozone (O_3), and nitrous oxide (N_2O).

- Three gases:

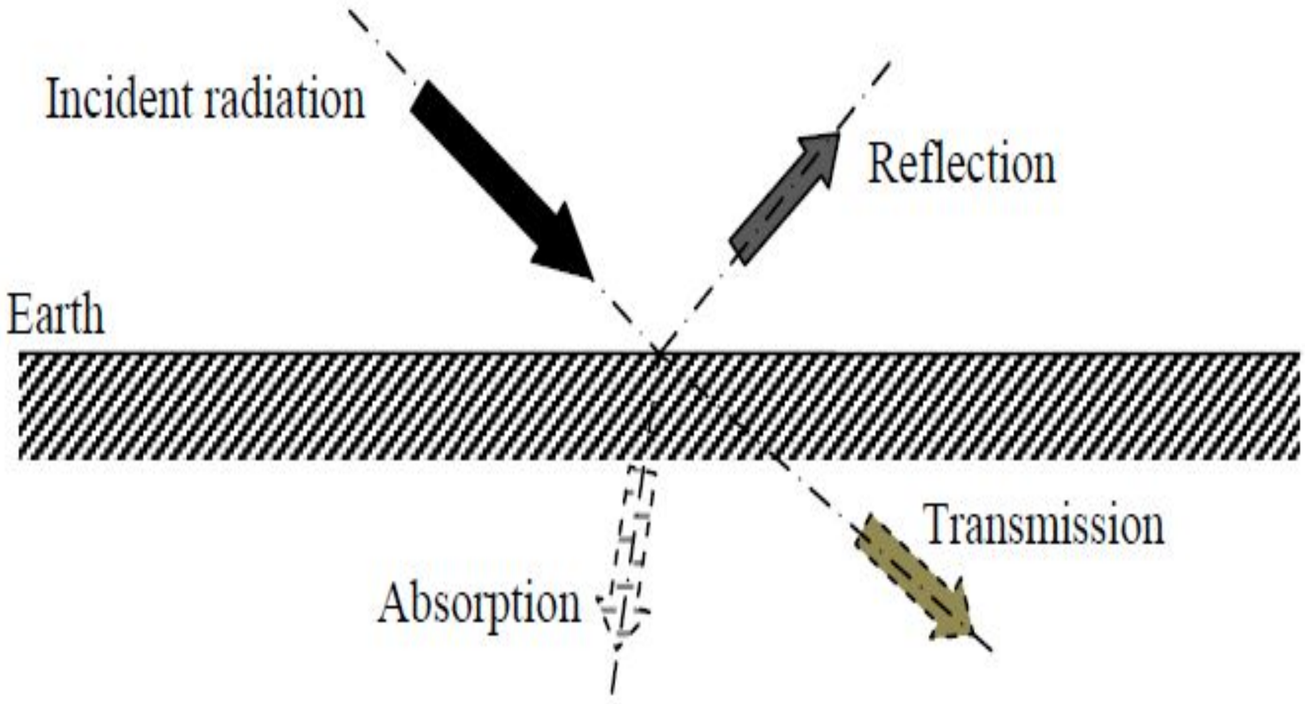
  - Ozone (O_3): absorbs ultraviolet radiation high in atmosphere

  - Carbon-dioxide (CO_2): absorbs mid and far infrared in lower atmosphere

  - Water vapor (H_2O): absorbs mid-far infrared in lower atmosphere

ENERGY INTERACTIONS WITH EARTH SURFACE FEATURES

- Energy incident on the Earth's surface is absorbed, transmitted or reflected depending on the wavelength and characteristics of the surface features

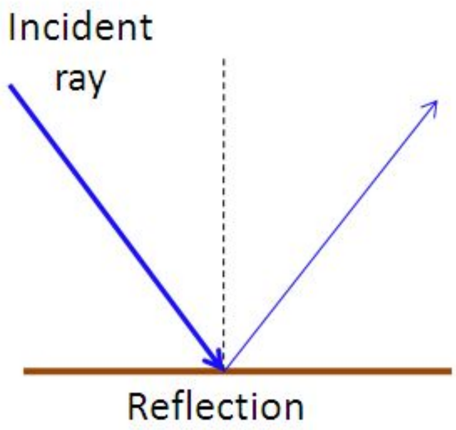

Incident radiation
Reflection
Earth
Transmission
Absorption

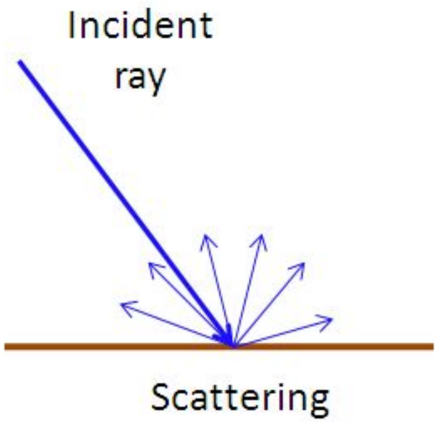
- The relationship between reflection, absorption and transmission can be expressed through the principle of conservation of energy
- EI denotes the incident energy, ER denotes the reflected energy, EA denotes the absorbed energy and ET denotes the transmitted energy
- $EI(\lambda) = ER(\lambda) + EA(\lambda) + ET(\lambda)$

- most remote sensing systems use reflected energy, the energy balance relationship can be better expressed in the form
- $ER(\lambda) = EI(\lambda) - EA(\lambda) - ET(\lambda)$
- reflected energy is equal to the total energy incident on any given feature reduced by the energy absorbed or transmitted by that feature

REFLECTION

- Reflection is the process in which the incident energy is redirected in such a way that the angle of incidence is equal to the angle of reflection


