Basics of Remote Sensing

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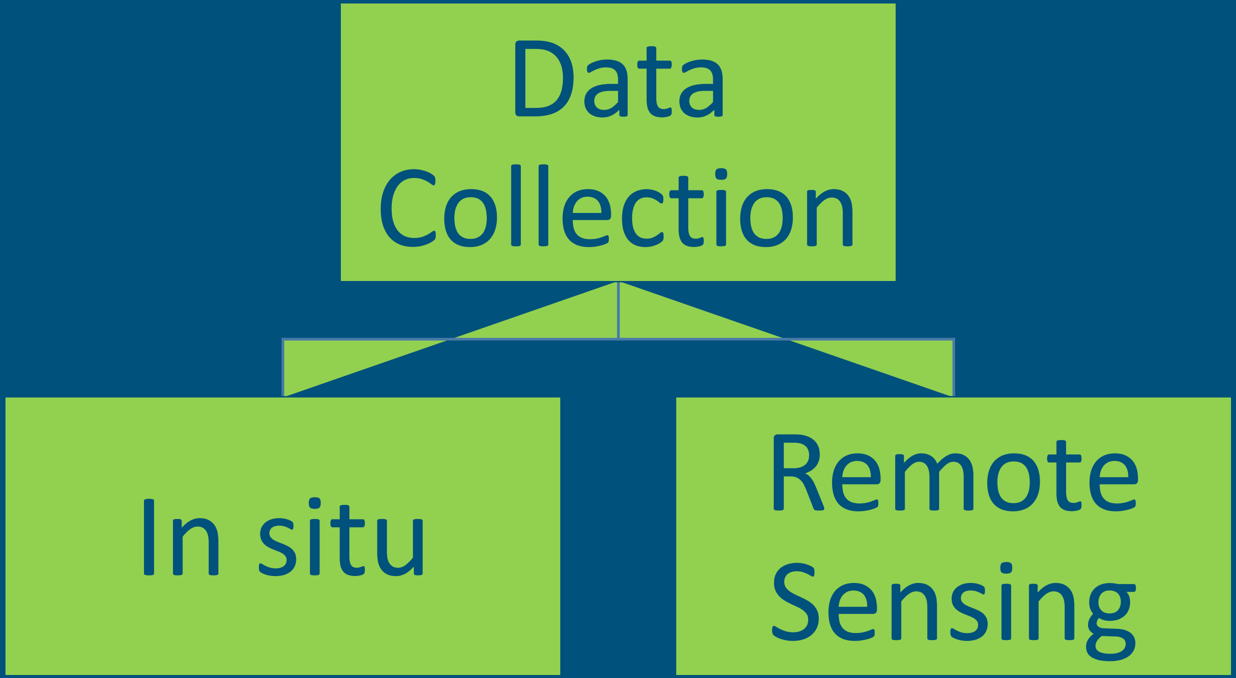
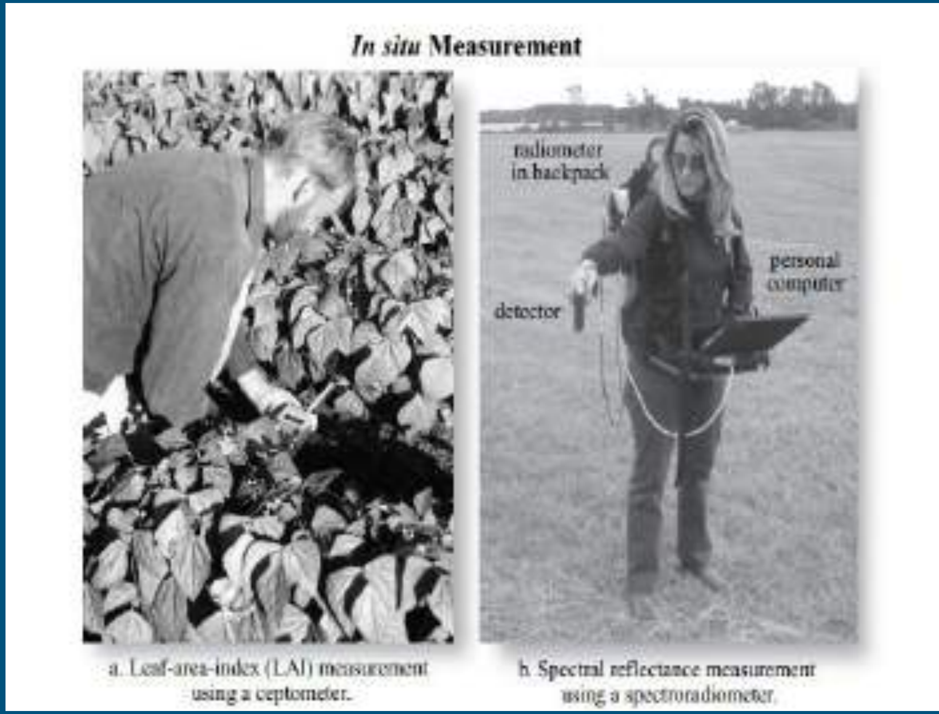
How can we collect information from an object?

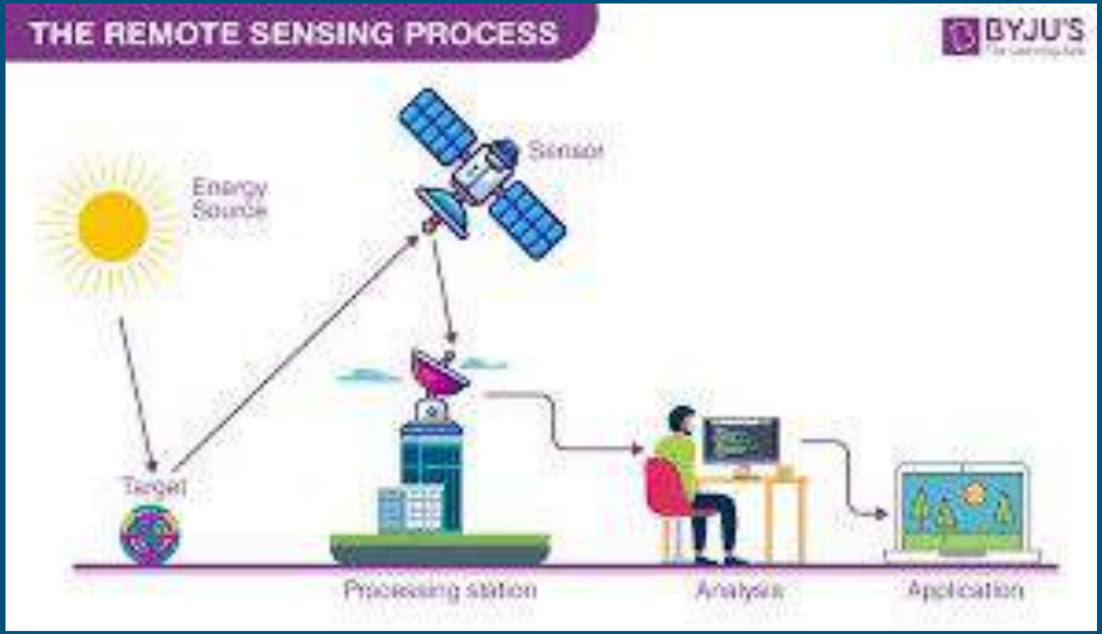
We collect information from an object using In situ collection techniques (collected directly from the field) and Remote sensing techniques.





What is Remote Sensing?

- ‘Remote’ means far away, and ‘sensing’ means observing or acquiring information. Remote sensing means acquiring information of things from a distance.



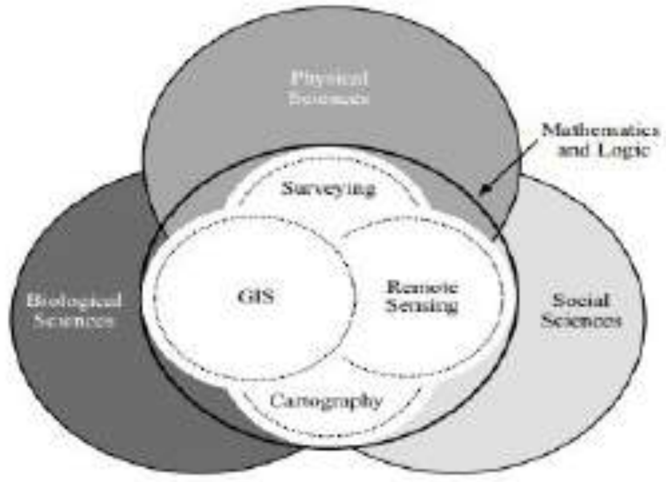


Figure 3 Interaction model depicting the relationship of the geographic information sciences (remote sensing, geographic information systems, cartography, and surveying) as they relate to mathematics and logic and the physical, biological, and social sciences.

