

# **18CEO407T RS & GIS App**

## ***Unit I***

*Compiled by*  
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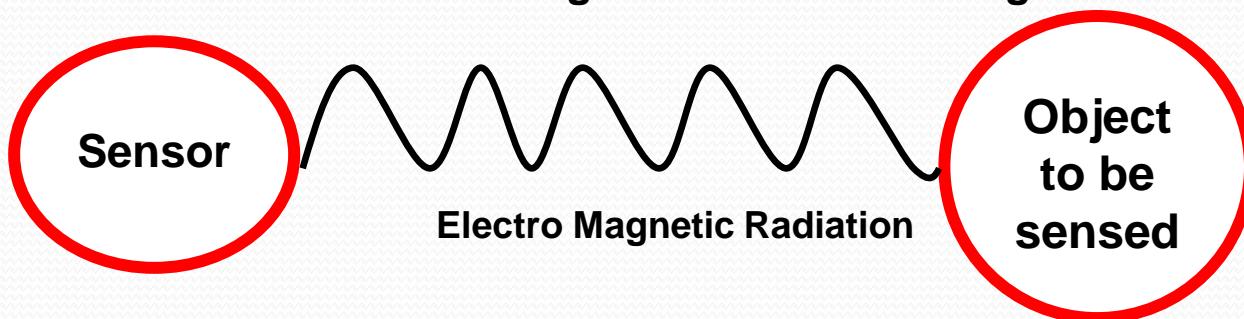
# What is remote sensing?

The acquisition of information about an object **without being** in physical contact with it.

# **REMOTE SENSING**

**"Remote sensing is the science 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."**

Three Essential Things for Remote Sensing



# Why has remote sensing been developed?

- Remote sensing has a very long history, dating back to the end of the 19th century, when cameras were first made airborne, using balloons and kites.
- The advent of aircraft further enhanced the opportunities to take photographs from the air. It was realized that the airborne perspective gave a completely different view to that which was available from the ground.

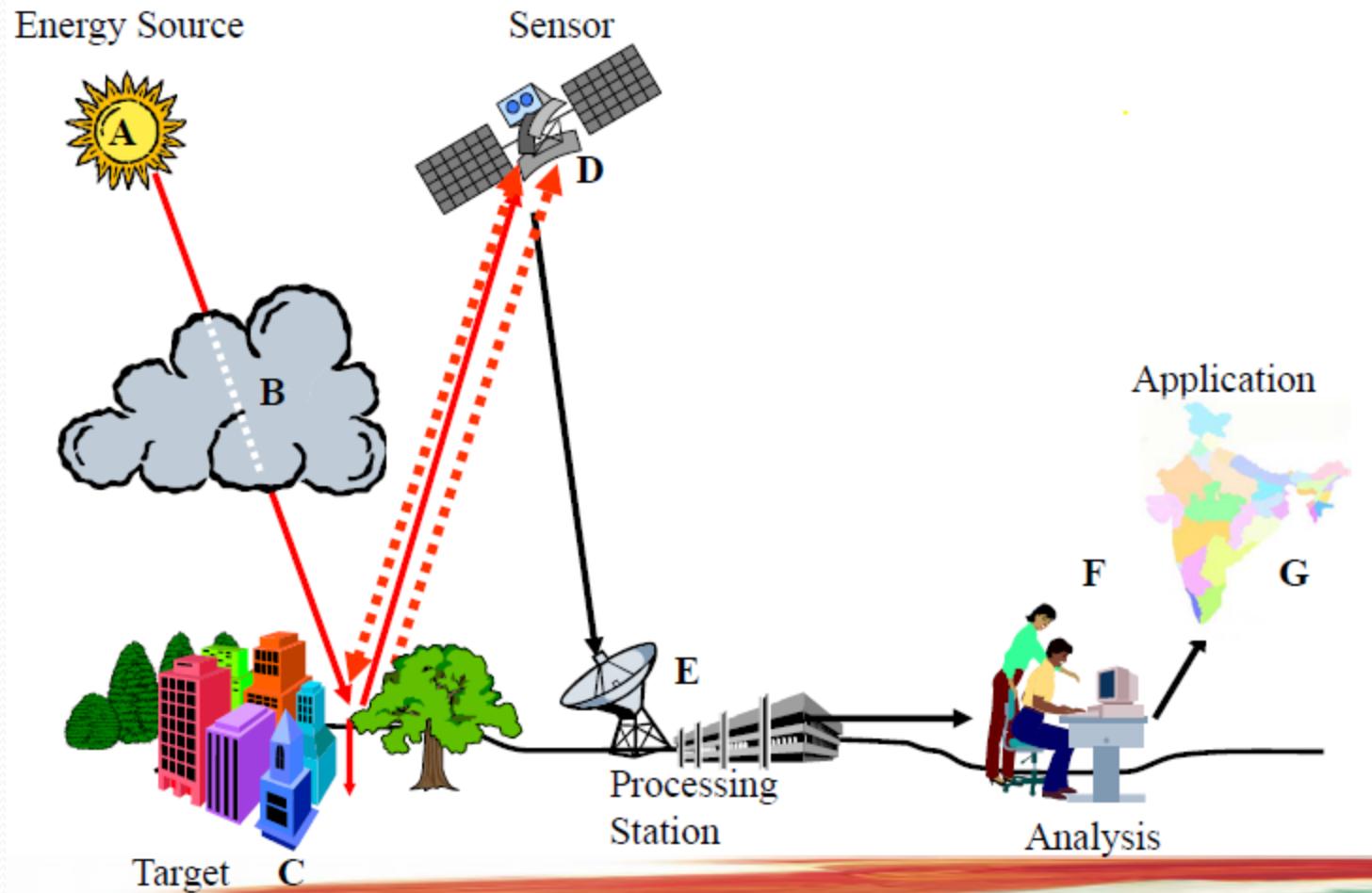
# History of Remote Sensing

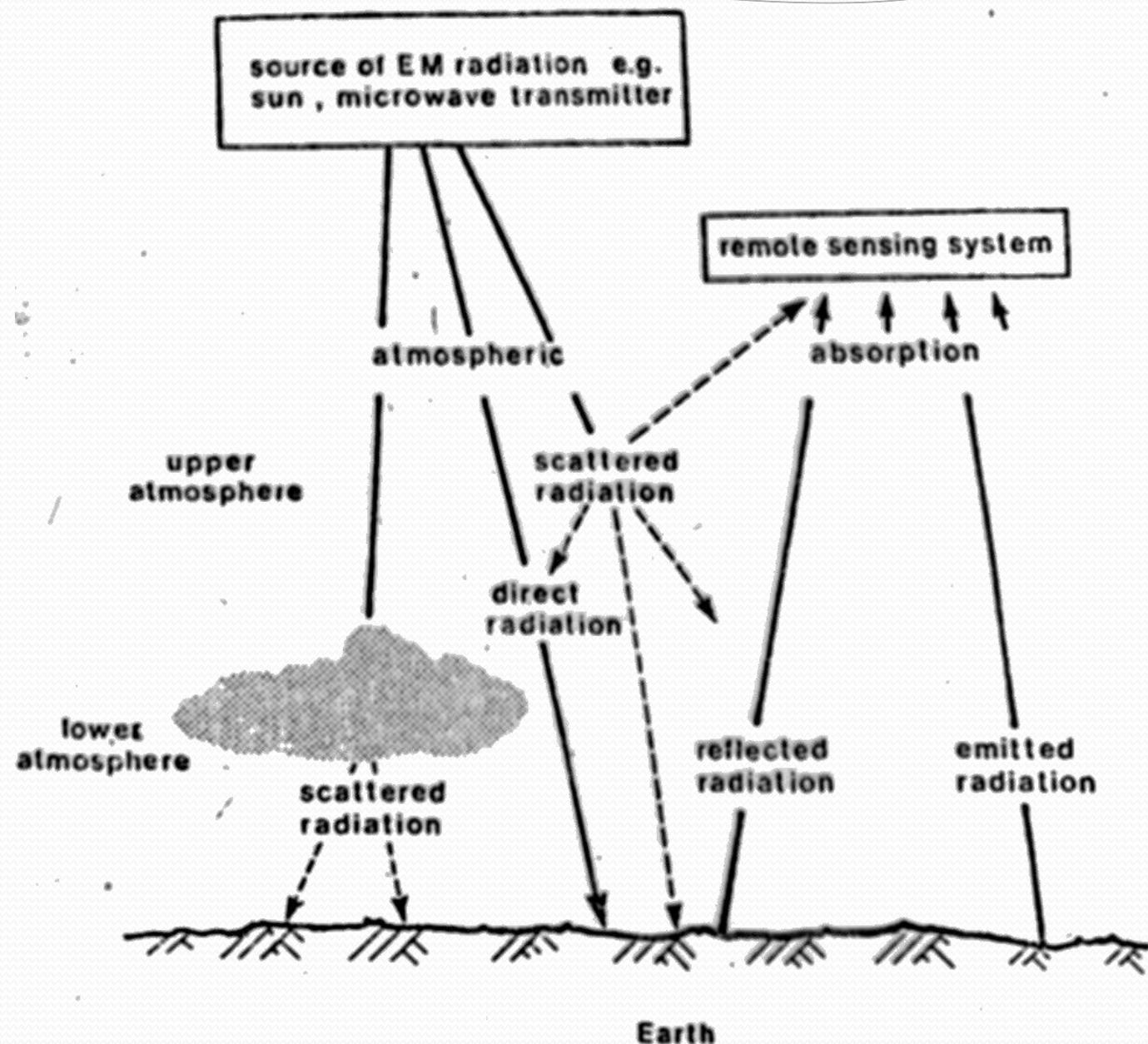
- Aerial photography is the original form of remote sensing (using visible spectrum) started in 1909
- Aerial photographic reconnaissance was widely used after 1915 in WWI.
- *Photogrammetric Engineering*, the official monthly publication of the *American Society of Photogrammetry*, was first published in 1934.
- Color infrared photography began 1931, then was widely used in agriculture and forestry.
- Development of radar (1930-1940).
- During WWII, non-visible spectrum (infrared and radar) were used as tools in remote sensing.
- After the first man-made satellite (*Sputnik 1*) was launched on 4 October 1957 by Soviet Union, remote sensing moved to outer space, ignited the Space Race within the Cold War.
- The United States' *Explorer 6* transmitted the first space photograph of the Earth in August 1959.
- The first systematic meteorological satellite observation came with the launch of the United States' *TIROS 1* in 1960.
- *Landsat 1* (originally called the Earth Resources Technology Satellite or *ERTS*) was the first satellite to collect data on the Earth's natural resources. It was launched on 23 July 1972.
- Hyperspectral remote sensing emerged (1980s), widely used in mineral, oil, etc. exploration.
- Since then, a large number and advanced types of remote sensing systems have been developed.

# Benefits of remote sensing

- Remote sensing has many advantages over ground-based survey in that *large tracts of land can be surveyed at any one time*, and *areas of land (or sea) that are otherwise inaccessible can be monitored*.
- The advent of satellite technology and multispectral sensors has further enhanced this capability, with the ability to *capture images of very large areas of land in one pass*, and by collecting data about an environment that would normally not be visible to the human eye.