Incident
ray
Reflection


Incident
ray
Scattering

- When electromagnetic energy is incident on the surface, it may get reflected or scattered depending upon the roughness of the surface relative to the wavelength of the incident energy.
- If the roughness of the surface is less than the wavelength of the radiation or the ratio of roughness to wavelength is less than 1, the radiation is reflected.
- When the ratio is more than 1 or if the roughness is more than the wavelength, the radiation is scattered

SPECTRAL REFLECTANCE OF VEGETATION, SOIL AND WATER

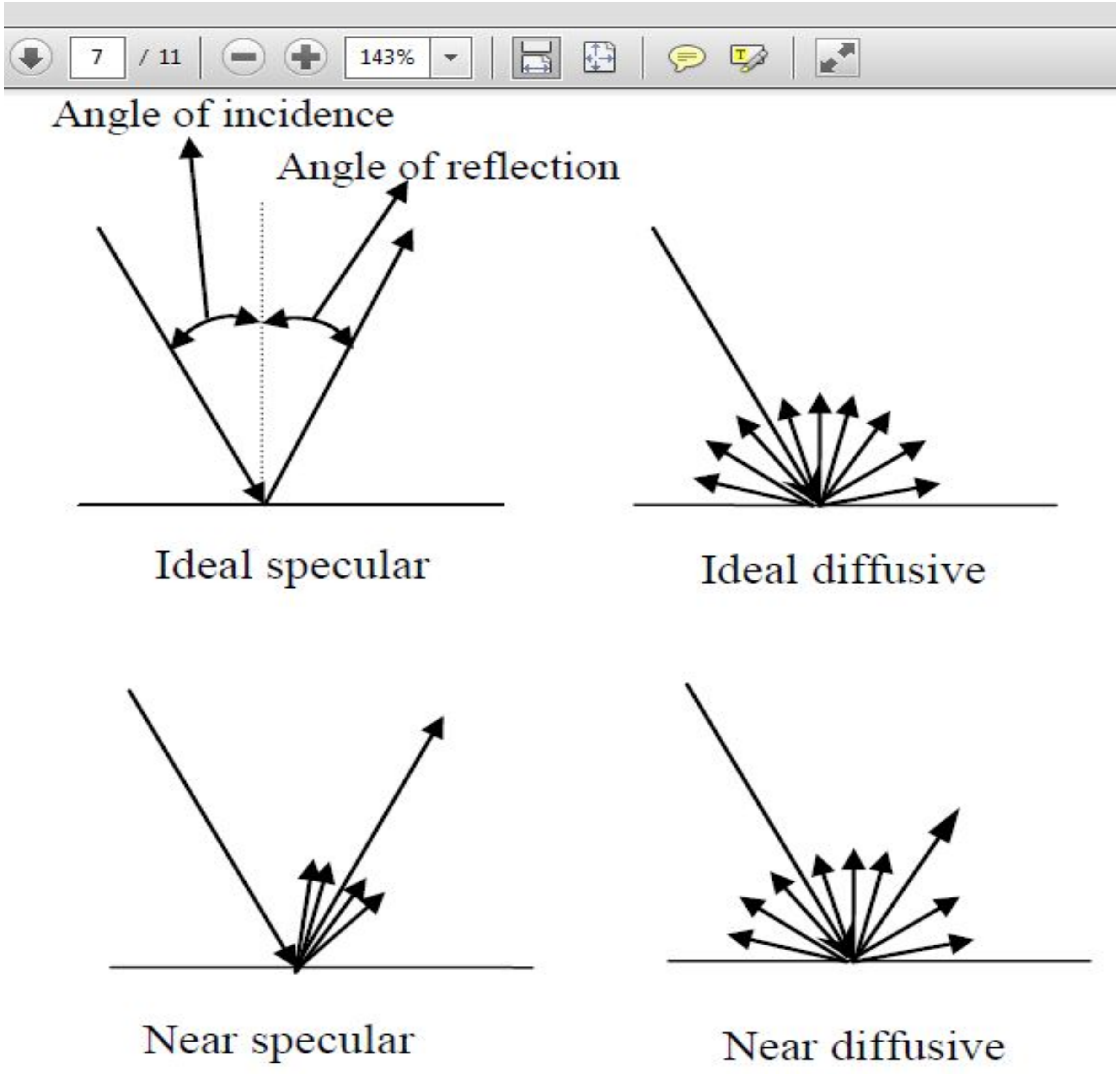
- Remote sensing system operates in the wavelength region in which reflected energy predominates
- Reflectance properties are of prime importance
- Reflected energy is primarily function of surface roughness

SPECULAR REFLECTION:

- It occurs when the surface is smooth and flat.
- A mirror-like or smooth reflection is obtained where complete or nearly complete incident energy is reflected in one direction.
- The angle of reflection is equal to the angle of incidence.
- Reflection from the surface is the maximum along the angle of reflection, whereas in any other direction it is negligible.

DIFFUSE (LAMBERTIAN) REFLECTION

- It occurs when the surface is rough.
- The energy is reflected uniformly in all directions.
- Since all the wavelengths are reflected uniformly in all directions, diffuse reflection contains spectral information on the "colour" of the reflecting surface.


7
/ 11
143%
Angle of incidence
Angle of reflection
Ideal specular
Ideal diffusive
Near specular
Near diffusive

- The reflectance characteristics of earth surface features are expressed as the ratio of energy reflected by the surface to the energy incident on the surface.
- This is measured as a function of wavelength and is called spectral reflectance, $R\lambda$.
- It is also known as albedo of the surface.