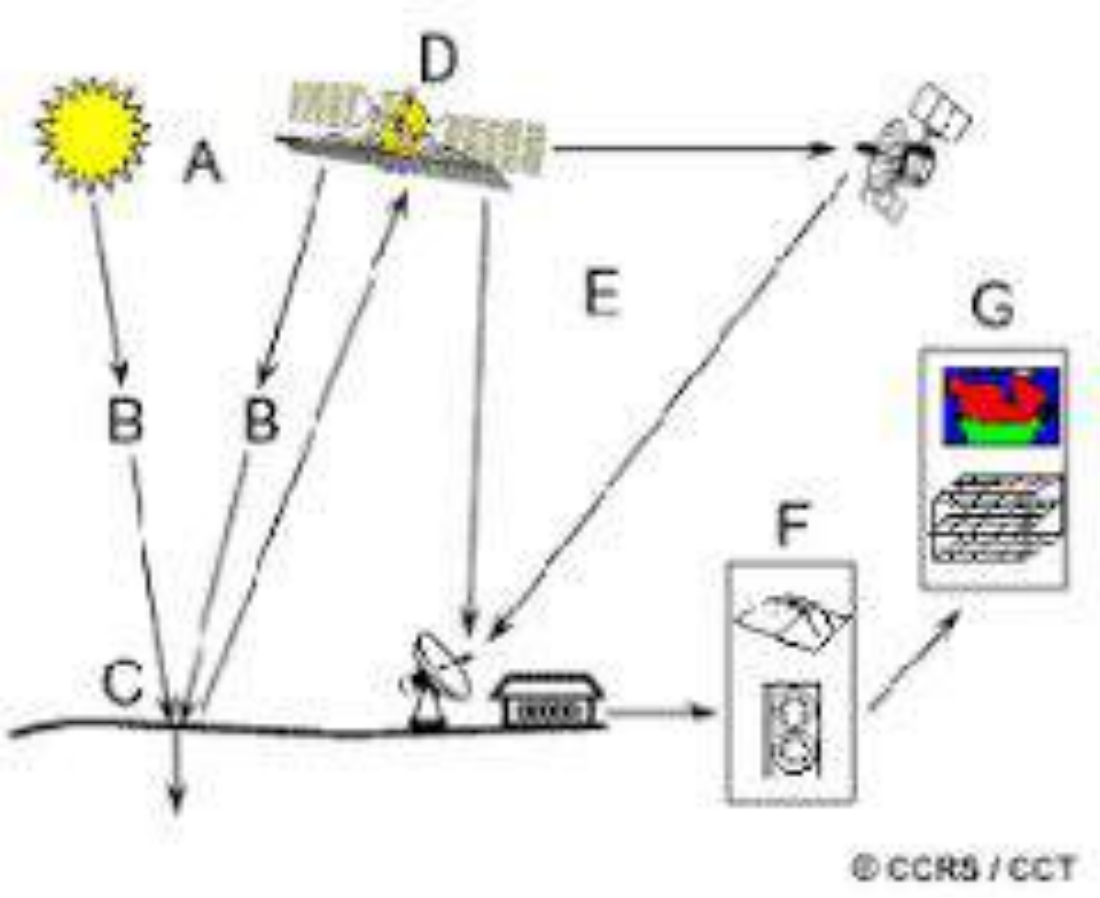
Definition:

- The art and science of obtaining information about an object without being in direct contact with the object. (J.R. Jensen,2000)
- Remote sensing is the process of obtaining information about an object or phenomenon without coming into physical contact with it. (ASPRS)
- Remote sensing is the science and art of acquiring information about the Earth's surface from a distance. (USGS)

How does Remote Sensing works?

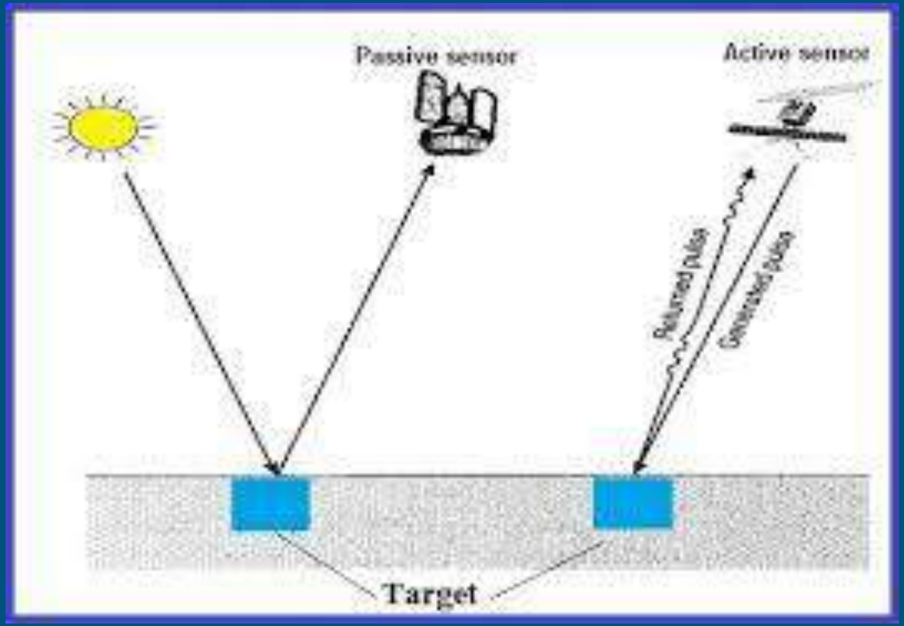
Here the different process of remote sensing (passive remote sensing)-

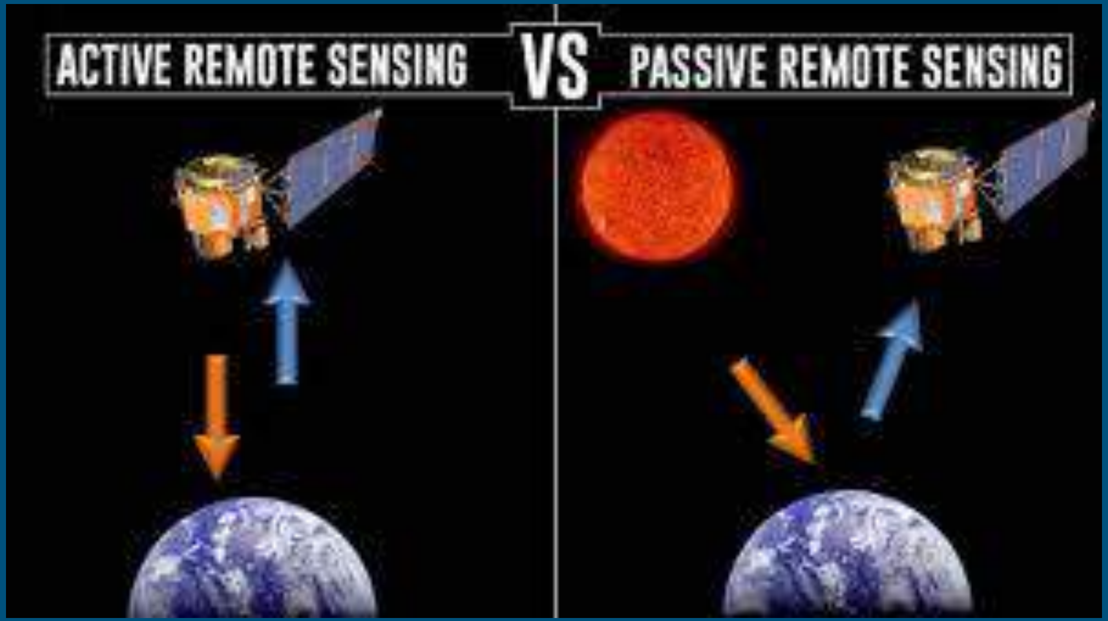
A. Radiation by energy source
B. Interaction with the earth atmosphere
C. Interaction with the target
D. Recording of energy by the sensor
E. Transmission, reception and processing
F. Interpretation and analysis
G. Applications



A. Radiation by energy source:

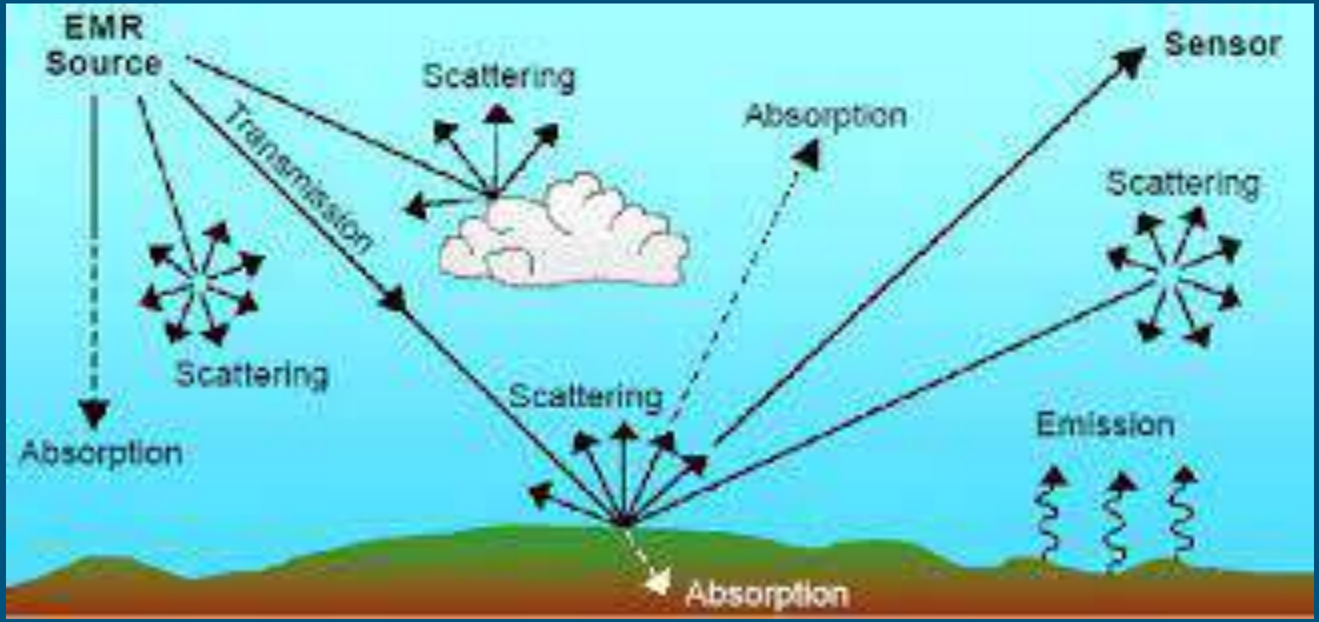
- The first requirement of remote sensing is to have an energy source that illuminates or radiates electromagnetic energy to the target of interest. The sun is the most common energy source for remote sensing, but other sources can be used such as lasers and radar.