# Remote Sensing Process



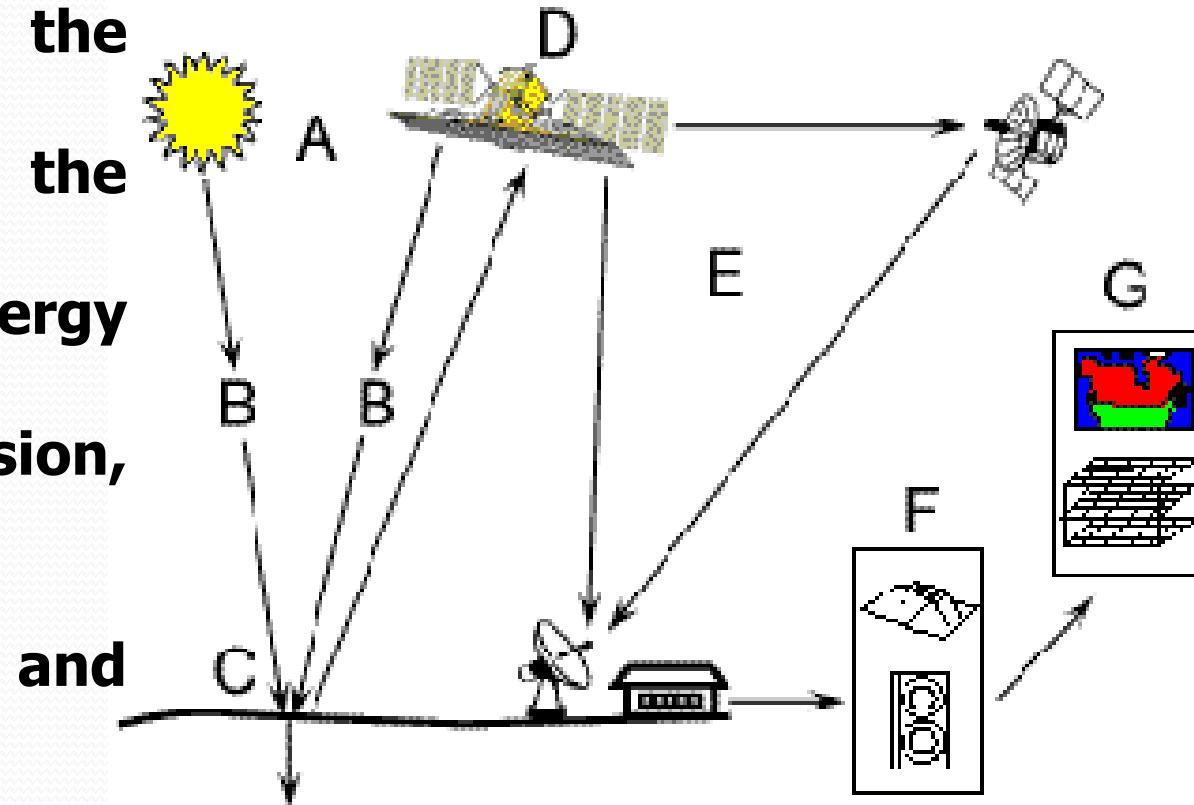


- A remote sensor collects the total radiation reaching the sensor - that emanating from the ground as well as that due to the atmospheric effects.
- The part of the signal emanating from the atmosphere is called *path radiance*, and that coming from the ground is called *ground radiance*.
- The path radiance tends to mask the ground signal and acts as a background noise.

# Remote Sensing System & Processes

The process involves an interaction between incident radiation and the targets of interest.

- (A) Energy Source or Illumination
- (B) Radiation and the Atmosphere
- (C) Interaction with the Target
- (D) Recording of Energy by the Sensor
- (E) Transmission, Reception, and Processing
- (F) Interpretation and Analysis
- (G) Application



# The Process

1. **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.
2. **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.
3. **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.
4. **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.
5. **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).
6. **Interpretation and Analysis (F)** - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.
7. **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.

# Principle of Remote Sensing

Interaction between incident radiation and the targets of interest

Everything in nature has its own unique distribution of reflected, emitted and absorbed radiation

These spectral characteristics, if ingeniously exploited, can be used to distinguish one thing from another or to obtain information about shape, size and other physical and chemical properties

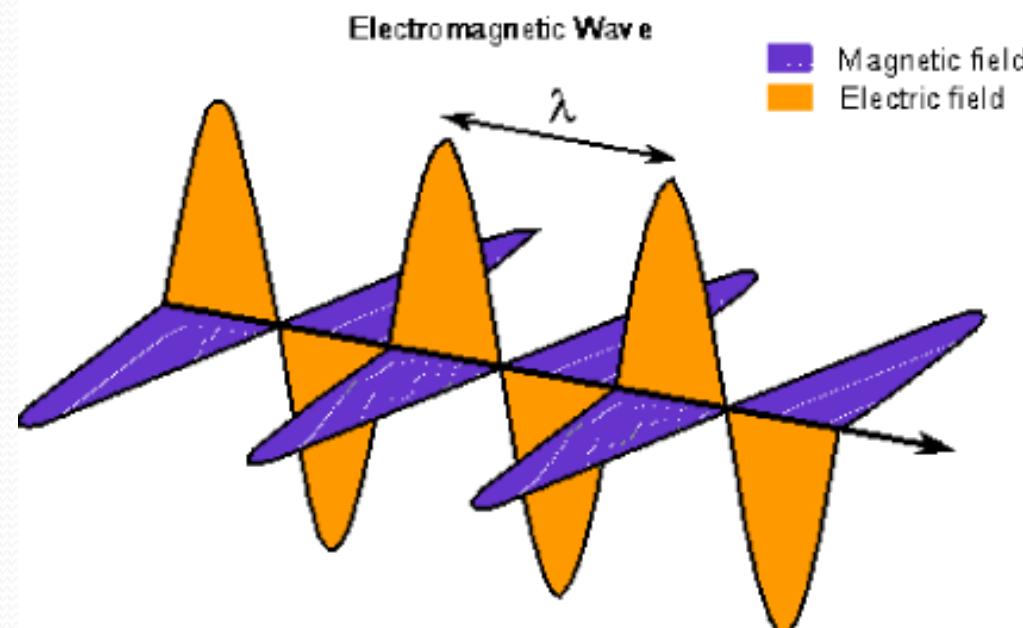
# Electromagnetic Radiation Models

To understand how electromagnetic radiation is created, how it propagates through space, and how it interacts with other matter, it is useful to describe the processes using two different models:

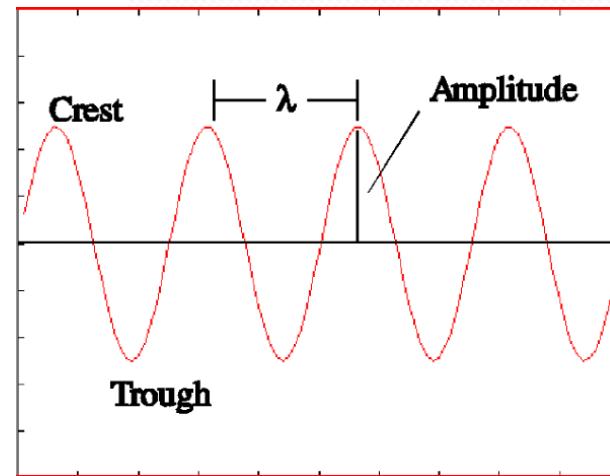
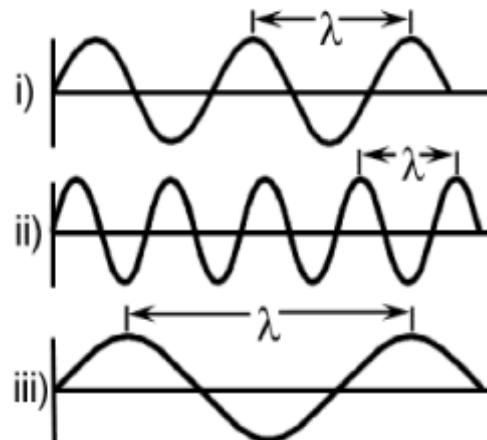
- the **wave** model, and
- the **particle** model.

# Wave Model of Electromagnetic Radiation

The *electromagnetic* wave consists of two fluctuating fields—one **electric** and the other **magnetic**. The two vectors are at right angles (orthogonal) to one another, and both are perpendicular to the direction of travel.



- **Wavelength** is formally defined as the mean distance between maximums (or minimums) of a roughly periodic pattern and is normally measured in micrometers ( $\mu\text{m}$ ) or nanometers (nm).
- **Frequency** is the number of wavelengths that pass a point per unit time. A wave that sends one crest by every second (completing one cycle) is said to have a frequency of one cycle per second or one hertz, abbreviated 1 Hz.



# Wave Model of Electromagnetic Energy

The relationship between the wavelength,  $\lambda$ , and frequency,  $\nu$ , of electromagnetic radiation is based on the following formula, where  $c$  is the speed of light:

$$c = \lambda \cdot \nu \quad \nu = \frac{c}{\lambda} \quad \lambda = \frac{\nu}{c}$$

Note that frequency,  $\nu$  is inversely proportional to wavelength  $\lambda$ . The longer the wavelength, the lower the frequency, and vice-versa.

# Particle Model of Electromagnetic Energy

- For a 100 years before 1905, light was thought of as a smooth and continuous wave. Then, Albert Einstein found that when light interacts with electrons, it has a different character.
- He found that when light interacts with matter, it behaves as though it is composed of many individual bodies called *photons*, which carry particle-like properties as energy and momentum.
- Thus, we sometimes describe electromagnetic energy in terms of its wave-like properties. But, when the energy interacts with matter it is useful to describe it as discrete packets of energy, or *quanta*.

# **Particle Theory**

**Particle (Quantum) theory suggests that EM radiation is composed of many discrete units called photons or quanta. The energy of a quantum is given as:**

$$Q = h \cdot v$$

**where:**

**Q = energy of a quantum (Joules - J)**

**h = Planks constant, ( $6.626 \times 10^{-34}$  J/sec)**

**v = frequency**

We can combine the Wave and Particle theories for EM radiation by substituting  $v = c/\lambda$  in the above equation. This gives us:

$$Q = \frac{h.c}{\lambda}$$

From this we can see that the energy of a quantum is inversely proportional to its wavelength. Thus, the longer the wavelength of EM radiation, the lower its energy content.

We can categorise EMR according to wavelength / frequency / energy

EMR is all the same - only thing that varies is the energy of the photons

Gamma rays (short wavelength/high frequency) = high energy

Radio waves (long wavelength /low frequency) = low

# **Blackbody emission**

**All bodies > absolute zero emit EMR**

**Blackbody: a perfect absorber of radiation**

**Blackbody radiation: radiation emitted from a perfect absorber**

## Sources and properties of EMR

Planck determined an experimental law that determined emission of EMR from a blackbody as a function of wavelength and temperature....

$$M_{\lambda} = \frac{2\pi hc^2}{\lambda^5 [\exp(hc/\lambda KT) - 1]}$$

## Stephen Boltzmann Law

We may think of the Sun as a  $6,000^{\circ}$  K **blackbody** (a theoretical construct which radiates energy at the maximum possible rate per unit area at each wavelength for any given temperature).