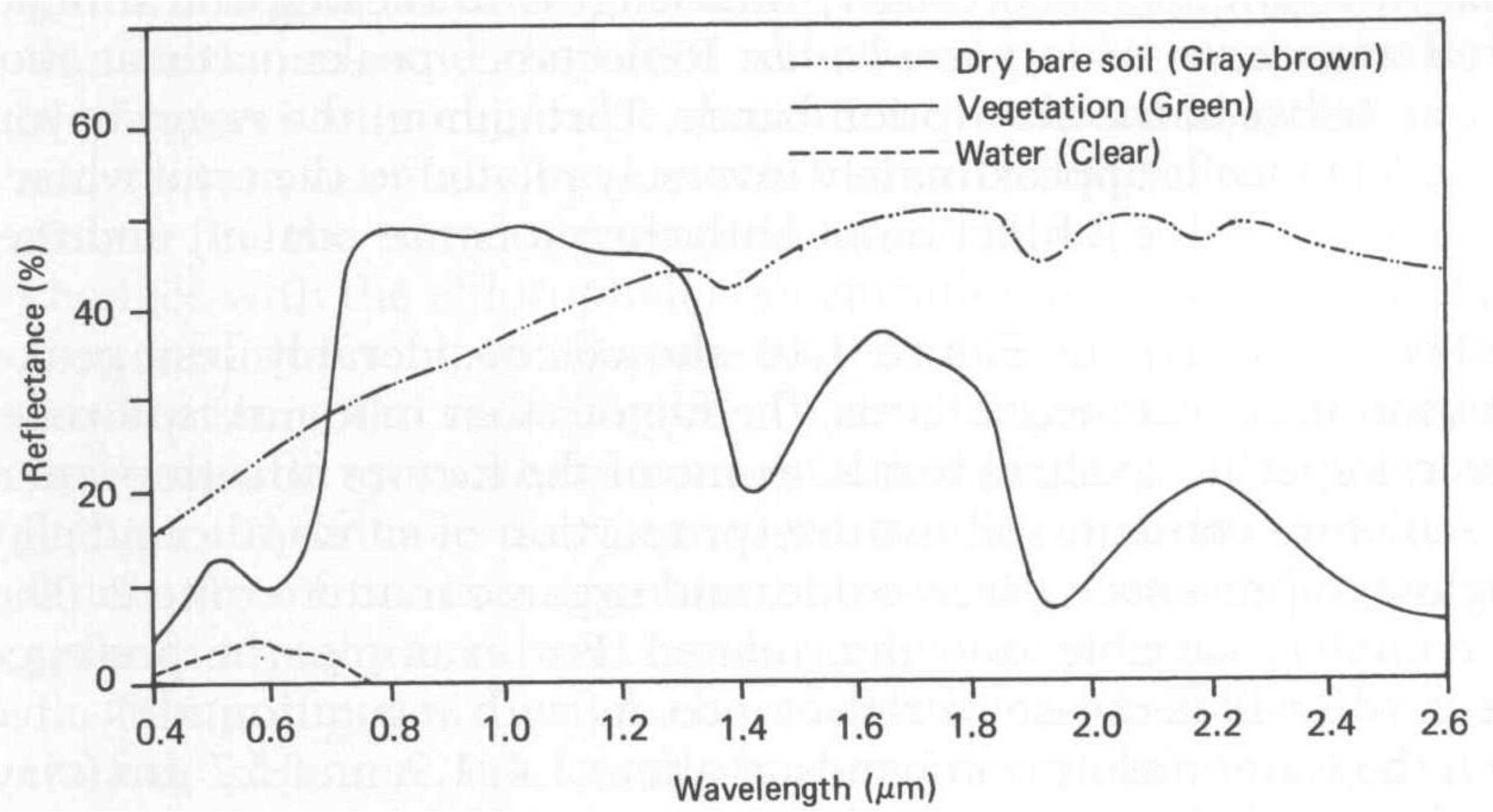
$$R_\lambda = \frac{E_R(\lambda)}{E_I(\lambda)}$$

$$= \frac{\text{Energy of wavelength } \lambda \text{ reflected from the object}}{\text{Energy of wavelength } \lambda \text{ incident on the object}} \times 100$$

Surface type	Albedo %
Grass	25
Concrete	20
Water	5-70
Fresh snow	80
Forest	5-10
Thick cloud	75
Dark soil	5-10

- The graphical representation of the spectral response of an object over different wavelengths of the electromagnetic spectrum is termed as spectral reflectance curve.
- These curves give an insight into the spectral characteristics of different objects, hence used in the selection of a particular wavelength band for remote sensing data aquisition

SPECTRAL REFLECTANCE CURVES FOR VEGETATION, SOIL, AND WATER



REMOTE SENSING SENSOR SYSTEMS

- Remote sensing – detection and recording of electromagnetic radiation
- Instrument used – sensors
- Sensor system placed – platforms
  - Stationary platform – mounted on tripod
  - Mobile platform – satellites or aircrafts
  - aircraft – local or limited area
  - Satellite – large area

TYPES OF REMOTE SENSING SENSOR SYSTEMS

- Depending on the source of electromagnetic energy
  - Passive system
  - Active system