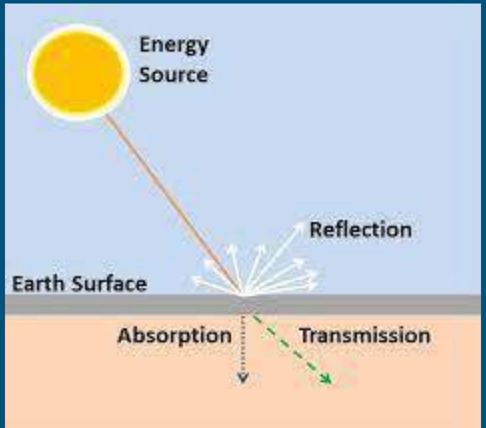
B. Interaction with the earth atmosphere:

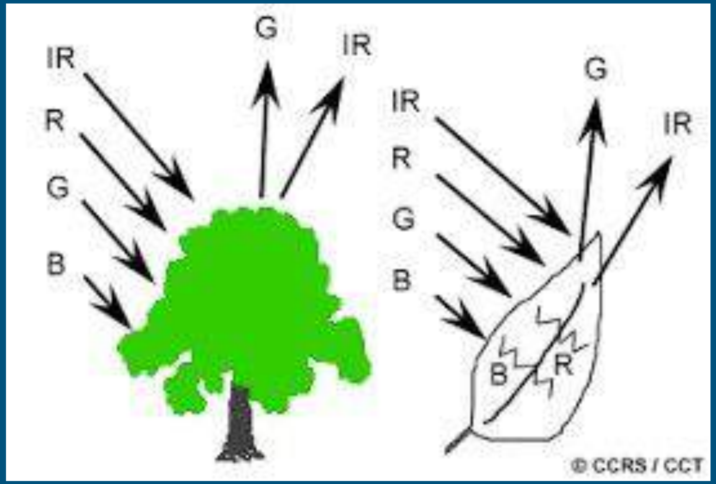
Once the energy reaches the Earth's atmosphere, it interacts with various gases, particles, and molecules. Some energy is absorbed, scattered, or reflected by the atmosphere before it reaches the Earth's surface.



C. Interaction with the Target:

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 radiation. The target can absorb, reflect, or transmit the energy. The amount of energy that is absorbed, reflected, or transmitted will depend on the target's surface characteristics, such as its color, roughness, and moisture contents.





D. Recording of energy by the sensor:

A sensor is used to collect and record the EMR that is reflected or emitted from the target. The sensor converted the radiation into a digital signal that can be processed and analyzed.

E. Transmission, reception and processing:

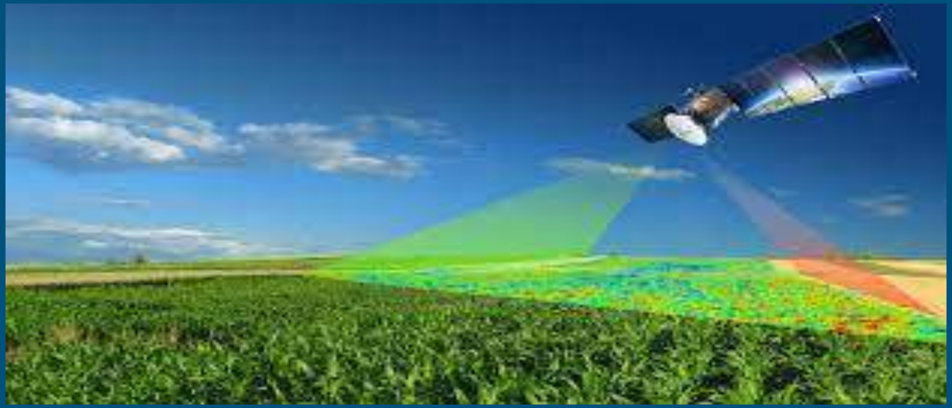
The energy recorded by the sensor is transmitted in electronic form to a ground station. The digital signal from the sensor is processed to remove noise to enhance the image.

F. Interpretation and analysis:

The analyst interprets the image and analyze the information to identify features of interest and to understand the spatial and temporal pattern of the target.

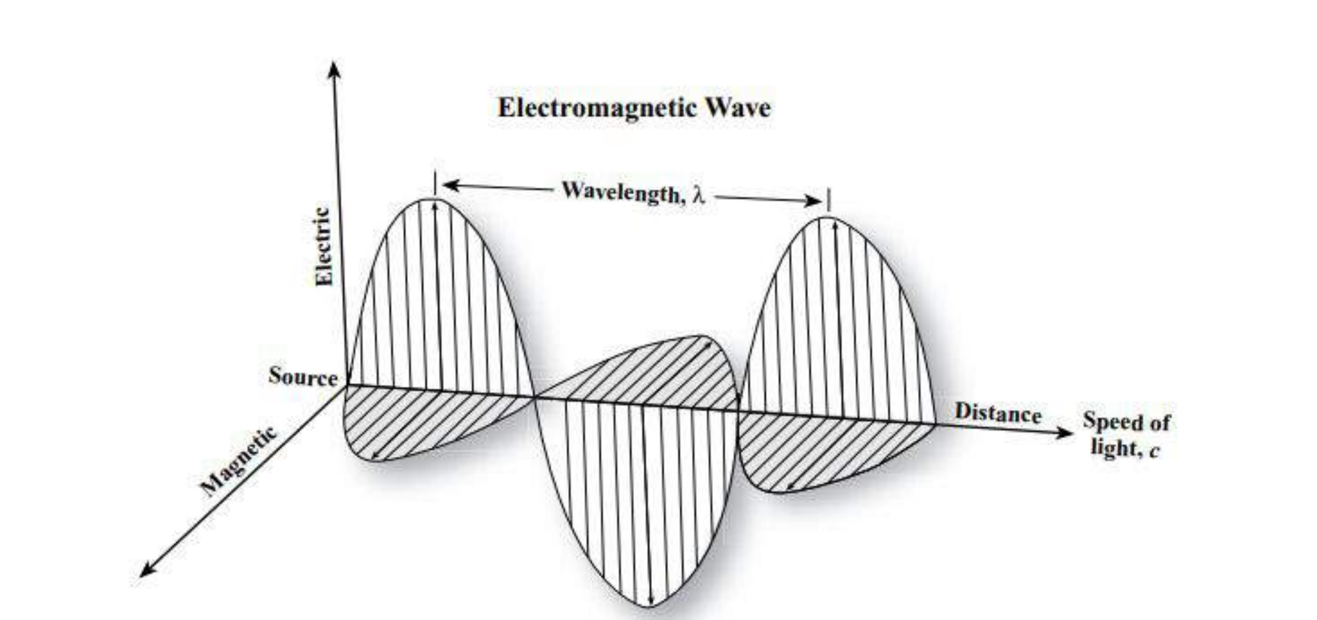
G. Application:

The information from the remote sensing image can be used to make a variety of decisions, such as land use planning, environmental monitoring and disaster management.



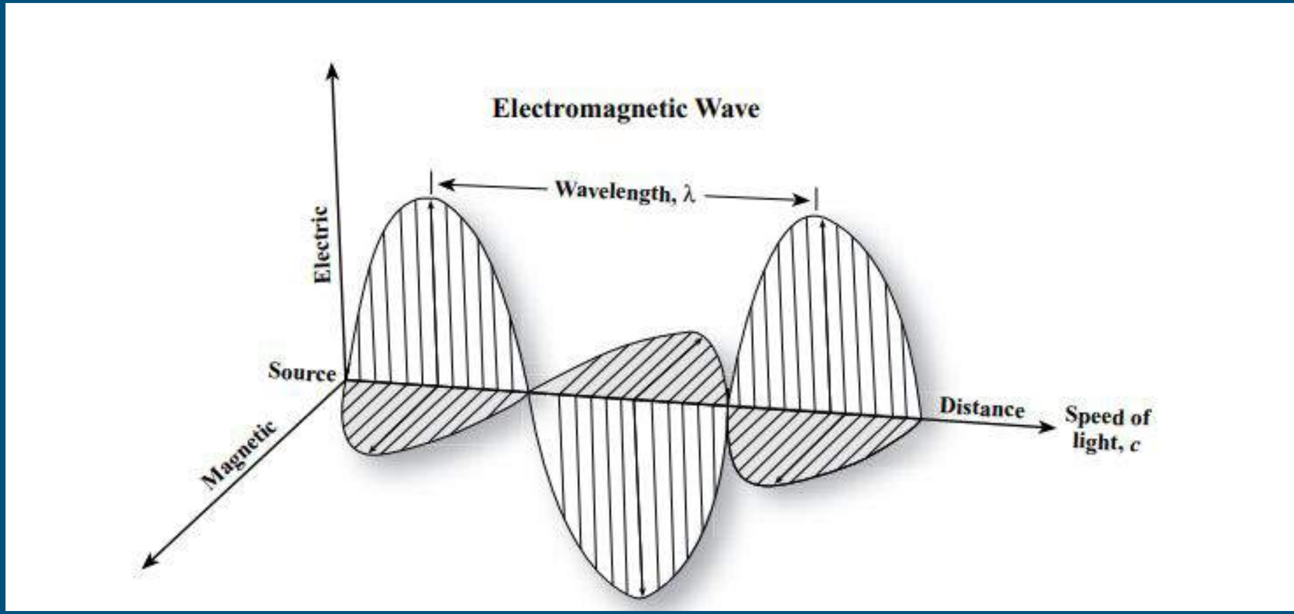
Electromagnetic radiation (EMR)

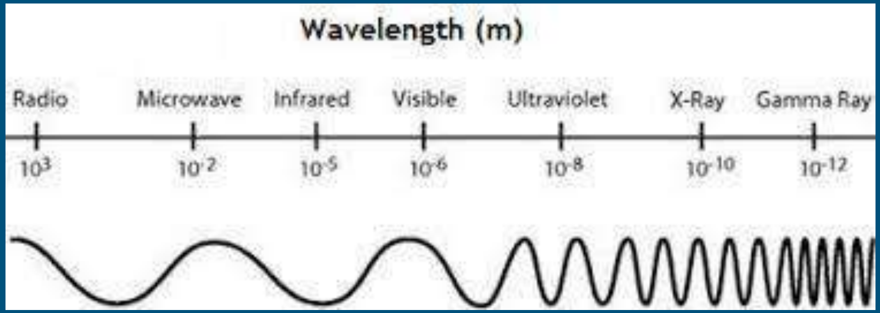
- Electromagnetic radiation is a form of energy that travels through space as waves.
- It consist of oscillating electric and magnetic fields that are perpendicular to each other and to the direction of propagation.
- EMR can travel through a vacuum, as well as through matter with the speed of light.



Wavelength & Frequency of EMR

- Wavelength (λ) is the distance between two consecutive peaks of the wave.
- Frequency (v) is the number of waves that pass a given point in a second.