**As the temperature of a blackbody increases, amount of EMR emitted increases at all wavelengths**

The *total emitted radiation* ( $M_\lambda$ ) from a blackbody is proportional to the fourth power of its absolute temperature. This is expressed as:

$$M_\lambda = \sigma T^4$$

where  $\sigma$  is the Stefan-Boltzmann constant,  $5.6697 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$ .

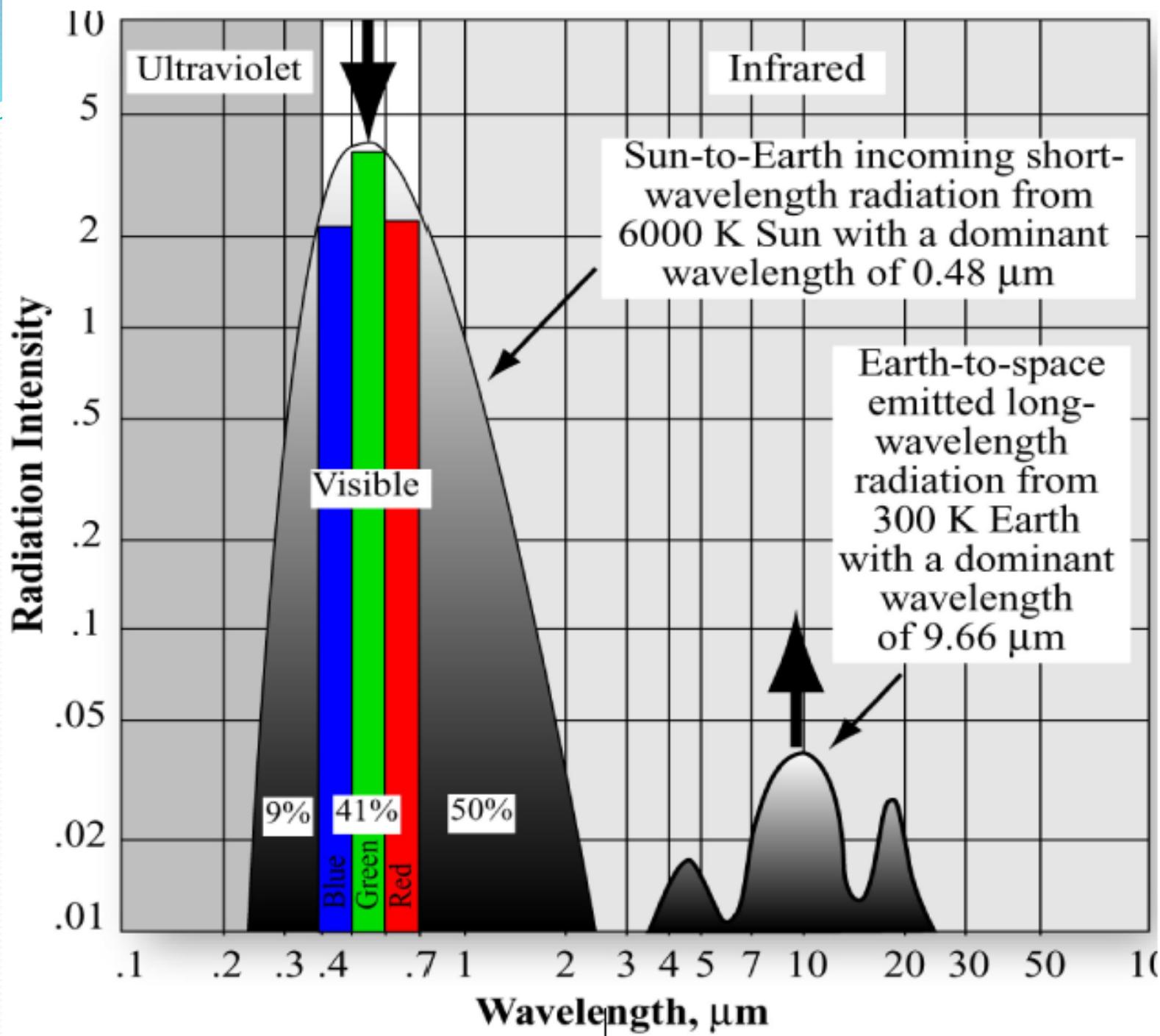
Thus, the amount of energy emitted by an object such as the Sun or the Earth is a function of its temperature.

## Wein's Displacement Law

In addition to computing the total amount of energy exiting a theoretical blackbody such as the Sun, we can determine its dominant wavelength ( $\lambda_{max}$ ) based on *Wein's displacement law*:

$$\lambda_{max} = \frac{k}{T}$$

where  $k$  is a constant equaling 2898 mm K, and  $T$  is the absolute temperature in kelvin. Therefore, as the Sun approximates a 6000 K blackbody, its dominant wavelength ( $\lambda_{max}$ ) is 0.48  $\mu\text{m}$ :



# Blackbody Radiation Curves

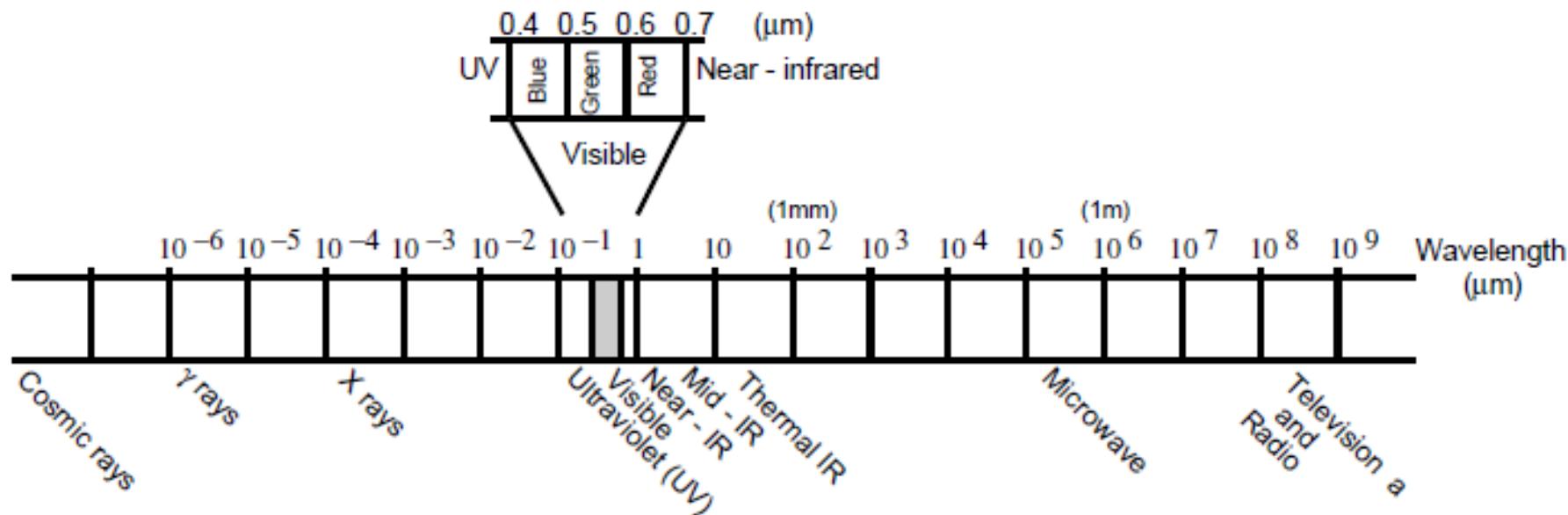
## Summary

Planck's Law tells us the spectral distribution of EMR

Wein's Law tells us the wavelength of maximum emission

Stefan's Law tell us the total emissive power

# THE ELECTROMAGNETIC SPECTRUM



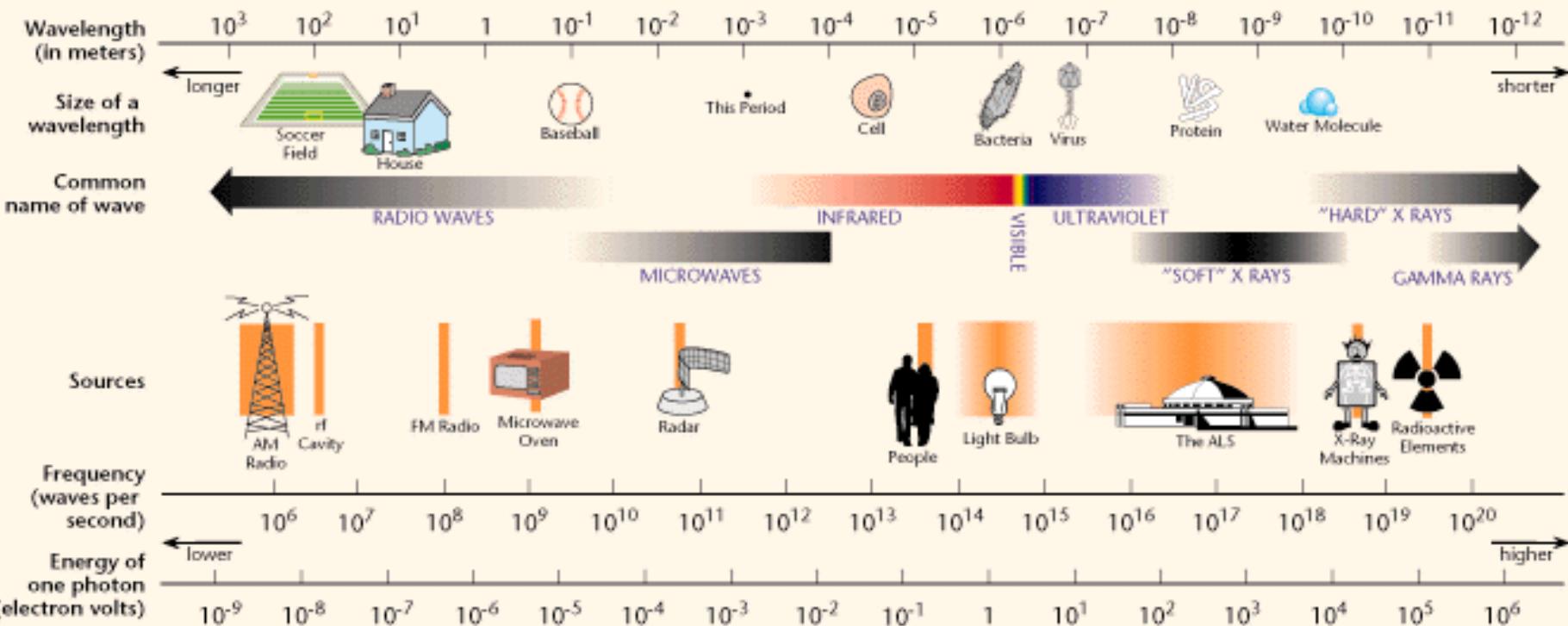
From Lillesand and Kiefer 1987

# Electromagnetic Spectrum

Ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves).

There are several regions of the EM spectrum which are useful for remote sensing.