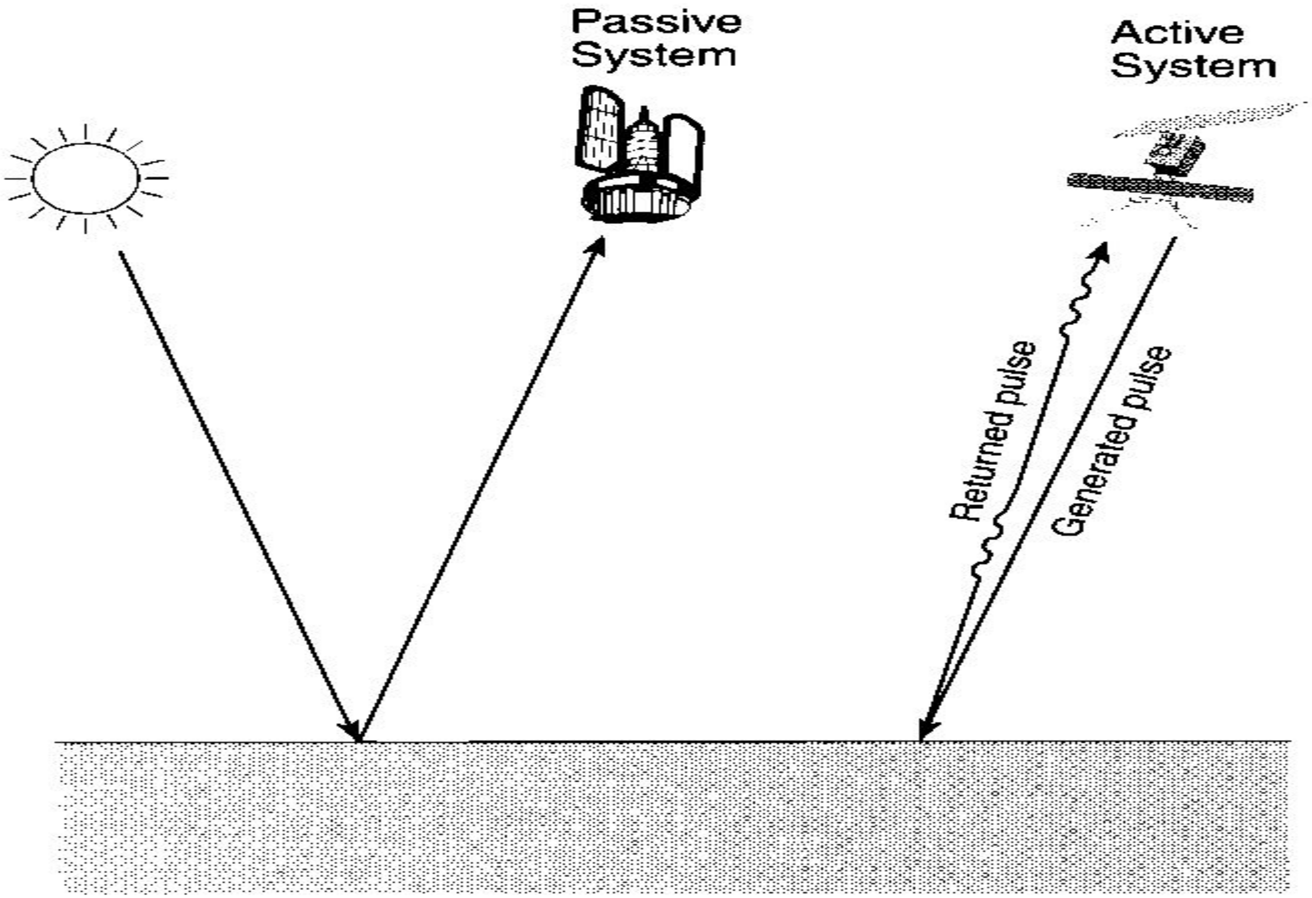
PASSIVE SYSTEM

- In the case of passive remote sensing, source of energy is that naturally available such as the Sun.
- Most of the remote sensing systems work in passive mode using solar energy as the source of EMR.
- Solar energy reflected by the targets at specific wavelength bands are recorded using sensors onboard air-borne or space borne platforms.

ACTIVE SYSTEM

- In the case of active remote sensing, energy is generated and sent from the remote sensing platform towards the targets.
- The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform