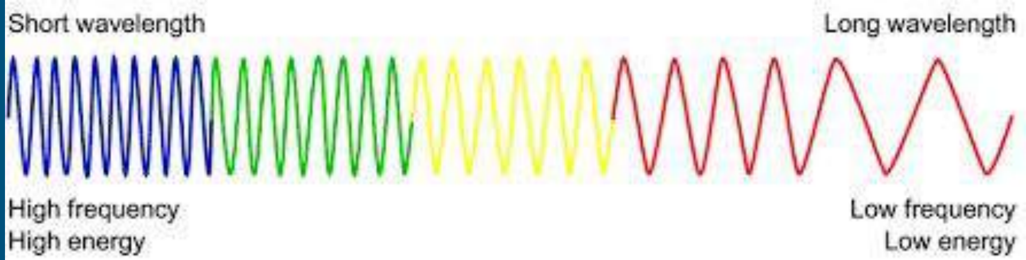


Wavelength-frequency relationship

- Frequency and wavelength is inversely proportional to each other. This mean waves with shorter waves with shorter wavelength have higher frequency, and wave with longer wavelength have lower frequency.
- The equation that describe the relationship between frequency and wavelength in EMR is –

$$c = \lambda\nu$$

where, C = speed of light, λ = wavelength, and ν = frequency



- The energy of an EMR wave is proportional to its frequency and inversely proportional to its wavelength.

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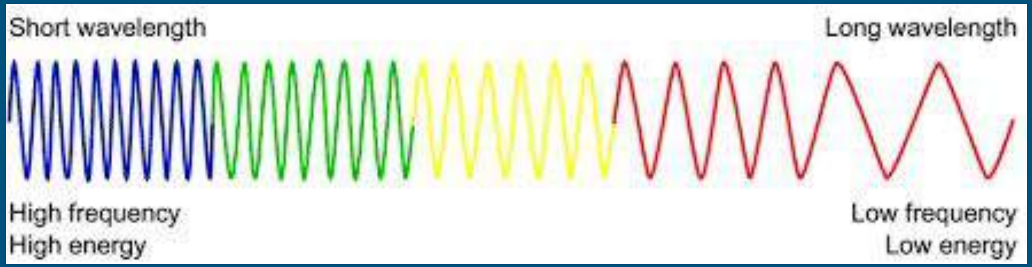

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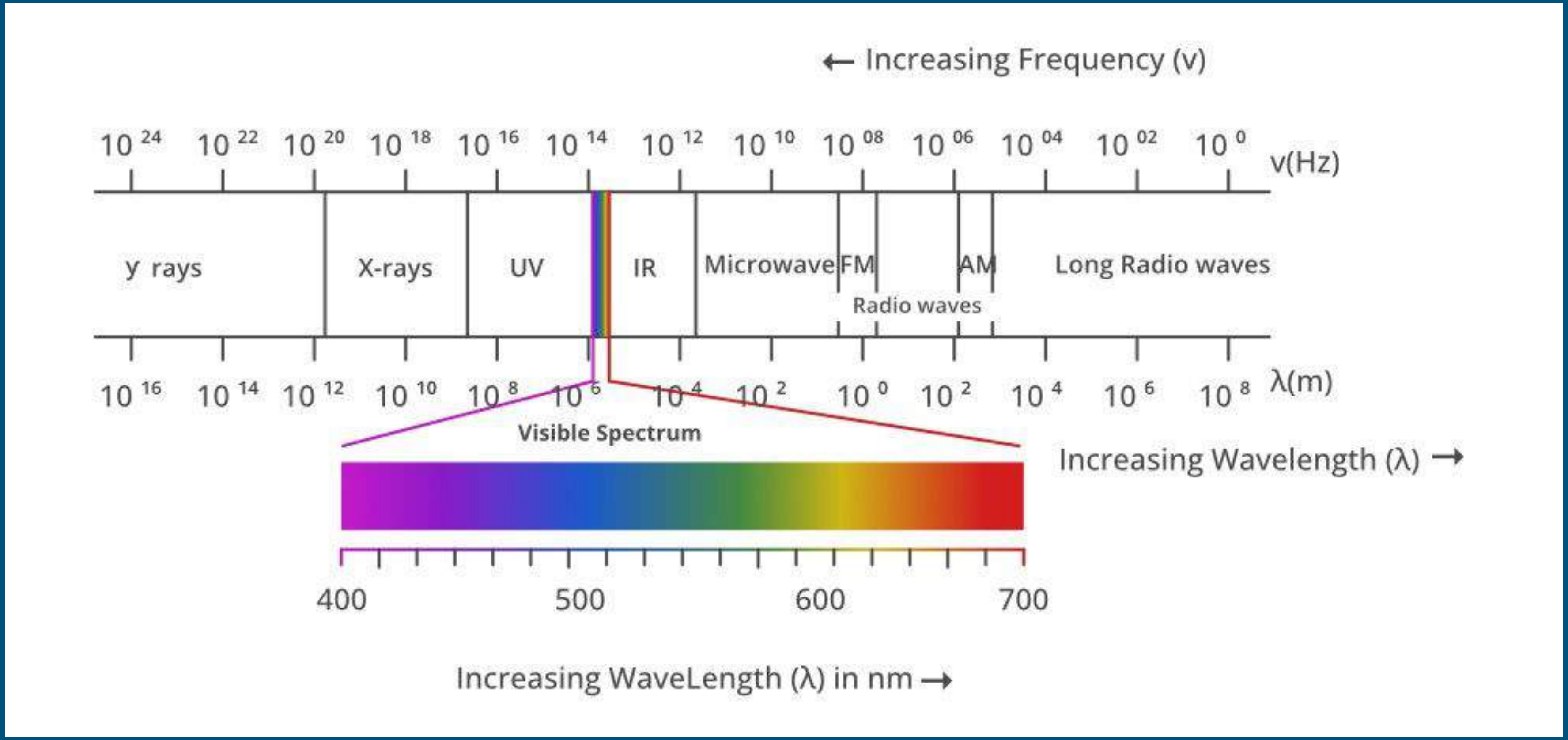
Electromagnetic spectrum

The electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation.



Electromagnetic region

- **Gamma rays**: The shortest wavelength and highest frequency type of electromagnetic radiation. Gamma rays are emitted by radioactive materials and can be very dangerous to living tissue. They are used in cancer treatment and medical imaging.
- **X-rays**: Shorter wavelength than ultraviolet radiation. X-rays are used for medical imaging, security screening, and industrial radiography.
- **Ultraviolet radiation**: Shorter wavelength than visible light, but still with wavelengths that are longer than X-rays. Ultraviolet radiation is emitted by the sun and can cause sunburn and skin cancer. It is also used in tanning beds and germicidal lamps.

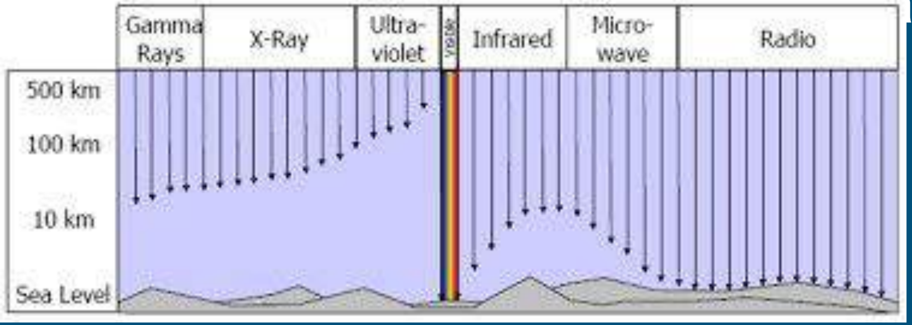
- **Visible light**: The range of electromagnetic radiation that can be detected by the human eye. Visible light is divided into seven colors: red, orange, yellow, green, blue, indigo, and violet.
- **Infrared radiation**: Shorter wavelength than microwaves, but still with wavelengths that are longer than visible light. Infrared radiation is emitted by warm objects and is used in heat lamps, night vision, and remote controls.
- **Microwaves:** Shorter wavelength than radio waves, but still with relatively long wavelengths. Microwaves are used for cooking, communication, and radar.
- **Radio waves**: The longest wavelength and lowest frequency type of electromagnetic radiation. Radio waves are used for communication, such as radio, television, and radar.