## THE ELECTROMAGNETIC SPECTRUM

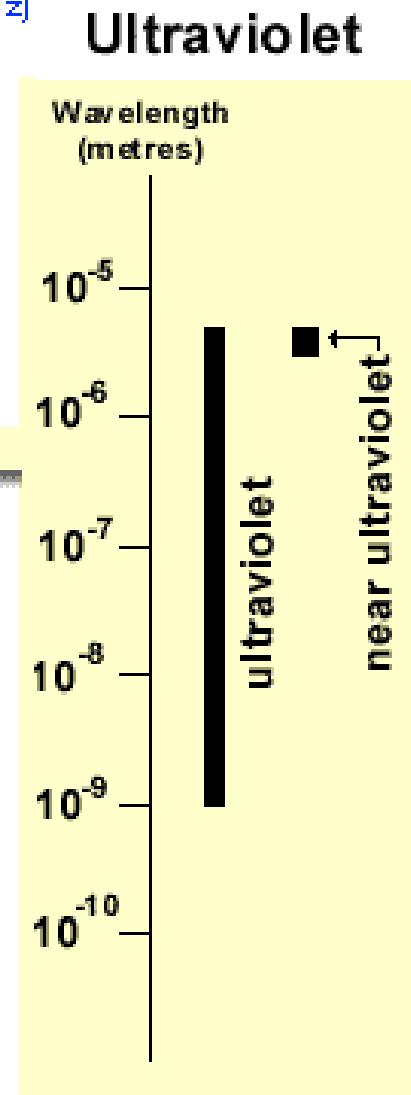
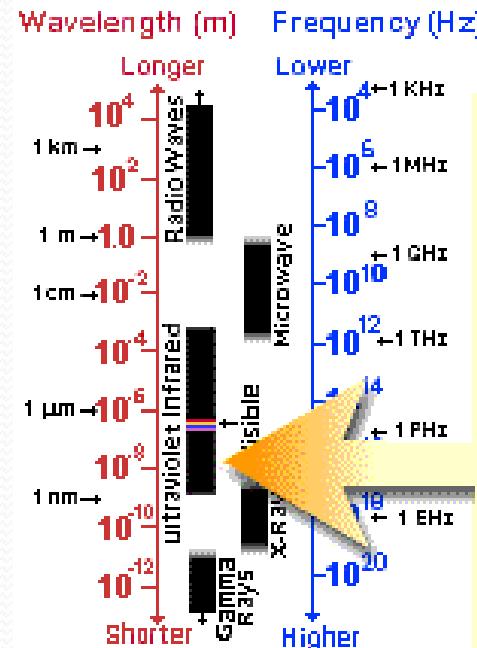


# Ultraviolet Spectrum (UV)

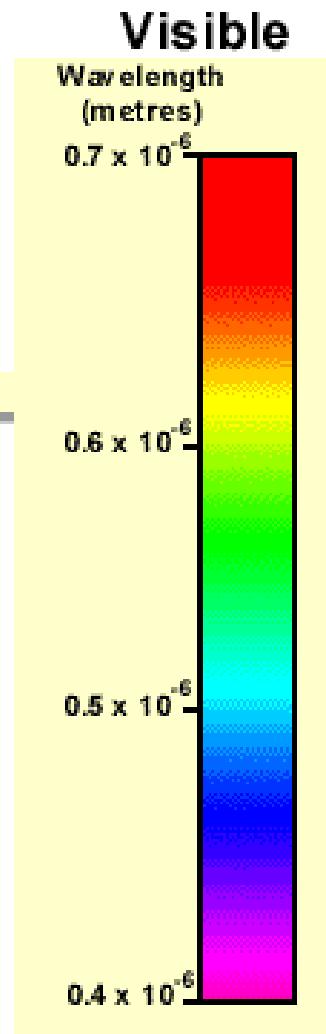
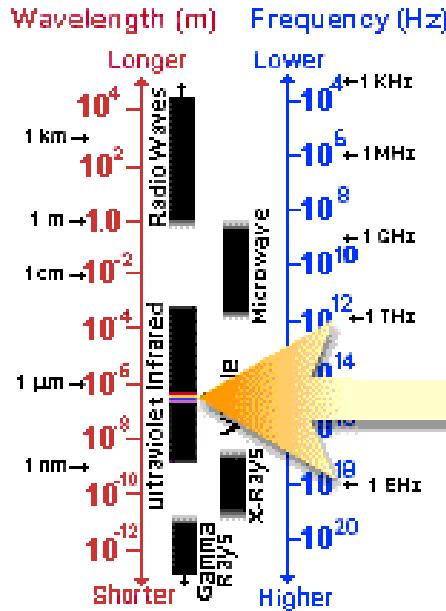
UV portion of the spectrum has the shortest wavelengths which are practical for remote sensing.

This radiation is just beyond the violet portion of the visible wavelengths, hence its name.

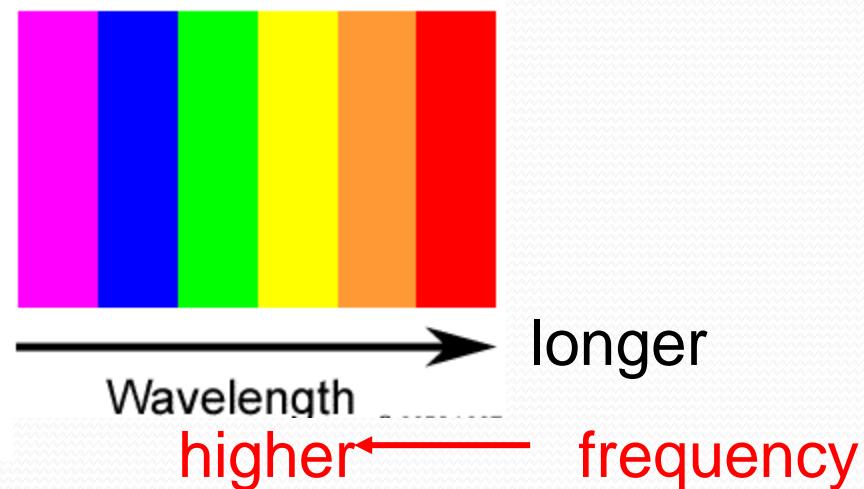
Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.



# Visible Spectrum



The light which our eyes - our "remote sensors" - can detect is part of the **visible spectrum**.



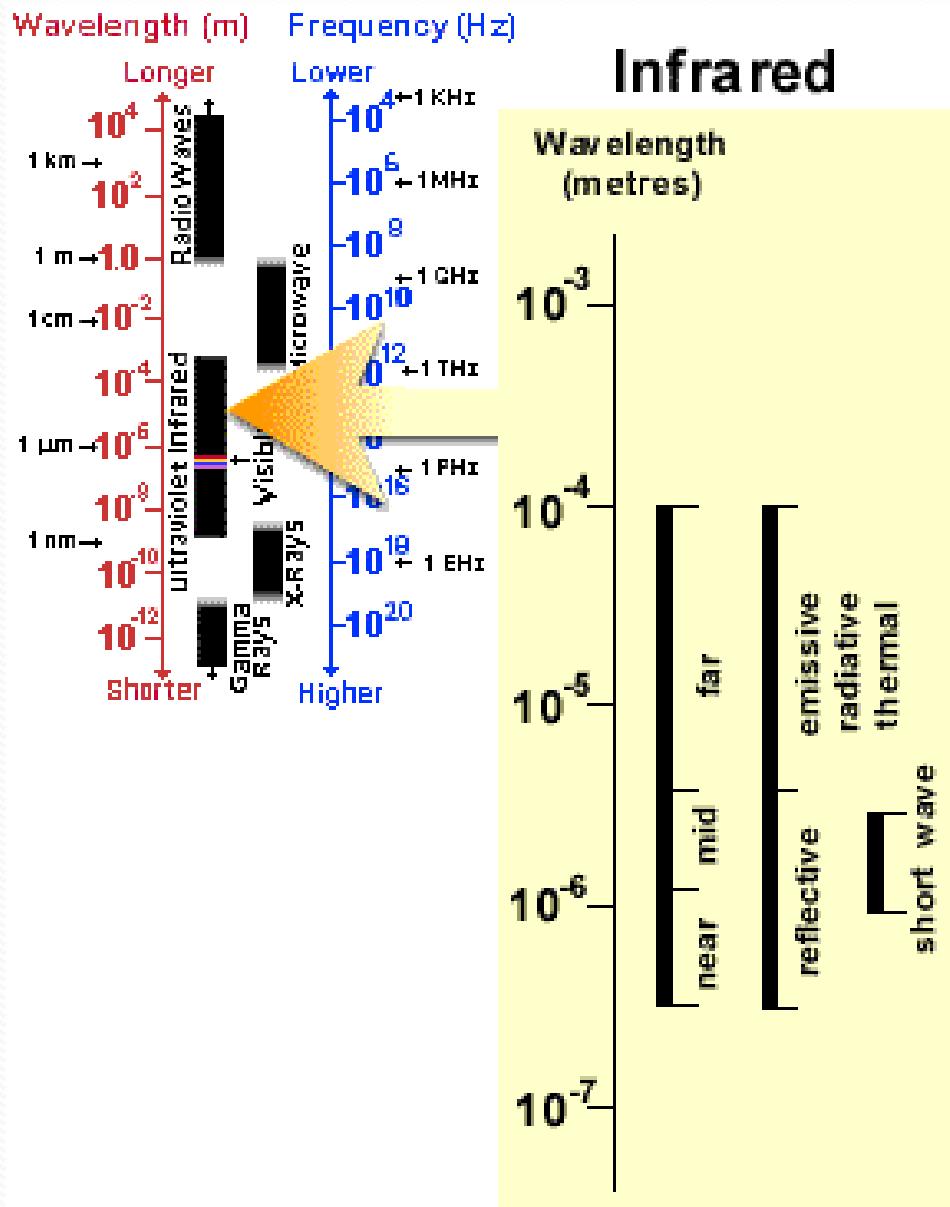
# Visible Spectrum

- It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage.
- The visible wavelengths cover a range from approximately 0.4 to 0.7  $\mu\text{m}$ . The longest visible wavelength is red and the shortest is violet.
- This is the only portion of the spectrum we can associate with the concept of colors.

# Infrared Spectrum (IR)

IR region covers the wavelength range from approximately **0.7 µm** to **100 µm** - more than 100 times as wide as the visible portion!

The IR can be divided into two categories based on their radiation properties - the **reflected IR**, and the emitted or **thermal IR**.