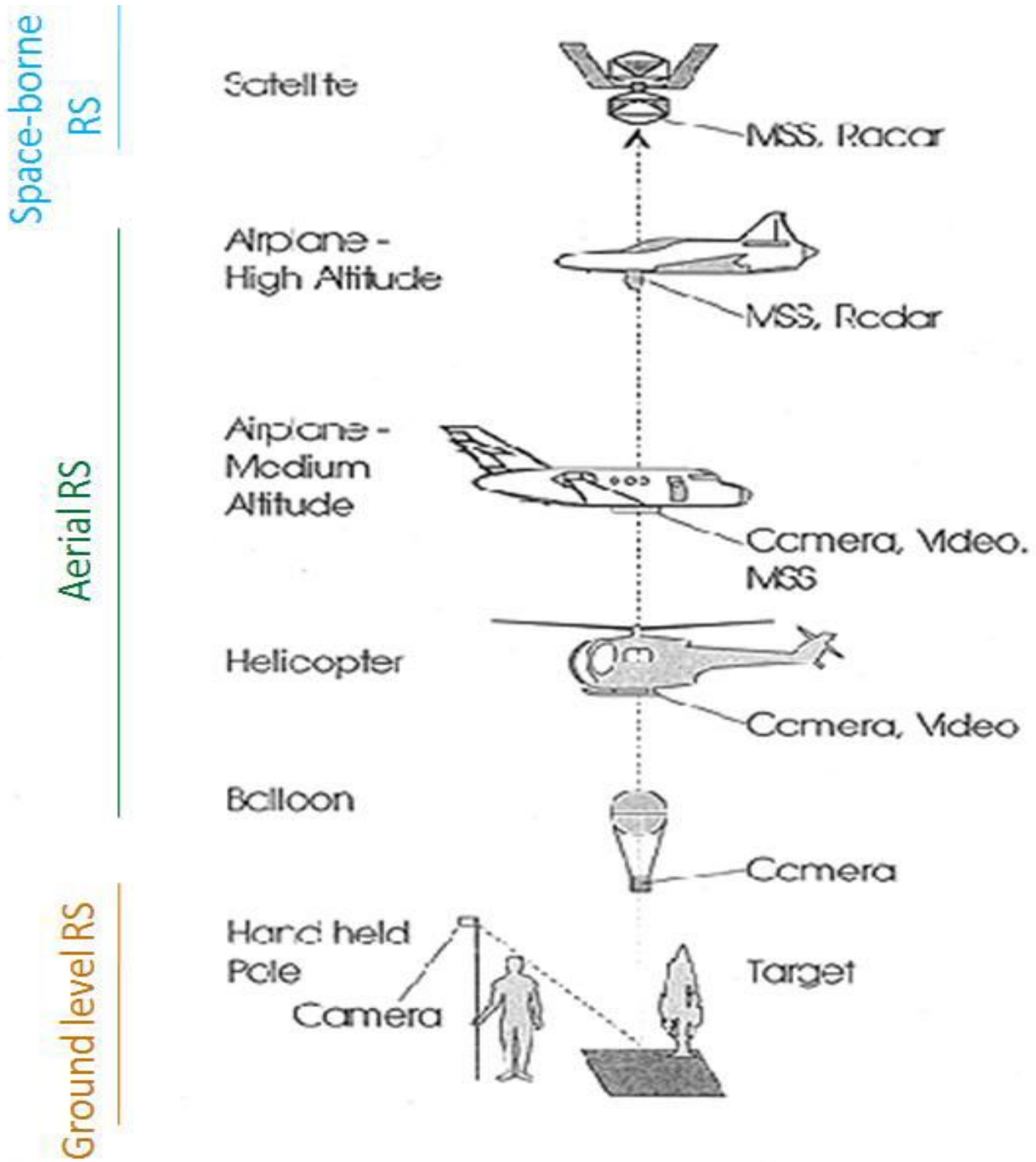
- passive remote sensing is similar to taking a picture with an ordinary camera whereas active remote sensing is analogous to taking a picture with camera having built-in flash



REMOTE SENSING PLATFORMS

- based on the elevation from the Earth's surface at which these platforms are placed.
- Ground level remote sensing
  - Ground level remote sensors are very close to the ground
  - They are basically used to develop and calibrate sensors for different features on the Earth's surface.

- Aerial remote sensing
  - Low altitude aerial remote sensing
  - High altitude aerial remote sensing
- Space borne remote sensing
  - Space shuttles
  - Polar orbiting satellites
  - Geo-stationary satellites


Space-borne RS
Aerial RS
Ground level RS
Satellite
MSS, Racar
Airplane - High Altitude
MSS, Radar
Airplane - Medium Altitude
Camera, Video, MSS
Helicopter
Camera, Video
Balloon
Camera
Hand held Pole
Camera
Target

AIRBORNE AND SPACE-BORNE REMOTE SENSING

- In airborne remote sensing, downward or sideward looking sensors mounted on aircrafts are used to obtain images of the earth's surface.
- Very high spatial resolution images (20 cm or less) can be obtained through this.
- Less coverage area and high cost per unit area of ground coverage are the major disadvantages of airborne remote sensing.
- analog aerial photography, videography, thermal imagery and digital photography are commonly used.

- In space-borne remote sensing, sensors mounted on space shuttles or satellites orbiting the Earth are used.
- There are several remote sensing satellites (Geostationary and Polar orbiting) providing imagery for research and operational applications.
- The main advantages of space-borne remote sensing are large area coverage, less cost per unit area of coverage, continuous or frequent coverage of an area of interest, automatic/ semiautomatic computerized processing and analysis.