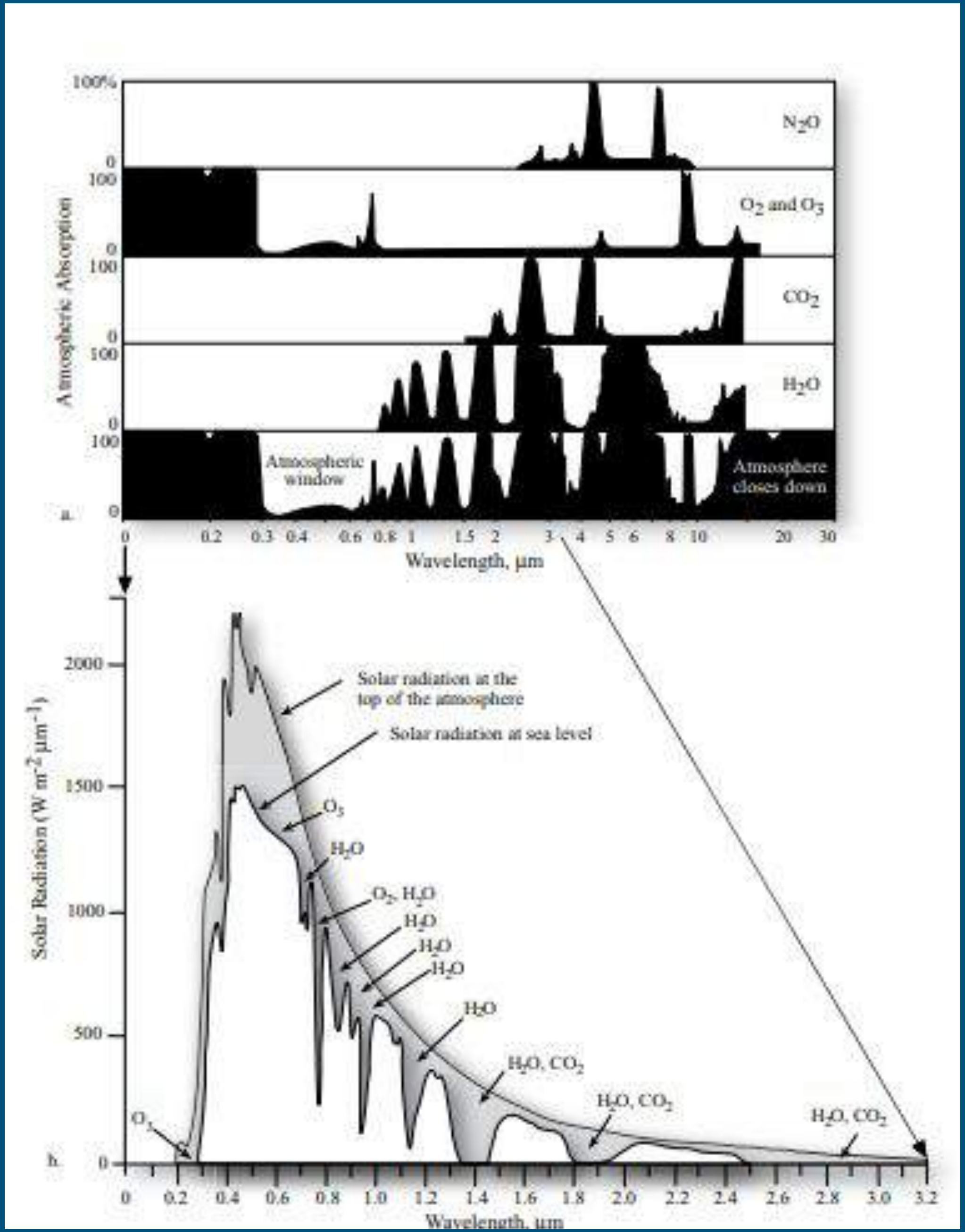
Energy interaction in the atmosphere

- Absorption: EMR can be absorbed by the gases and particles in the atmosphere. This is the most common interaction of EMR with the atmosphere. Absorption of EMR can heat the atmosphere, or it can be used to study the composition of the atmosphere.
- Reflection: EMR can be reflected off of the gases and particles in the atmosphere. This is why we can see the sun even though it is behind the atmosphere. Reflection of EMR can also be used to study the composition of the atmosphere.
- Transmission: EMR can pass through the atmosphere without being absorbed or reflected. This is how we can see stars and planets at night. Transmission of EMR can also be used to study the atmosphere, such as by using radar to detect clouds and precipitation.
- Scattering: EMR can be scattered by the gases and particles in the atmosphere. This is why the sky is blue. Scattering of EMR can also be used to study the atmosphere, such as by using lidar to measure the concentration of pollutants in the air.

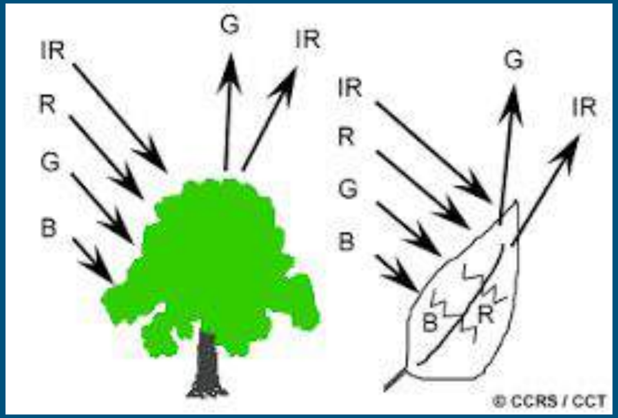
Atmospheric window

- An atmospheric window is a range of wavelengths of the electromagnetic spectrum that can pass through the atmosphere of Earth. The optical, infrared and radio windows comprise the three main atmospheric windows.
- The visible window is the range of wavelengths that can be detected by the human eye. It is from about 0.4 to 0.7 micrometers (µm).
- The infrared window is the range of wavelengths that are emitted by warm objects. It is from about 0.7 to 100 µm.
- The radio win ... are used for com ... about 1 mm t ...





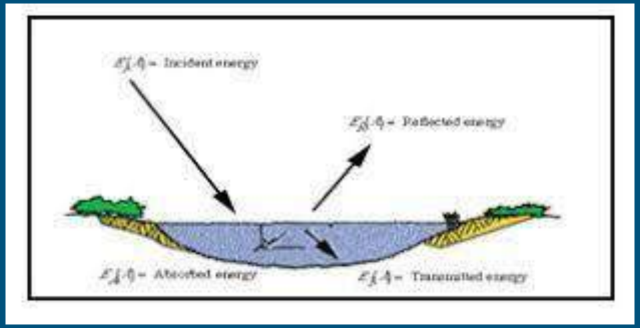
Interaction of EMR with matter

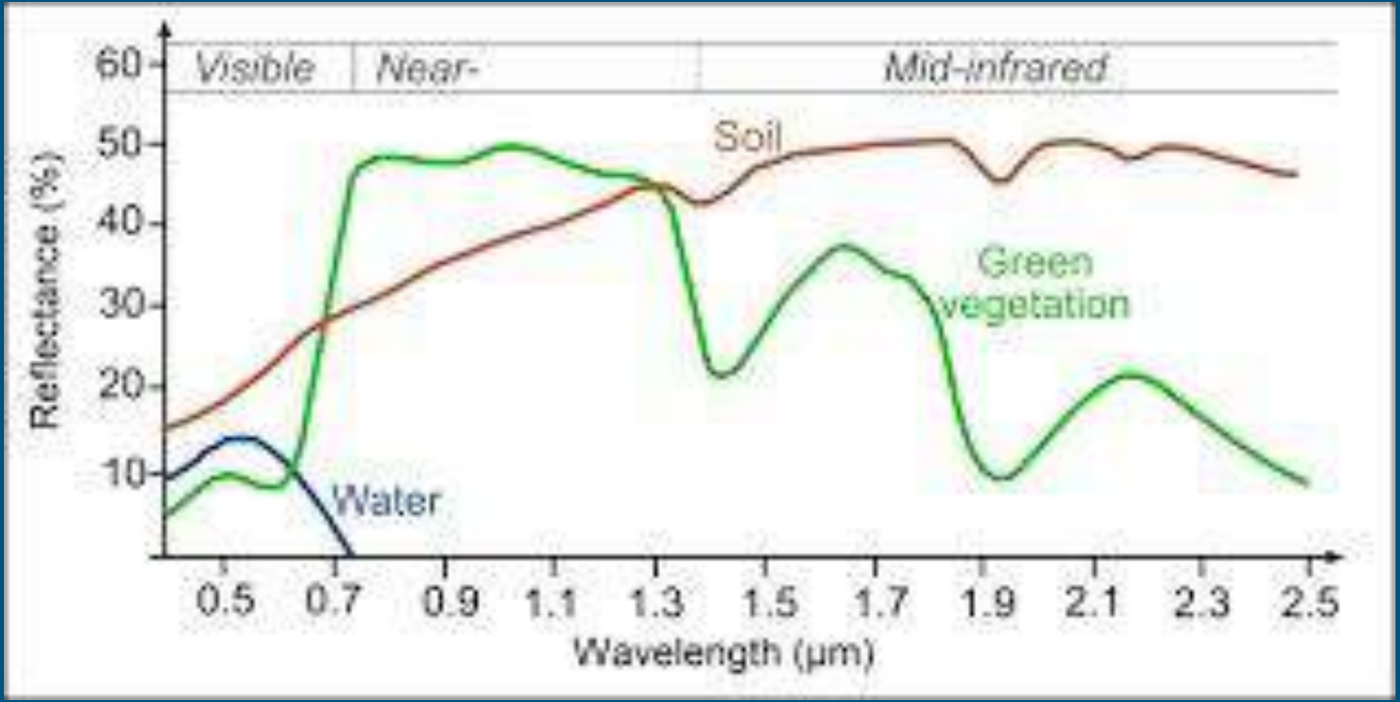


The interaction of EMR with earth surface features depends upon the wavelength of EMR, the properties of the earth surface features and the angle of incidence of the EMR.

Electromagnetic radiation (EMR) can interact with matter in four ways:

1. Absorption: EMR is absorbed by matter and converted into heat. This is the most common interaction of EMR with matter.
2. Reflection: EMR is reflected off of matter without being absorbed. This is why we can see objects.
3. Transmission: EMR passes through matter without being absorbed or reflected. This is how radio waves can travel through the air.
4. Scattering: EMR is scattered by matter in all directions. This is why the sky is blue.





Here are some specific examples of how EMR interacts with earth surface features:

- **Vegetation:** Vegetation absorbs EMR in the visible and near-infrared (NIR) regions of the spectrum. This is why plants appear green to our eyes. The chlorophyll in plant leaves absorbs red and blue light, but it reflects green light. Vegetation also absorbs EMR in the thermal infrared (TIR) region of the spectrum. This is how thermal imaging cameras can be used to detect vegetation at night.

- **Water:** Water absorbs EMR in the visible and NIR regions of the spectrum. This is why water appears blue to our eyes. Water also absorbs EMR in the TIR region of the spectrum. This is why thermal imaging cameras can be used to detect water at night.
- **Soil:** Soil absorbs EMR in the visible and NIR regions of the spectrum. The amount of EMR that is absorbed depends on the composition of the soil. Sandy soils absorb less EMR than clay soils. Soil also absorbs EMR in the TIR region of the spectrum. This is how thermal imaging cameras can be used to detect soil at night.
- **Agriculture land:** Agriculture land is a diverse mix of vegetation, soil, and water. The interaction of EMR with agriculture land depends on the specific crops that are being grown, the stage of growth of the crops, and the amount of moisture in the soil.