# Infrared Spectrum

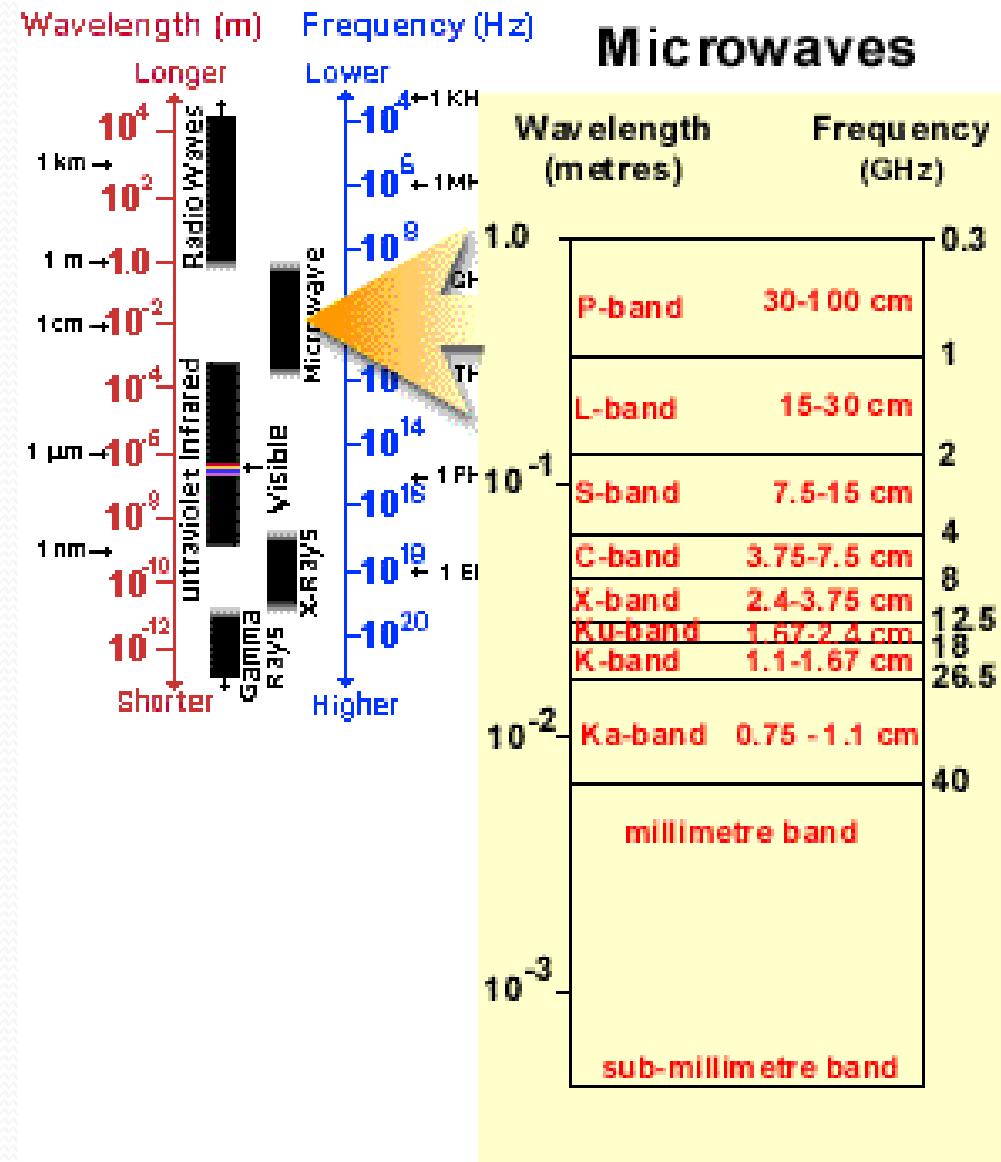
- Radiation in the **reflected IR** region is used for remote sensing purposes in ways very similar to radiation in the visible portion.
- The reflected IR covers wavelengths from approximately **0.7 μm to 3.0 μm**.
- The **thermal IR** region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat.
- The thermal IR covers wavelengths from approximately **3.0 μm to 100 μm**.

# Microwave Spectrum

The portion of the spectrum of more recent interest to remote sensing is the **microwave region** from about **1 mm to 1 m**.

This covers the longest wavelengths used for remote sensing.

The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcast.

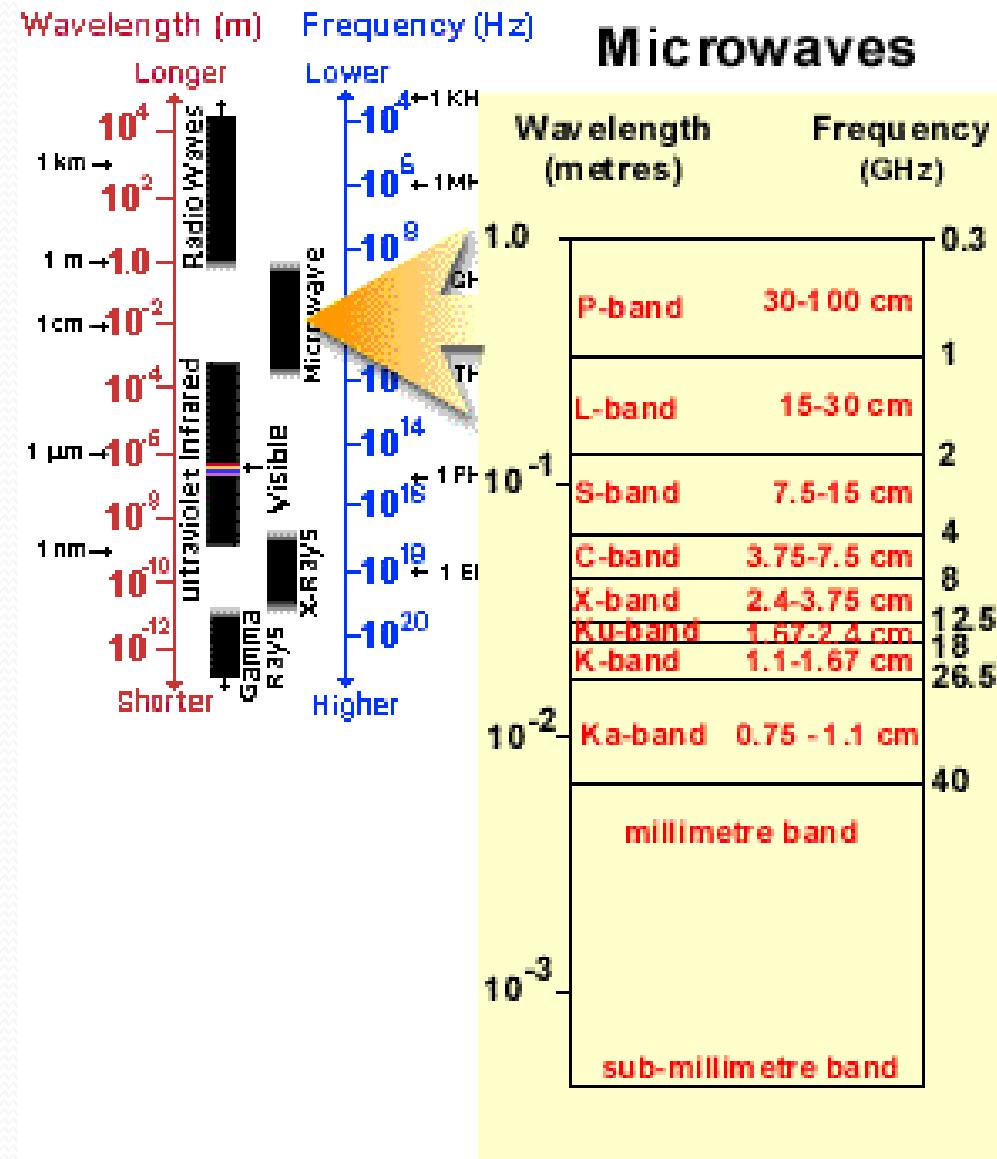


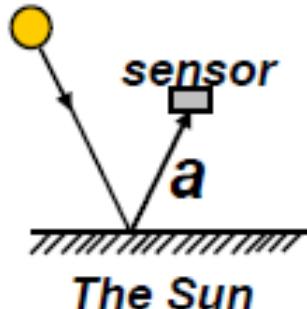
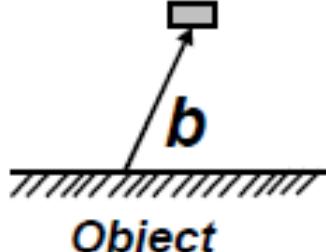
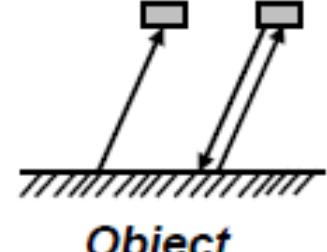
# Microwave Spectrum

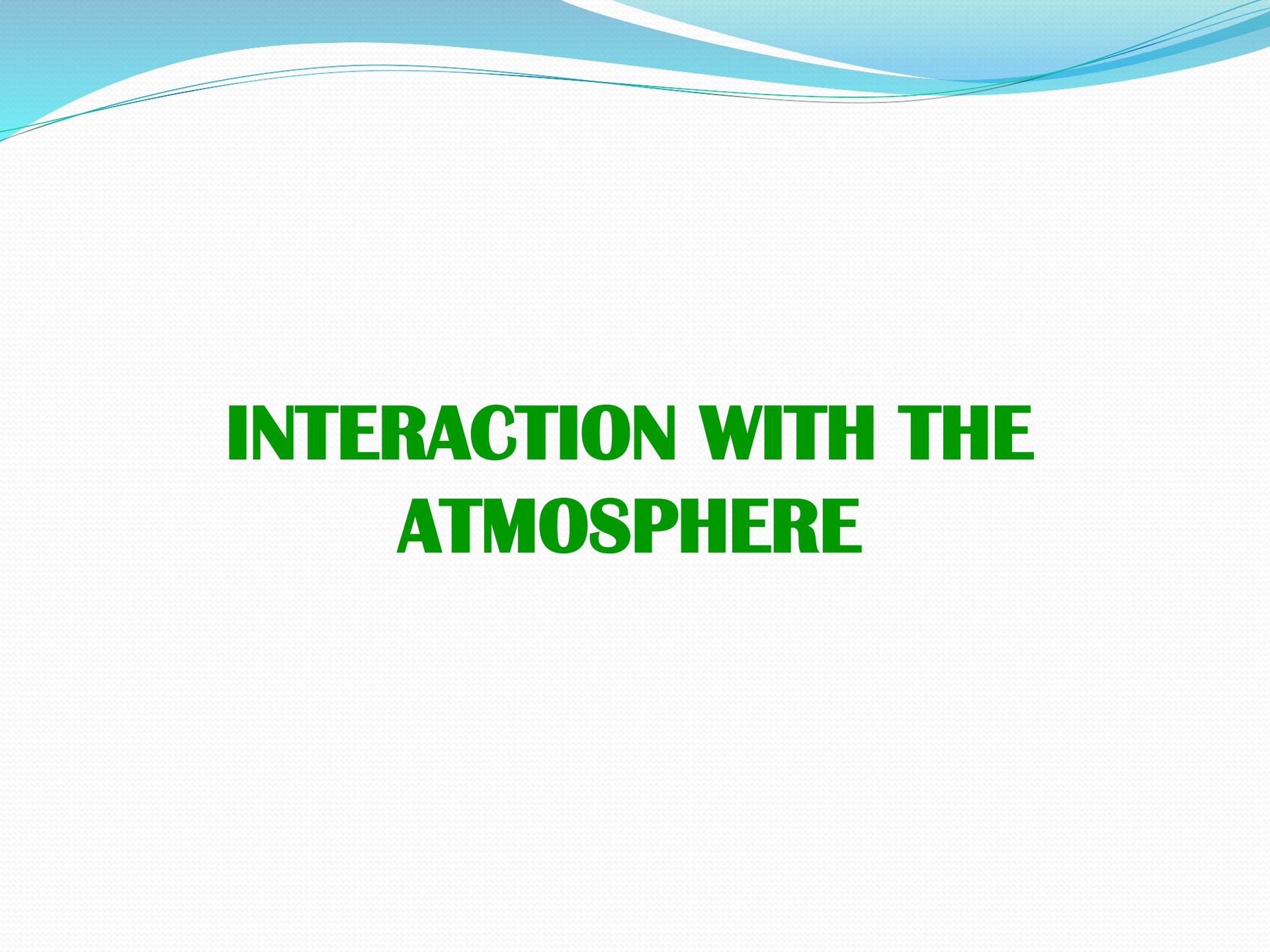
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	<i>Visible- reflective IR remote sensing</i>	<i>Thermal IR Remote sensing</i>	<i>Microwave Remote sensing</i>
<b>Radiation Source</b>	 <p>The Sun</p>	 <p>Object</p>	 <p>Object</p>
<b>Object</b>	<i>Reflectance</i>	<i>Thermal radiation (Temperature, emissivity)</i>	<i>Microwave radiation</i>
<b>Electro-magnetic Spectrum</b>	UV	Visible	Reflective IR
			Thermal IR
	<i>0.3 μm – 3 μm</i>		<i>3 μm – 14 μm</i>
			<i>1mm – 1m</i>