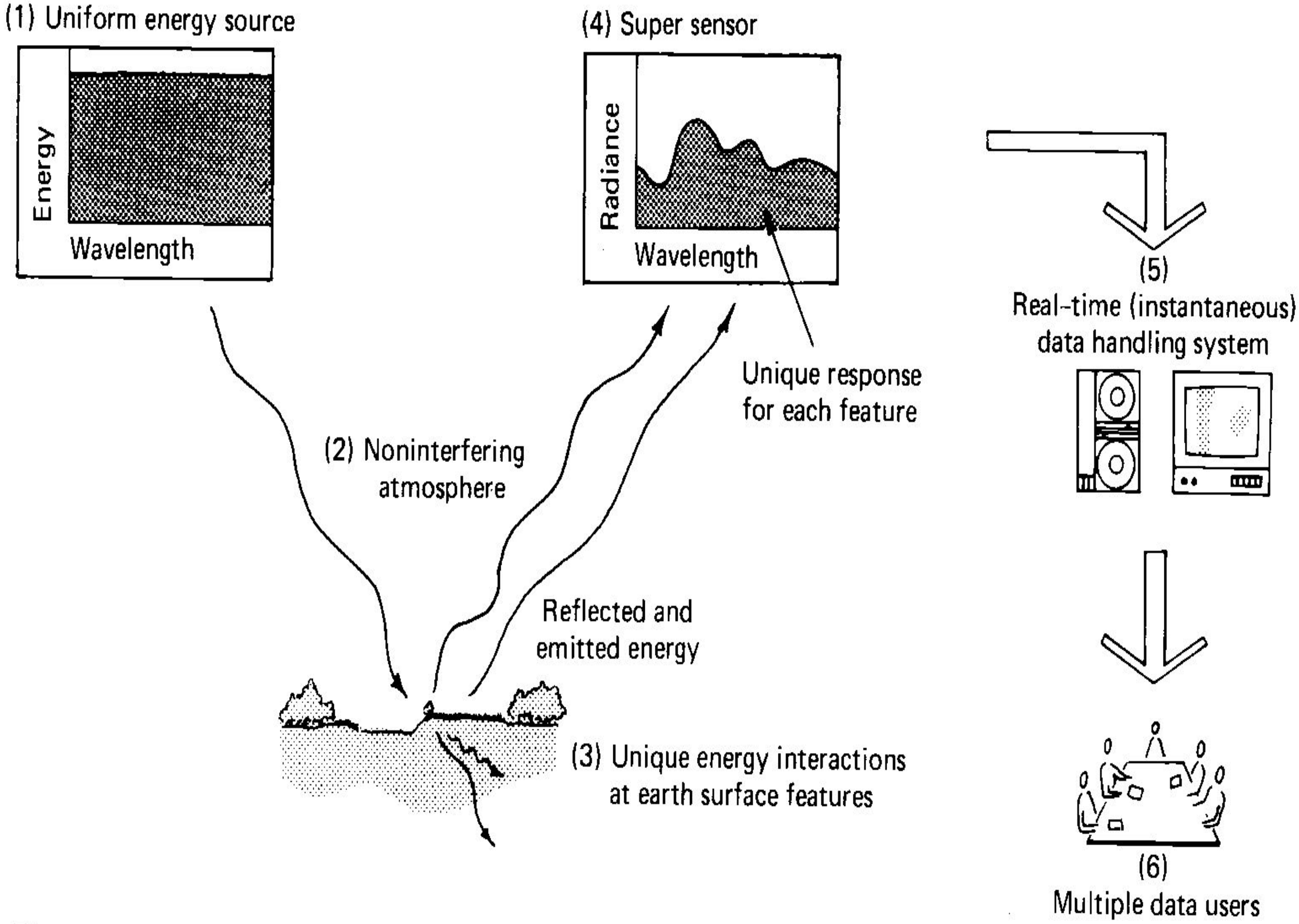
- Landsat satellites, Indian remote sensing (IRS) satellites, IKONOS, SPOT satellites, AQUA and TERRA of NASA and INSAT satellite series are a few examples.

IDEAL REMOTE SENSING SYSTEM

- A Uniform Energy Source -which provides energy over all wavelengths, at a constant, known, high level of output
- A Non-interfering Atmosphere- which will not modify either the energy transmitted from the source or emitted (or reflected) from the object in any manner.
- A Series of Unique Energy/Matter Interactions at the Earth's Surface - which generate reflected and/or emitted signals that are selective with respect to wavelength and also unique to each object or earth surface feature type.

- A Super Sensor which is highly sensitive to all wavelengths. A super sensor would be simple, reliable, accurate, economical, and requires no power or space. This sensor yields data on the absolute brightness (or radiance) from a scene as a function of wavelength.
- A Real-Time Data Handling System which generates the instance radiance versus wavelength response and processes into an interpretable format in real time. The data derived is unique to a particular terrain and hence provide insight into its physical-chemical-biological state.

- Multiple Data Users having knowledge in their respective disciplines and also in remote sensing data acquisition and analysis techniques. The information collected will be available to them faster and at less expense. This information will aid the users in various decision making processes and also further in implementing these decisions.


(1) Uniform energy source
Energy
Wavelength
(4) Super sensor
Radiance
Wavelength
Unique response
for each feature
(5)
Real-time (instantaneous)
data handling system
(2) Noninterfering
atmosphere
Reflected and
emitted energy
(3) Unique energy interactions
at earth surface features
(6)
Multiple data users

REAL REMOTE SENSING SYSTEM

RESOLUTION

- In order for a remote sensor to collect and record energy reflected or emitted from a target area, it must reside on a stable platform.
- Platforms for remote sensors may be situated on the ground, on an aircraft, or on a spacecraft or satellite.
- The quality of remote sensing images acquired by theses sensors is affected by many factors including the orbit and speed of platforms and sensor characteristics.

- resolution is the amount of details that can be observed in an image
- to represent the resolving power, which includes not only the capability to identify the presence of two objects, but also their properties
- an image that shows finer details is said to be of finer resolution compared to the image that shows coarser details.

TYPES OF RESOLUTION

- Spatial resolution (what area and how detailed)
- Spectral resolution (what colors – bands)
- Temporal resolution (time of day/season/year)
- Radiometric resolution