Concepts of bands

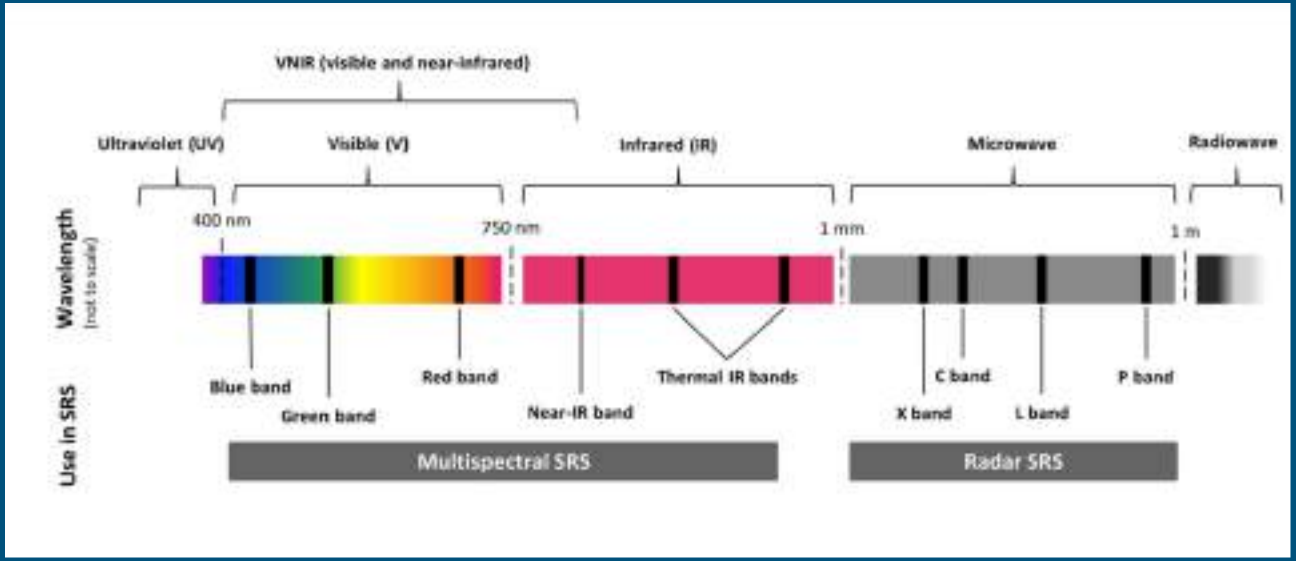
- In remote sensing, a band refers to a specific range of wavelengths of light that a sensor can detect.
- Remote sensing sensors are designed to detect specific bands of light.
- The choice of bands depends on the application.
- For example, a sensor designed to map vegetation will typically have bands that detect visible light and near-infrared light. A sensor designed to map water resources will typically have bands that detect thermal infrared light.

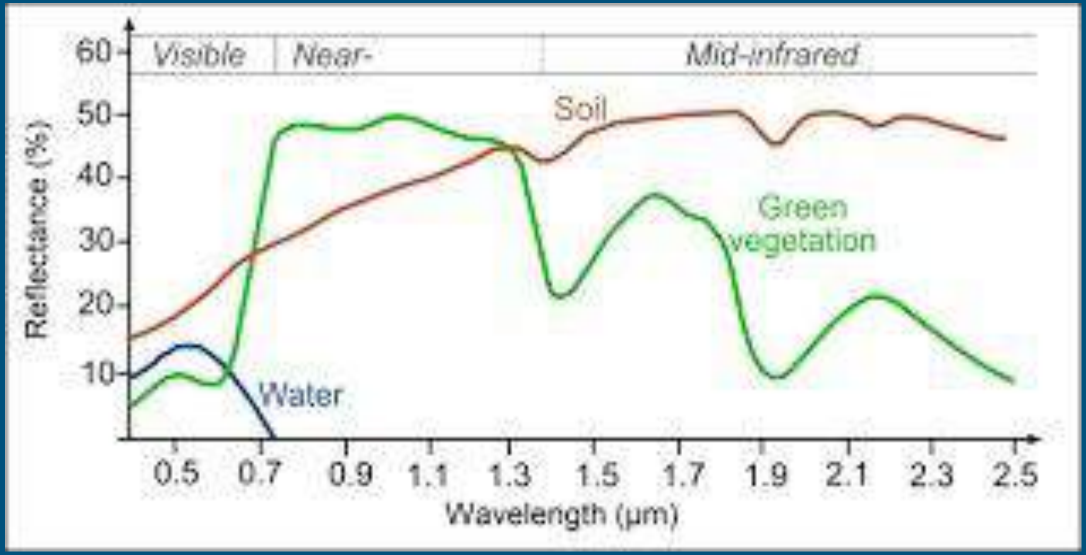
Bands

A band is a specific range of wavelengths in the electromagnetic spectrum that is detected by a remote sensor. The different bands are often referred to as "spectral bands" or "color bands".

The most common bands used in remote sensing are –

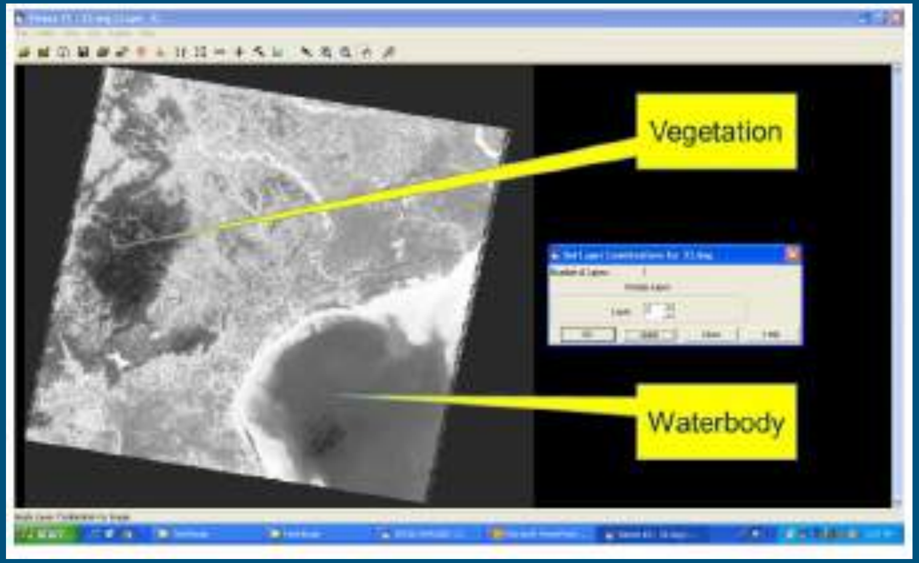
Visible (blue, green, red), near infrared, thermal infrared etc

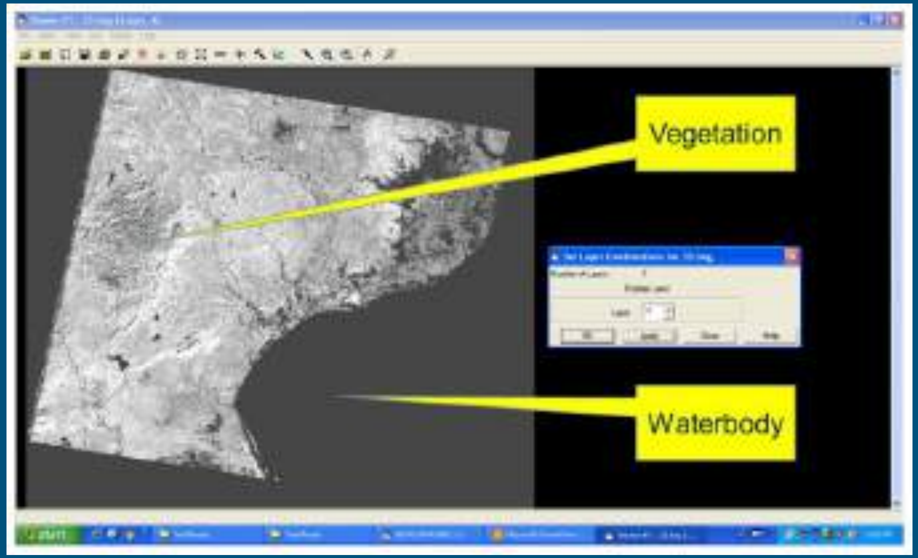




Bands of Landsat-8

- Band 1 Coastal Aerosol (0.43 - 0.45 µm) 30 m
- Band 2 Blue (0.450 - 0.51 µm) 30 m
- Band 3 Green (0.53 - 0.59 µm) 30 m
- Band 4 Red (0.64 - 0.67 µm) 30 m
- Band 5 Near-Infrared (0.85 - 0.88 µm) 30 m
- Band 6 SWIR 1(1.57 - 1.65 µm) 30 m
- Band 7 SWIR 2 (2.11 - 2.29 µm) 30 m
- Band 8 Panchromatic (PAN) (0.50 - 0.68 µm) 15 m
- Band 9 Cirrus (1.36 - 1.38 µm) 30 m
- Band 10 TIRS 1 (10.6 - 11.19 µm) 100 m
- Band 11 TIRS 2 (11.5 - 12.51 µm) 100 m

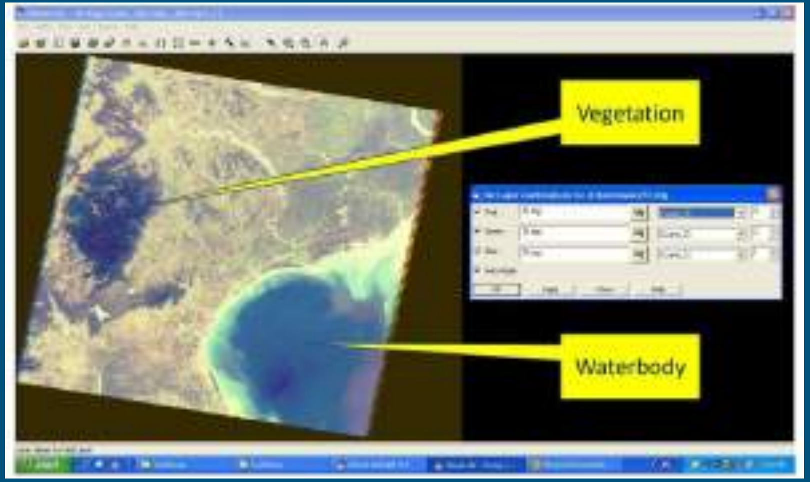




Color combination

- **True Color Composite (TCC) or real color composite**

Display color	Band color
Red (R)	red
Green (G)	green
Blue (B)	blue

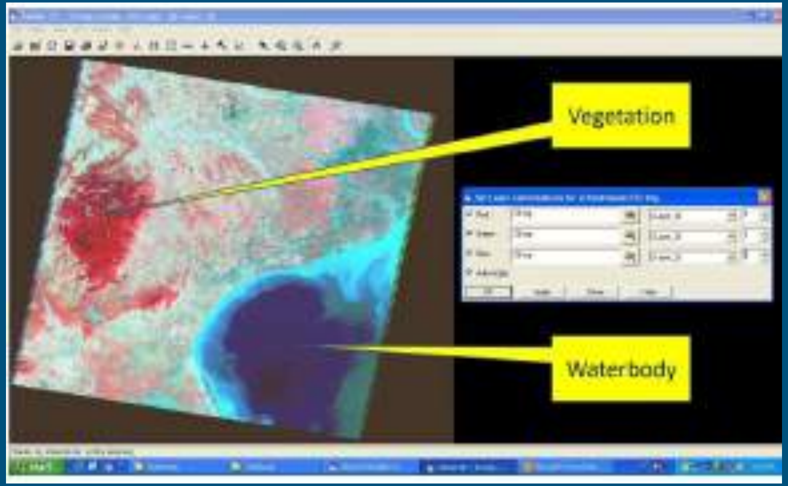


- **False color composite (FCC):**

Any other composite than true color composite

- Standard false color composite (SFCC):