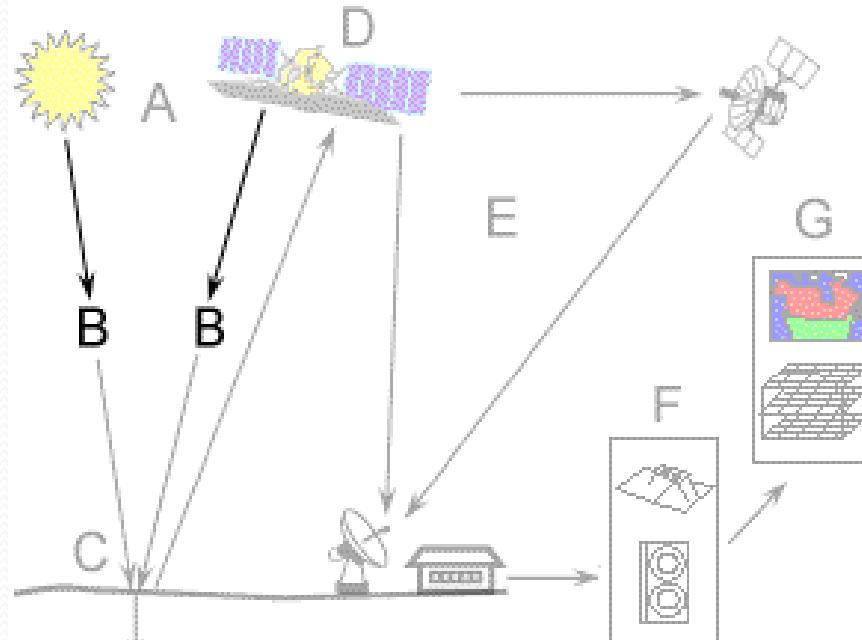
# **INTERACTION WITH THE ATMOSPHERE**

# Interactions with Atmosphere

Most remote sensing is conducted above the Earth either within or above the atmosphere.

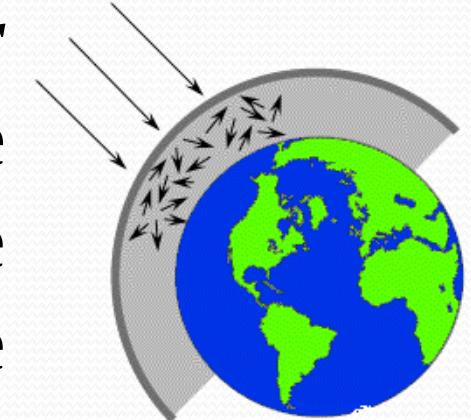
Before radiation used for remote sensing reaches the Earth's surface, it has to travel through some distance of the Earth's atmosphere.

Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of **scattering and absorption**.



# Interactions with Atmosphere

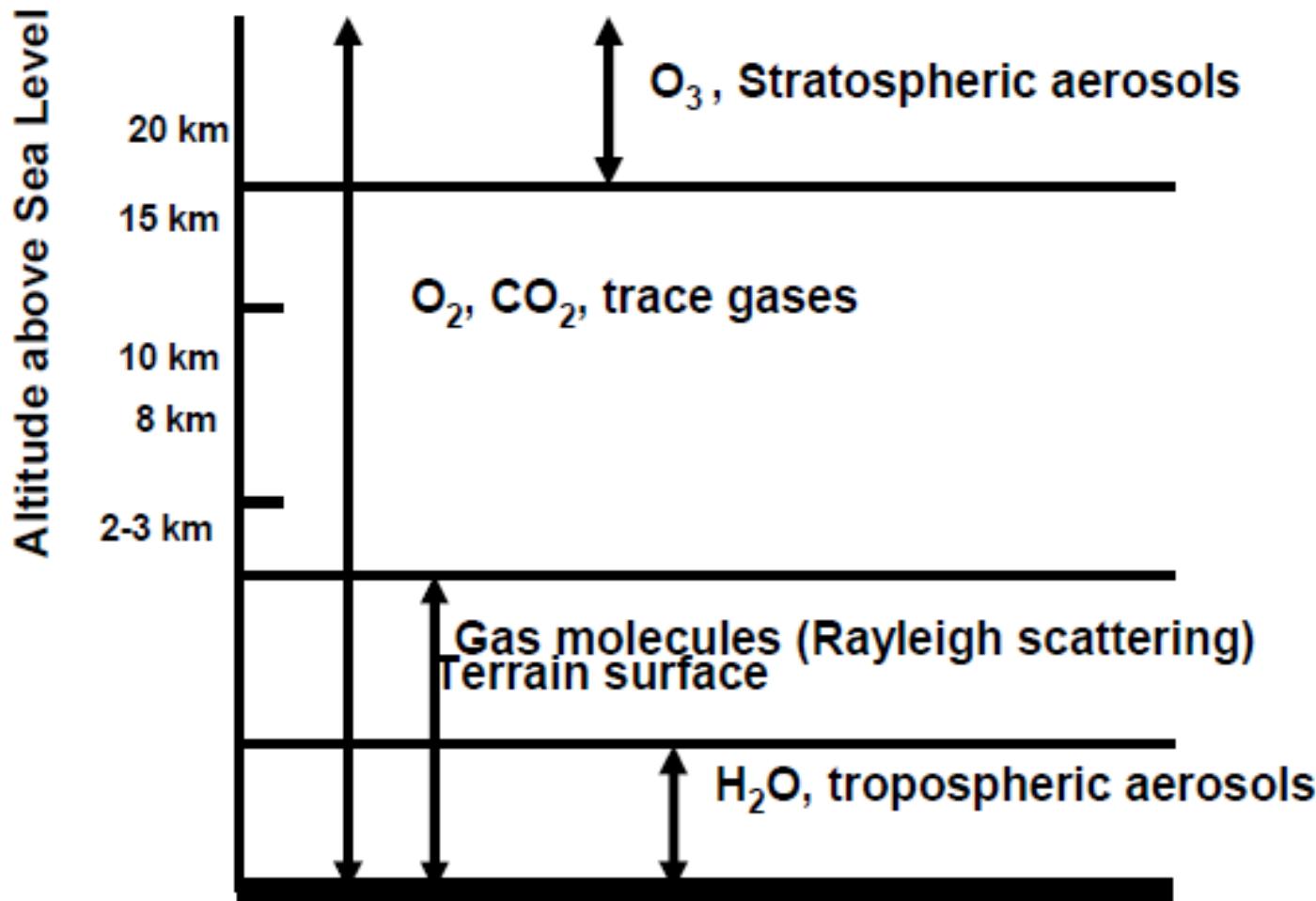
- Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be *redirected from its original path.*



How much scattering takes place 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.

# Atmospheric Layers and Constituents

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



## Types of Scatterers

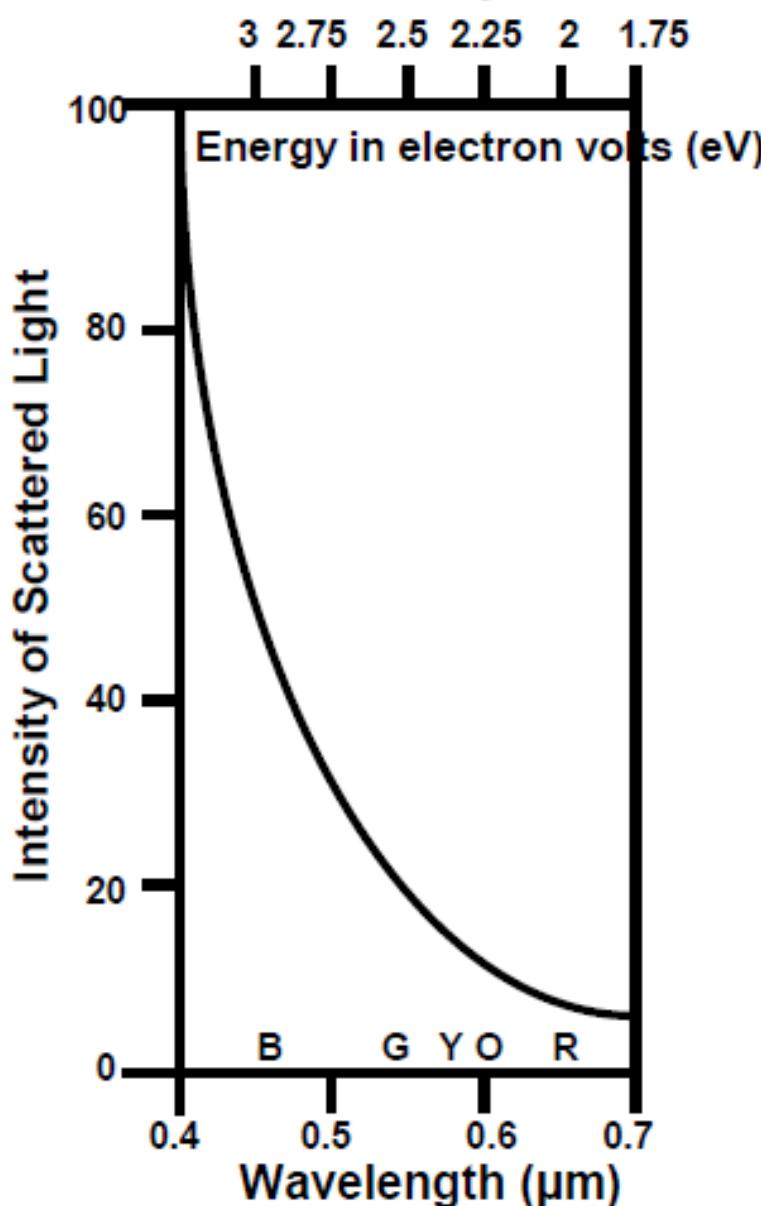
- Oxygen and nitrogen ( $\sim 10^{-4}$   $\mu\text{m}$ ) - troposphere
- Ozone ( $\sim 10^{-4}$   $\mu\text{m}$ )
  - In the lower stratosphere
- Aerosols ( $\sim 1$   $\mu\text{m}$ )
  - Usually in the lower atmosphere (except volcanoes)
  - sulphates, sea spray, minerals, soot
- Cloud droplets ( $\sim 10$   $\mu\text{m}$ )
  - Mostly lower troposphere
- Ice ( $\sim 100$   $\mu\text{m}$ )
  - Mostly lower troposphere
- Rain and hail ( $\sim 1000$  -  $10000$   $\mu\text{m}$ )
  - Lower troposphere

# Scattering

There are three (3) types of scattering which take place:

1. Rayleigh scattering
2. Mie scattering
3. Non-selective scattering

Varies Inversely with  $\lambda^{-4}$

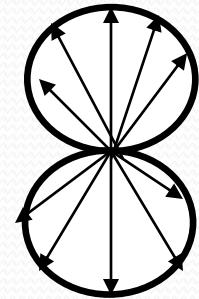


# Rayleigh Scattering

The intensity of Rayleigh scattering varies inversely with the fourth power of the wavelength ( $\lambda^{-4}$ ).