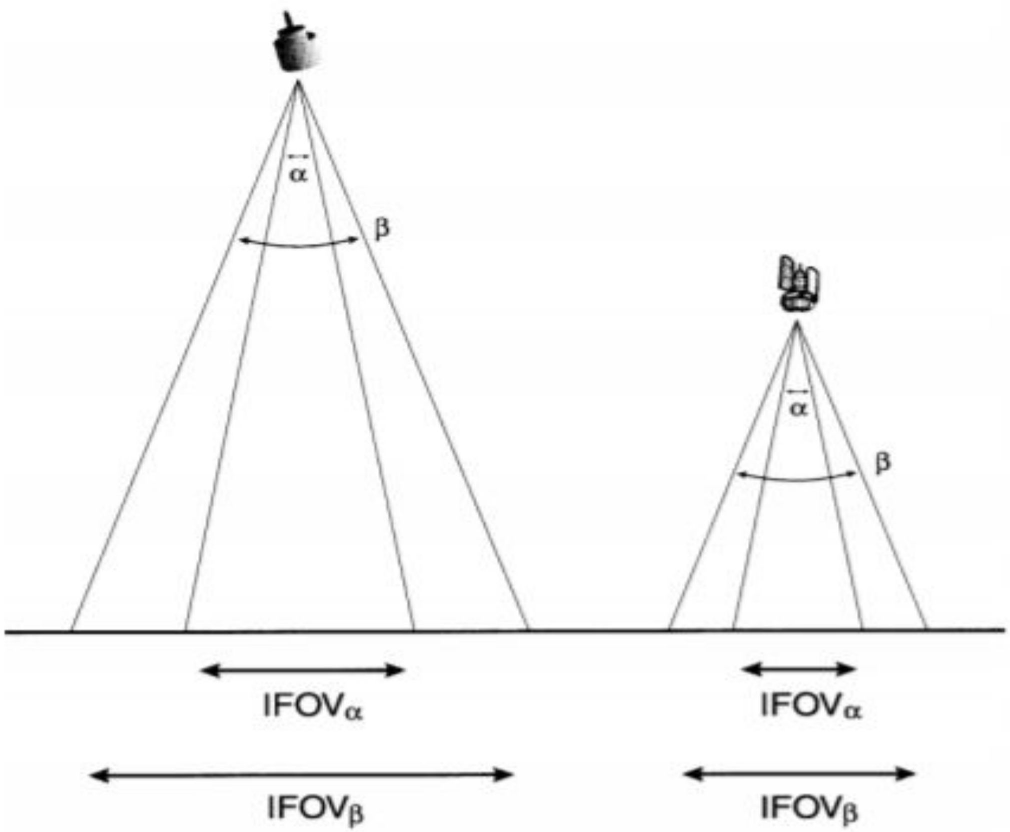
SPATIAL RESOLUTION

- The earth surface area covered by a pixel of an image is known as spatial resolution
- a measure of the spatial detail in an image, which is a function of the design of the sensor and its operating altitude above the surface.
- spatial resolution is most commonly expressed as the size of the ground sample.

Coarse Spatial Resolution

Fine Spatial Resolution

- A measure of size of pixel is given by the Instantaneous Field of View (IFOV).
- The IFOV is the angular cone of visibility of the sensor, or the area on the Earth's surface that is seen at one particular moment of time.
- IFOV is dependent on the altitude of the sensor above the ground level and the viewing angle of the sensor.


α
β
α
β
IFOVα
IFOVβ
IFOVα
IFOVβ

- It can be seen that viewing angle β being greater than the viewing angle α, IFOVβ is greater than IFOVα.
- IFOV also increases with altitude of the sensor
- IFOVβ and IFOVα of the sensor at smaller altitude are less compared to those of the higher altitude sensor.

- The size of the area viewed on the ground can be obtained by multiplying the IFOV (in radians) by the distance from the ground to the sensor.

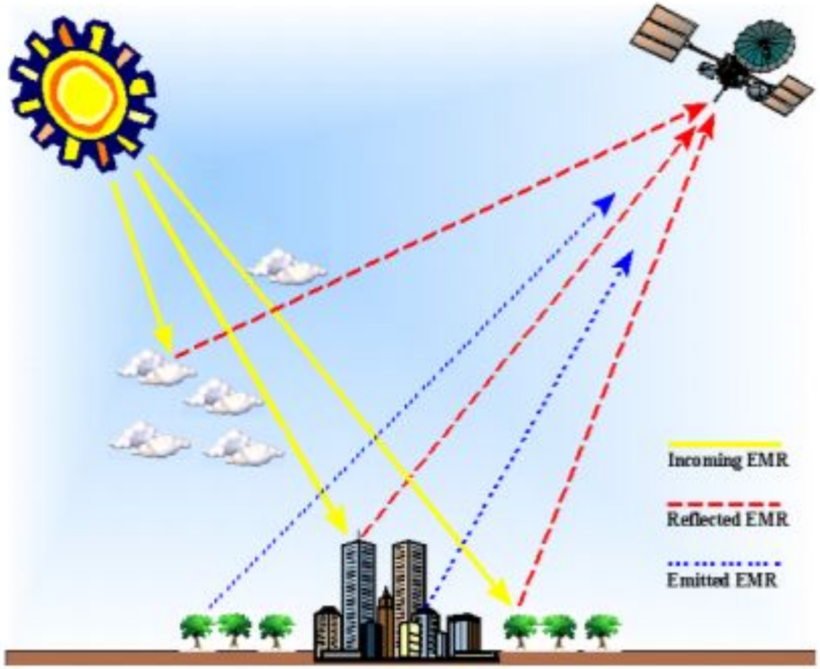
Area = IFOV x distance from the ground to the sensor

- This area on the ground is called the ground resolution or ground resolution cell.
- It is also referred as the spatial resolution of the remote sensing system.

SPECTRAL RESOLUTION

- The spectral resolution may be defined as the ability of a sensor to define fine wavelength intervals or the ability of a sensor to resolve the energy received in a spectral bandwidth to characterize different constituents of earth surface.
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

Spectral Response Curve

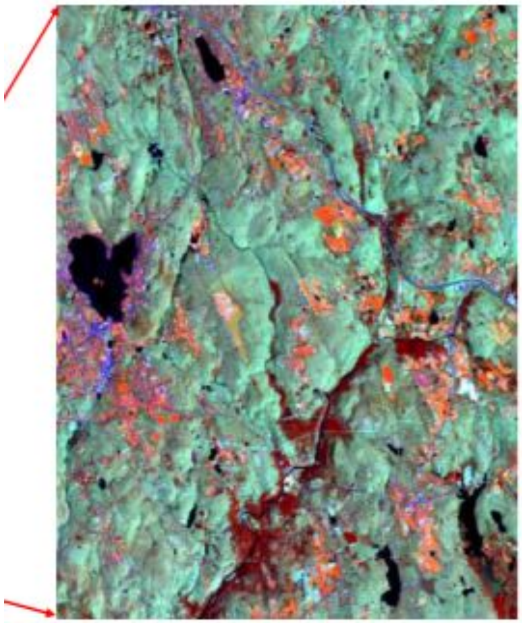


EMR patterns are recorded by sensors with separated spectral bands.