Display color	Band color
Red (R)	Near infrared (NIR)
Green (G)	red
Blue (B)	green



Remote sensing platforms

A platform is the physical structure that supports a sensor and allows it to collect data about the Earth's surface. There are three main types of platforms:

1. Ground based platforms:

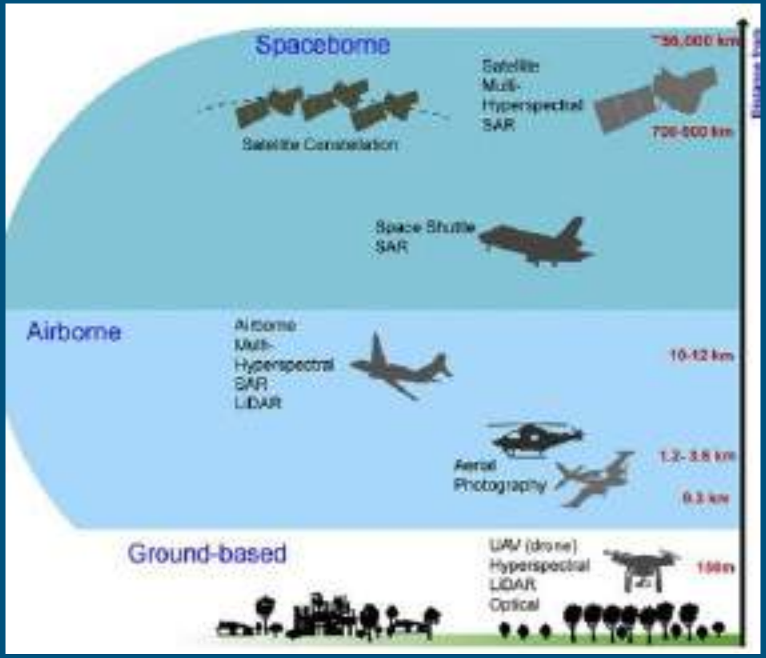
These platforms are located on the Earth's surface and can be used to collect data over a relatively small area. Ground-based platforms include towers, tripods, and aircraft.

2. Airborne platforms:

These platforms are located in the atmosphere and can be used to collect data over a larger area than ground-based platforms. Airborne platforms include aircraft, balloons, and drones.

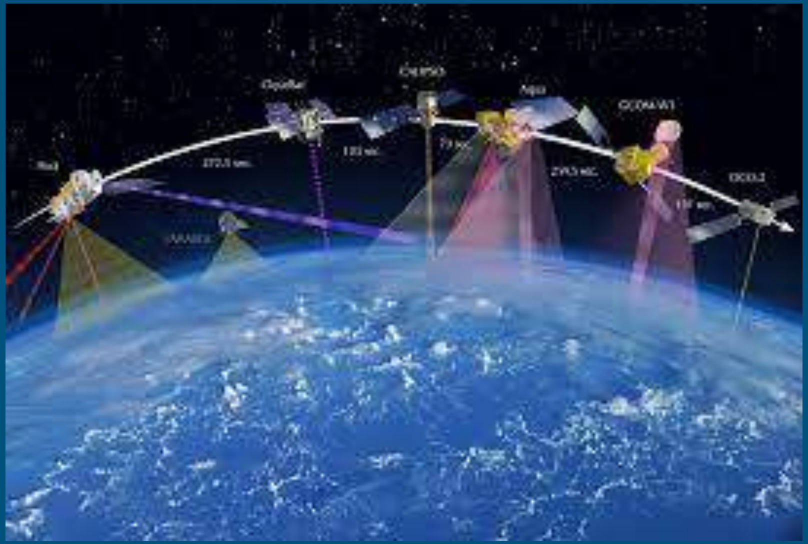
3. Speceborne platforms:

These platforms are located in space and can be used to collect data over the entire Earth. Spaceborne platforms include satellites.



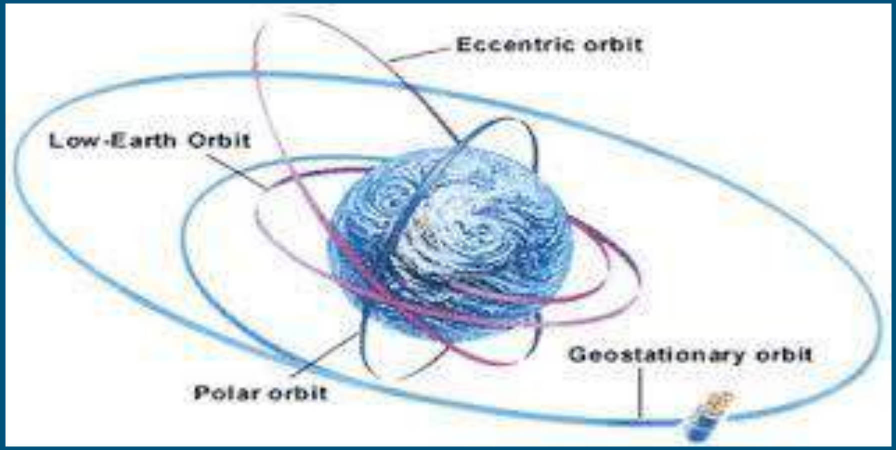
Satellites

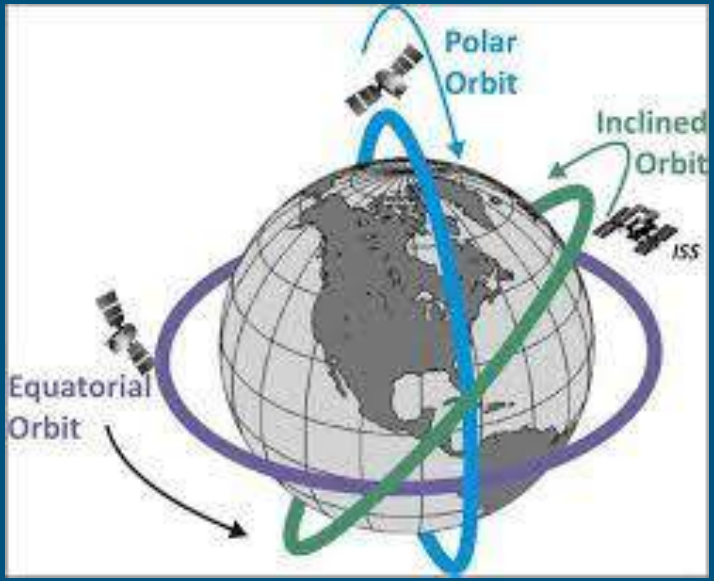
- A satellite is an object that orbits another object in space. Most satellites are artificial, meaning that they are made by humans. However, there are also natural satellites, such as the moon.



Satellites orbits

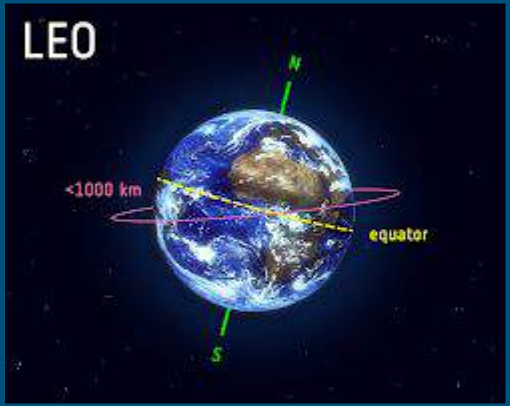
The orbit of a satellite is the path it takes around a planet or other celestial body. The shape of the orbit, its distance from the body it is orbiting, and its speed are all determined by the gravitational pull of the body and the initial velocity of the satellite.