# RAYLEIGH SCATTERING

- Rayleigh scattering occurs particles are very small compared to the wavelength of the radiation.
- Small specks of dust or nitrogen and oxygen molecules
- The fact that the sky appears "blue" during the day and red sunset is because of this phenomenon.
- Rayleigh Scattering  $\propto 1/\lambda^4$



# Rayleigh Scattering

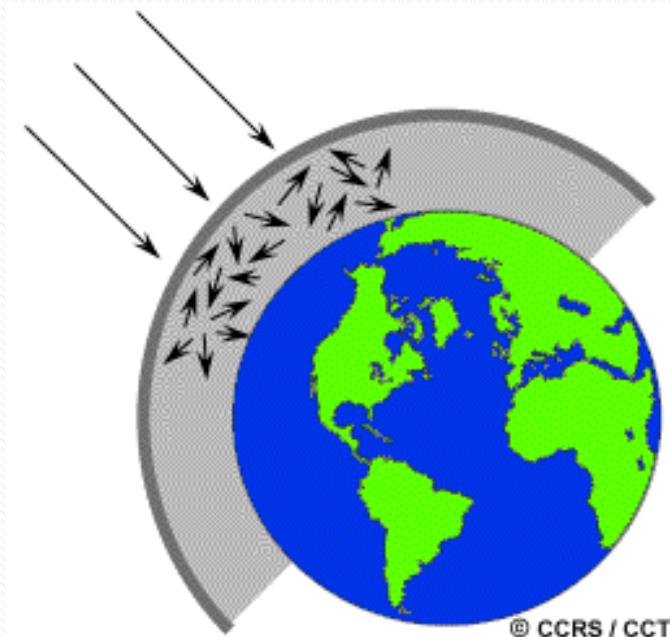
Rayleigh scattering also called molecular scattering occurs when particles are ***very small compared to the wavelength*** of the radiation, e.g. small specks of dust or nitrogen and oxygen molecules.

Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. This is the ***dominant scattering mechanism in the upper atmosphere***.

Raleigh scattering is **inversely proportional to the fourth power of the wavelength**.

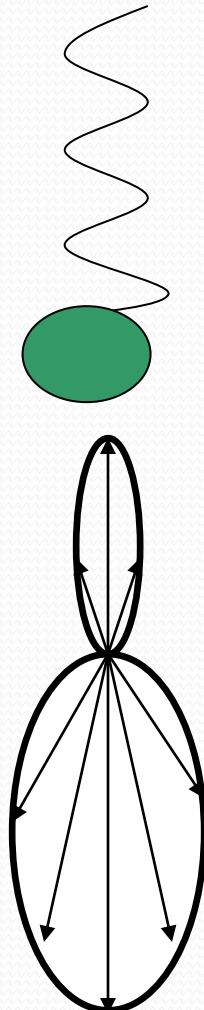
Shorter wavelengths are scattered more  
Negligible at wavelengths beyond micro  
meter.

It leads to haze on images and photographs



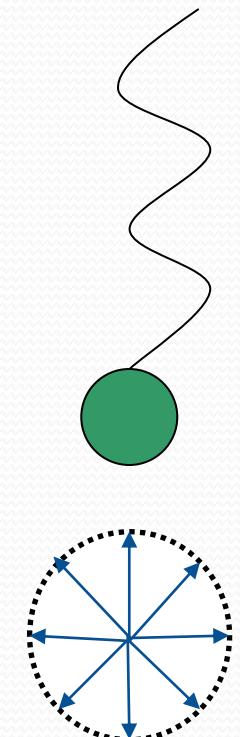
# MIE SCATTERING

- Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation. e.g., Dust, pollen, smoke and water vapour
- Mie Scattering  $\propto 1/\lambda$  to  $1/\lambda^2$



# **NONSELECTIVE SCATTERING**

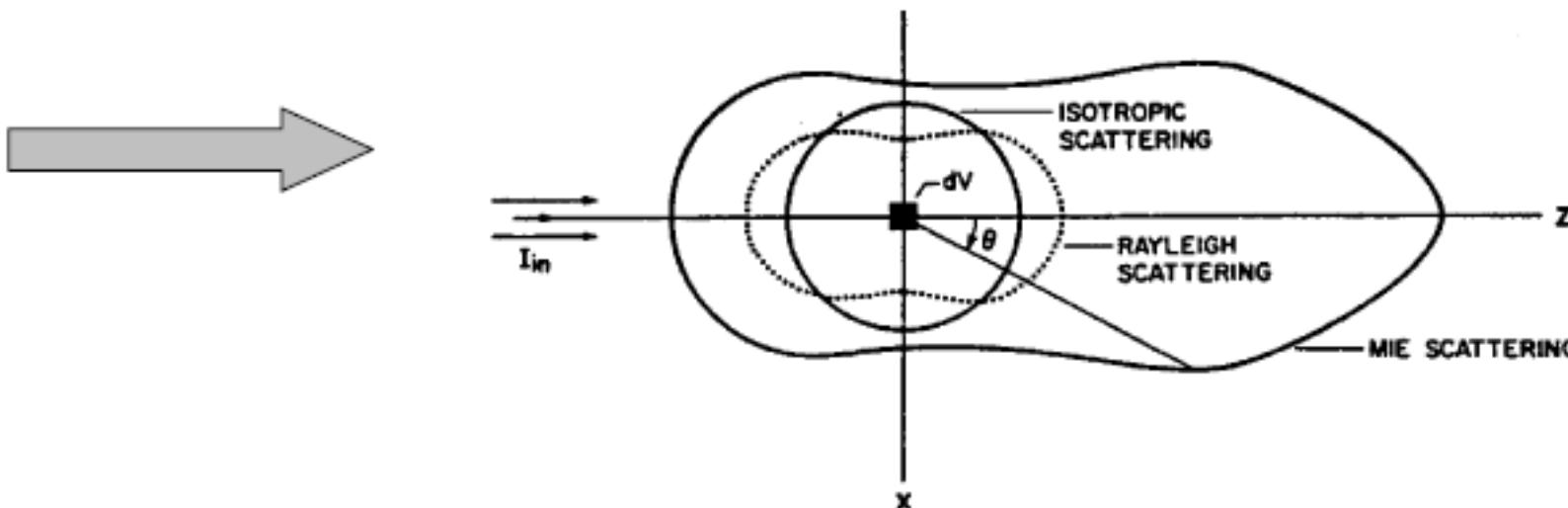
- This occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering.
- Nonselective scattering gets its name from the fact that all wavelengths are scattered in all directions without following any law.



## Types of Atmospheric Scatter in order of importance (Curran. 1988)

Type of Scatter of particles	Size of effective atmospheric particles	Type of effective atmospheric particles	Scatter of particles	Effect of scatter on visible and near visible wavelength
Rayleigh	Smaller than the wavelength of radiation.	Gas molecules	Molecule absorbs high energy radiation and re-emits. skylight scatter is inversely proportional to fourth power of wave length.	Affects short visible wave lengths, resulting in haze in photography, and blue skies.
Mie	Same size as the wavelength of radiation.	Spherical particles, fumes and dust	Physical scattering under overcast skies.	Affects all visible wave lengths
Non-selective	Larger than the wavelength of radiation.	Water droplets and dust.	Physical scattering by fog and clouds.	After all visible wave lengths equally, resulting white fog and clouds
Raman	Any	Any	Photon has elastic collision with molecule resulting in a loss or a gain in energy; this can decrease or increase wave length.	Variable

# Scattering Direction



from Introduction to Satellite Oceanography by Maul (1985)

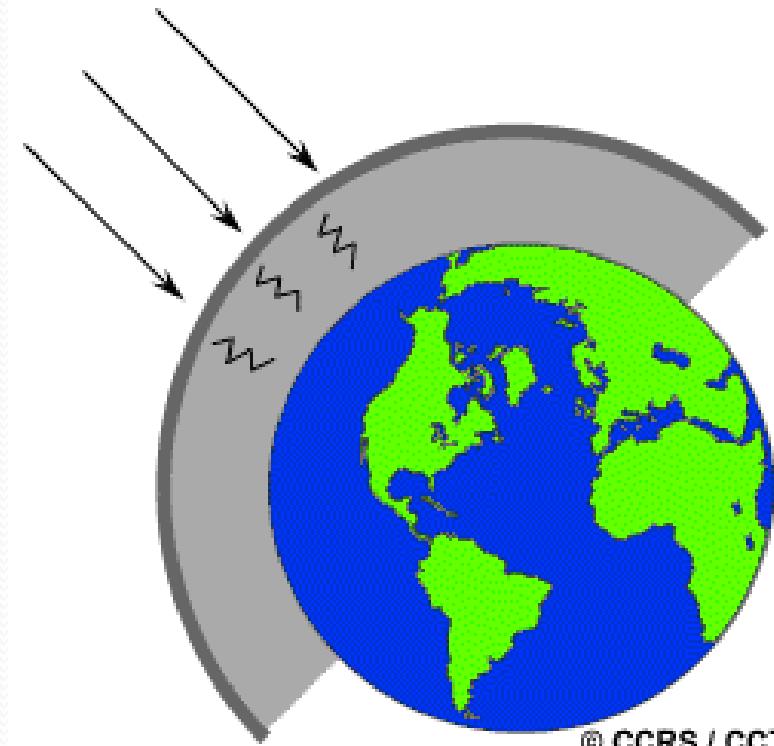
- Rayleigh scatter equally forward and back
- Mie scatter mostly forward
- Non Selective in all directions

# Interactions with Atmosphere - Absorption

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere.

In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths.