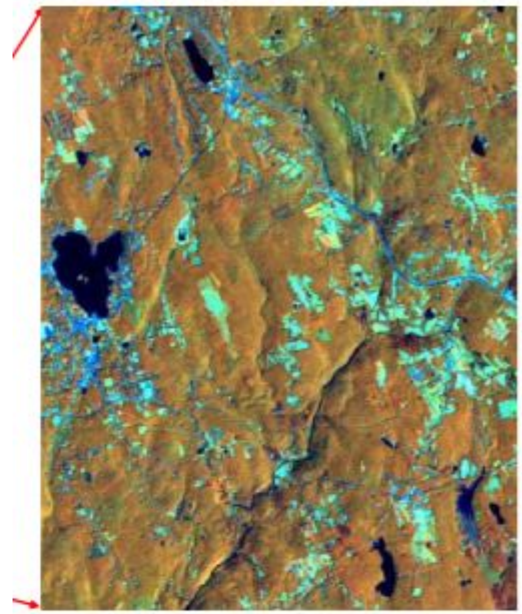
http://www.cas.sc.edu/geog/rslab/Rscc/mod1/emrpaths.gif

TEMPORAL RESOLUTION

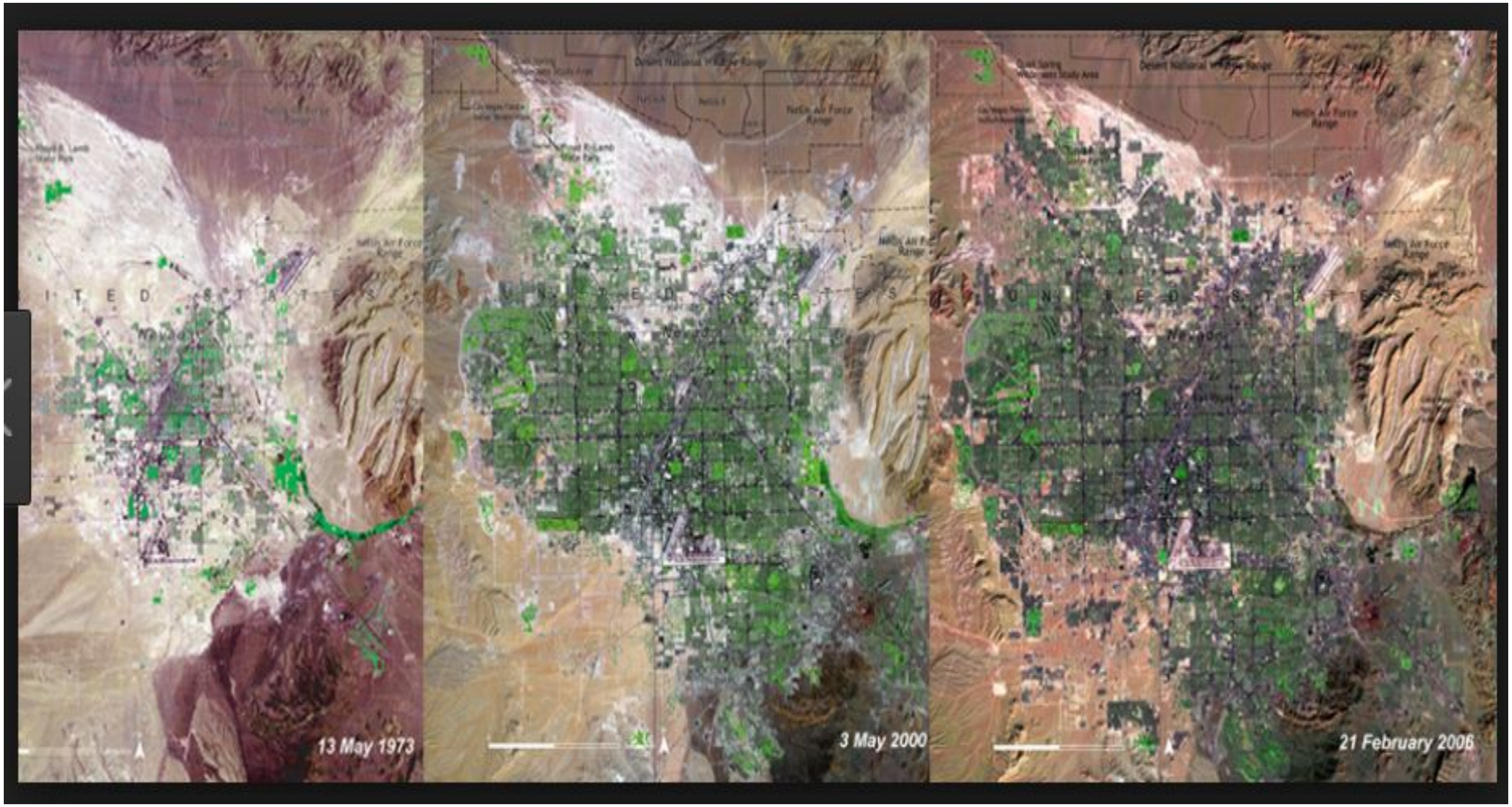
- Temporal resolution describes the number of times an object is sampled or how often data are obtained for the same area



Spring - bands 4,5,3



Summer - bands 4,5,3


13 May 1973
3 May 2000
21 February 2006