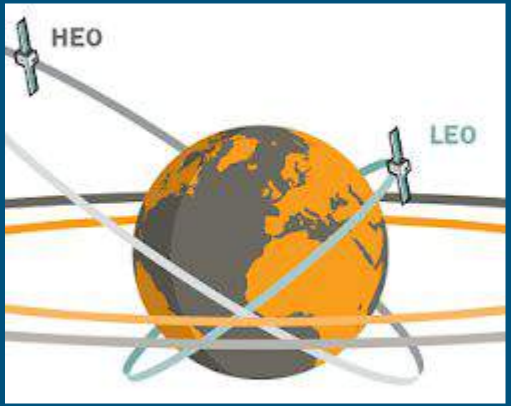


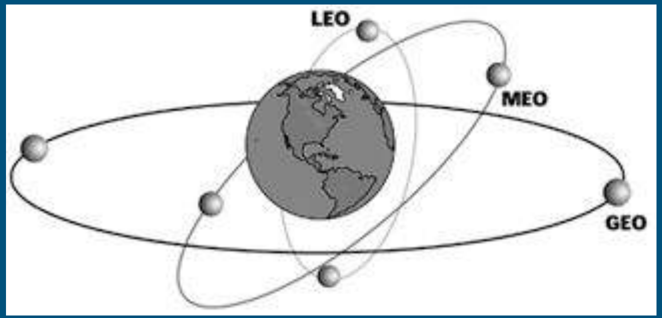


Different satellite orbits

	Low Earth Orbit (LEO)	Medium Earth Orbit (MEO)	High Earth Orbit (HEO)
Altitude	100 to 2,000 kilometers	2,000 to 35,786 kilometers	35,786 kilometers or more
Time periods	90 to 120 minutes	2 to 24 hours	12 to 24 hours
Applications	Communication, Earth observation, scientific research	Navigation, communication	Scientific research, missile early warning, communications

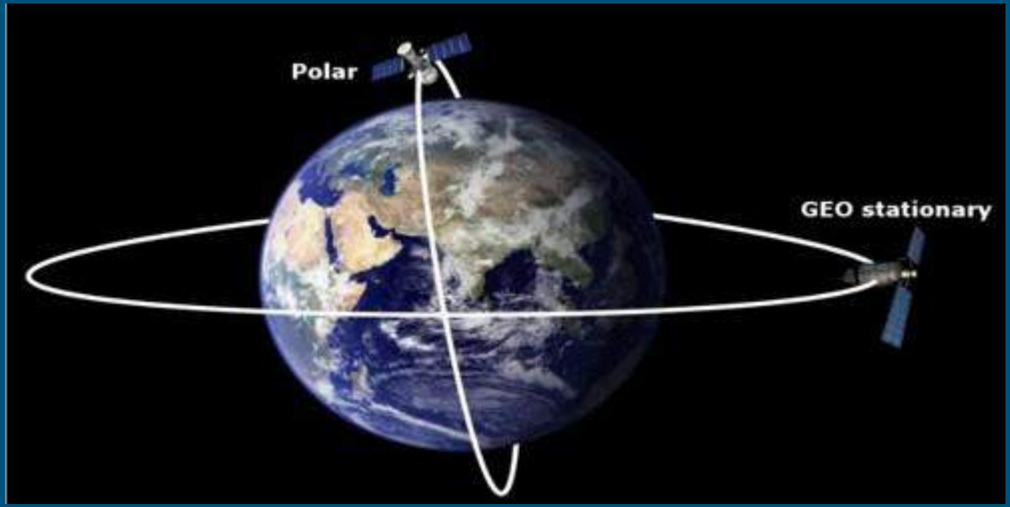






Equatorial orbits

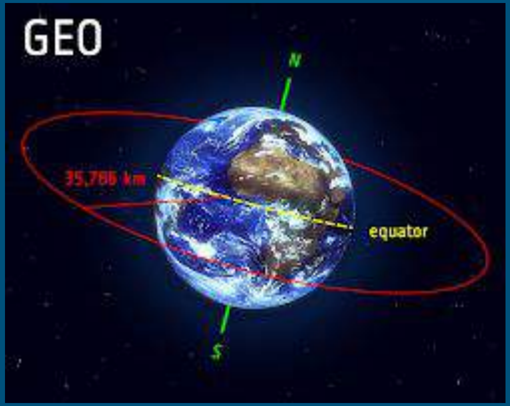
1. Pass over the equator of the Earth.
2. Inclination is 0^0
3. Altitude 200 km – 36000 km
4. Time period 2 – 24 hours
5. Global coverage
6. Communication, weather forecasting.

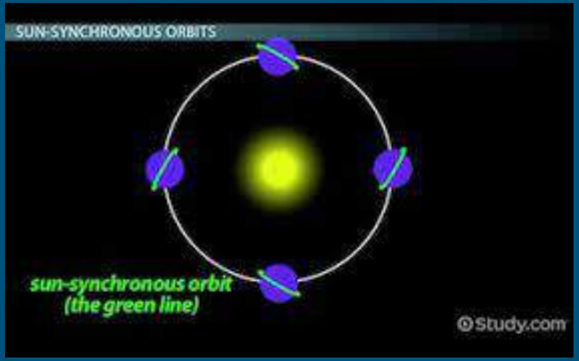


Polar orbits

1. pass over the poles of the Earth.
2. Inclination is 90^0
3. Altitude 700-1000 km
4. Time period 90-120 minutes
5. Earth observation

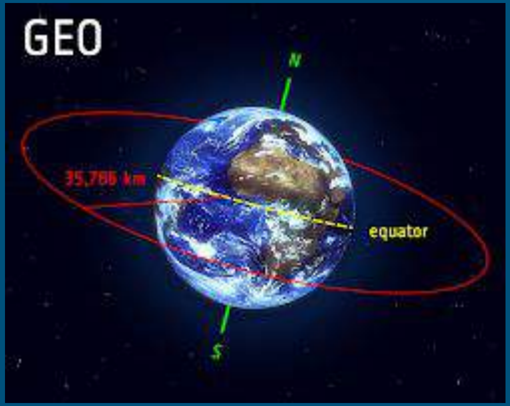
- **Geosynchronous orbit (GEO):** GEO satellites orbit the Earth at an altitude of 35,786 kilometers and inclination is 0⁰. GEO satellites appear to be stationary in the sky, which makes them ideal for communication.

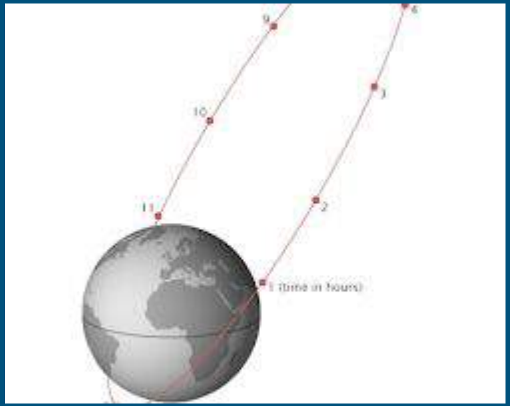




- **Sunsynchrounous orbit:** Sun-synchronous orbits are orbits that have a period of exactly one sidereal day. This means that they pass over the same point on the Earth's surface at the same time each day.

- **Geostationary orbit (GEO):** GEO satellites orbit the Earth at an altitude of 35,786 kilometers, inclination is 0^0 and eccentricity is 0. GEO satellites appear to be stationary in the sky, which makes them ideal for communication.





- **Molniya orbit:** Molniya orbits are highly elliptical orbits that are used for communication in high-latitude regions. Molniya orbits allow satellites to spend more time over high-latitude regions than they would in a geostationary orbit

Some satellites :

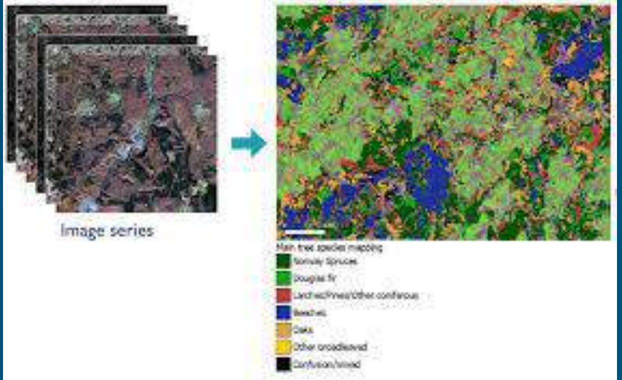
	Landsat	Sentinel	SPOT	IRS
Country	NASA	ESA	ESA	ISRO
Orbit	Sun-synchronous	Sun-synchronous	Sun-synchronous	Sun-synchronous
Altitude	705 km	786 km	693 km	800-900 km
Sensors	MSS, LISS, TIRS, ETM, ETM+, OLI	MSI, Sentinel-2, Sentinel-3	HRV, HRG	MSS, LISS, TIRS

Sensor

- In remote sensing, a sensor is a device that measures and records electromagnetic radiation emitted or reflected from an object.
- There are two main types of sensor used in remote sensing: active and passive.
- Active sensors emit their own energy and measure the energy that is reflected back. (ex- RADAR, LiDAR)
- Passive sensors measure the energy that is emitted or reflected from an object. Do not have their own source of energy.

Resolutions of Remote sensing sensors

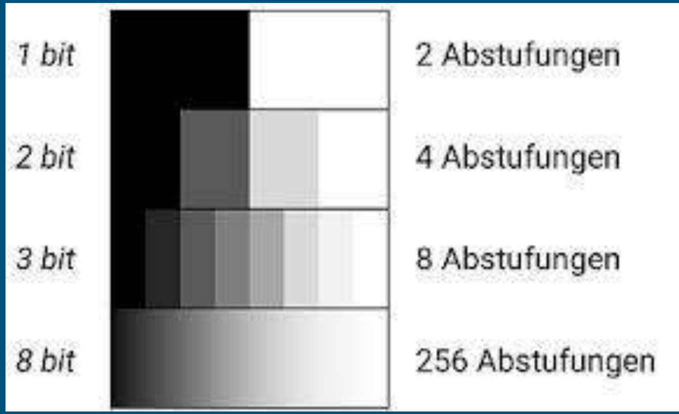
- **Spatial resolution:** This is the size of the smallest object that can be distinguished in an image. It is measured in pixels, with a higher number of pixels indicating a higher spatial resolution. For example, a satellite image with a spatial resolution of 10 meters means that each pixel in the image represents an area of 10 meters on the ground.



- **Spectral resolution:** This is the number of different bands of light that a sensor can detect. A higher spectral resolution allows for more detailed information about the object being imaged. For example, a sensor with a spectral resolution of 10 bands can detect 10 different wavelengths of light.

- **Radiometric resolution:** This is the range of brightness values that a sensor can detect. A higher radiometric resolution allows for more precise measurements of the brightness of objects.

For example, a sensor with a radiometric resolution of 10 bits can distinguish between 1,024 different brightness levels.



- **Temporal Resolution:** Temporal resolution refers to how often a satellite revisits a particular location on Earth. Satellites with high temporal resolution can provide frequent updates and monitoring of changes over time.

Types of remote sensing

- Platform
  - Ground-based
  - Air-borne
  - Space based
- Source of energy
  - Active
  - Passive
- Region of EMR
  - Optical
  - Thermal
  - Microwave
- No of bands
  - Panchromatic
  - Multi-spectral
  - Hyper-spectral
  - Ultra-spectral

Application area of remote sensing

- Mapping and surveying
- Environmental monitoring
- Agriculture
- Natural resource management
- Military intelligence
- Disaster management