**Ozone, carbon dioxide, and water vapor** are the three main atmospheric constituents which absorb radiation.



# Absorbers of the Atmosphere

- **Ozone** serves to absorb the harmful (to most living things) *ultraviolet* radiation from the sun.
- **Carbon dioxide** tends to absorb radiation strongly in the *far infrared* portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere.
- **Water vapor** in the atmosphere absorbs much of the incoming *longwave infrared and shortwave microwave radiation* (*between 22μm and 1m*).

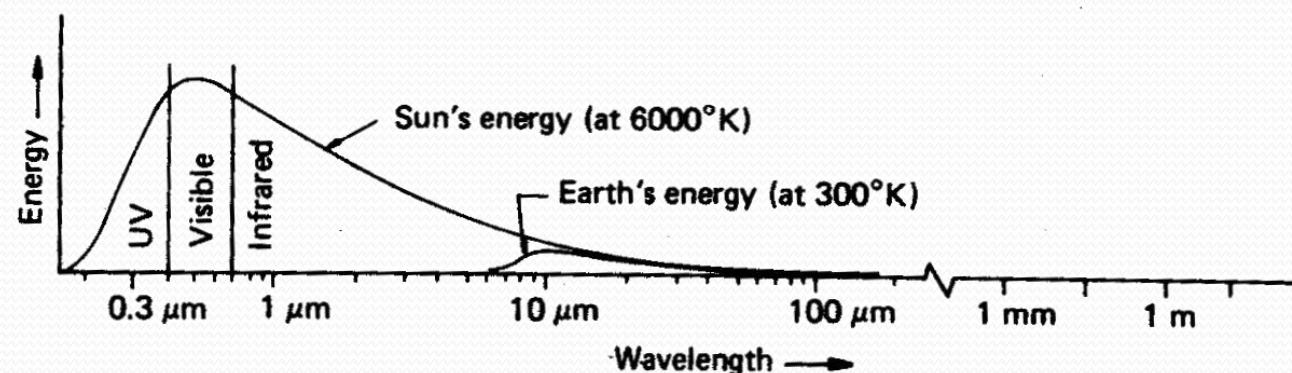
# Atmospheric Window

- One important practical consequence of the interaction of electromagnetic radiation with matter and of the detailed composition of our atmosphere is that *only light in certain wavelength regions can penetrate the atmosphere well.*
- Those areas of the frequency spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**.

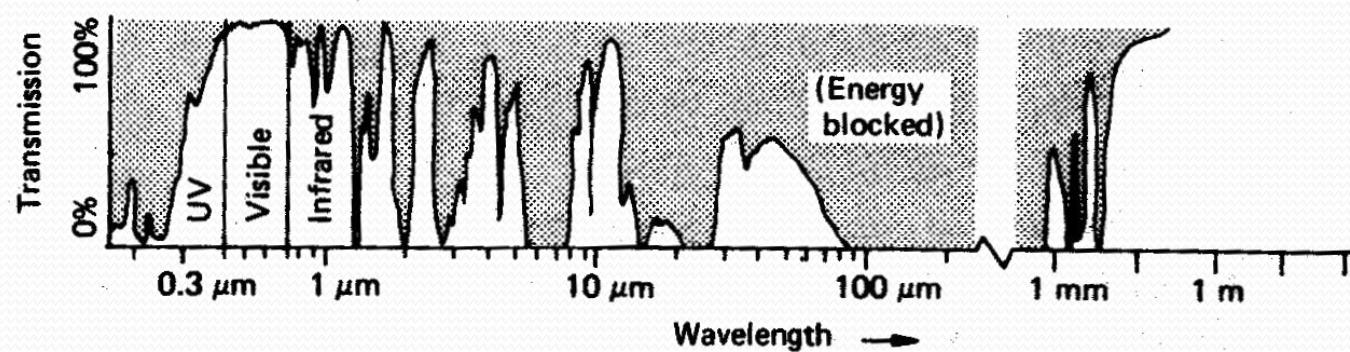
**Table 2.1** Major atmospheric windows (clearer windows shown in boldface)

Name	Wavelength range	Region
Ultraviolet-visible	<b>0.30–0.75 μm</b>	Optical
Near-IR	<b>0.77–0.91 μm</b>	Optical
Short-wave-IR	1.00–1.12 μm  <b>1.19–1.34 μm</b>  <b>1.55–1.75 μm</b>  <b>2.05–2.4 μm</b>	Optical
Mid-IR (Thermal-IR)	3.50–4.16 μm  4.50–5.0 μm  <b>8.00–9.2 μm</b>  <b>10.20–12.4 μm</b>  ( <b>8–14 μm</b> for aerial sensing)	Optical
Microwave	17.00–22.0 μm  2.06–2.22 mm  <b>7.50–11.5 mm</b>  20.0 + mm	Microwave

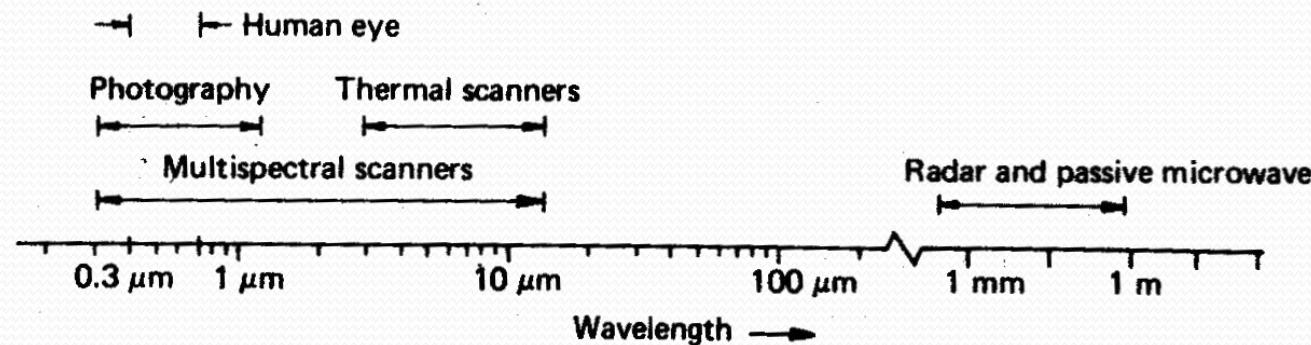
# ENERGY INTERACTIONS WITH EARTH SURFACE FEATURES



(a) Energy sources



(b) Atmospheric transmittance



# **RADIATION - TARGET INTERACTIONS**

- Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface

**Three forms of interaction are**

Absorption (A)

Transmission (T)

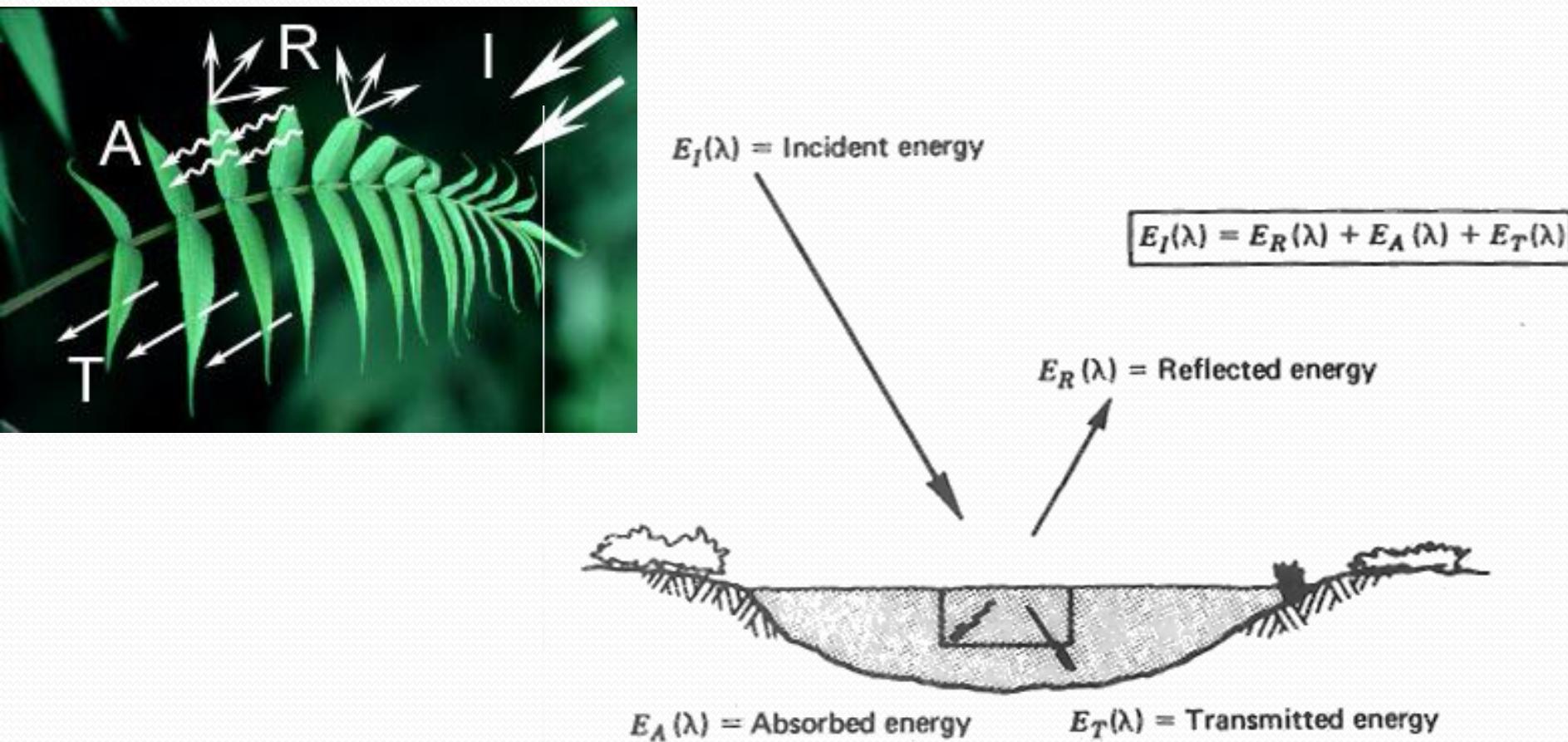
Reflection (R).

# Incident energy (I) from the source

**Absorption (A)** occurs when radiation (energy) is absorbed into the target

**Transmission (T)** occurs when radiation passes through a target

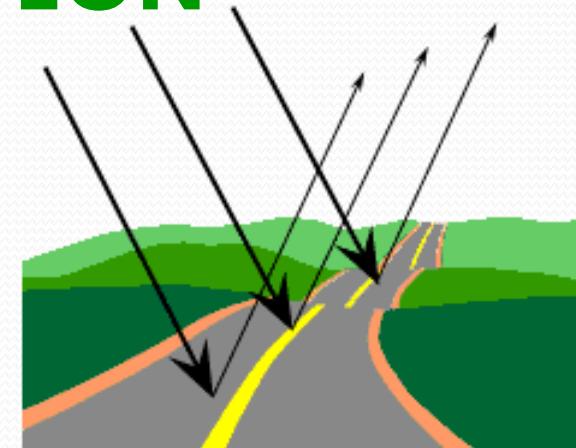
**Reflection (R)** occurs when radiation "bounces" off the target and is redirected.



# **TWO TYPES OF REFLECTION**

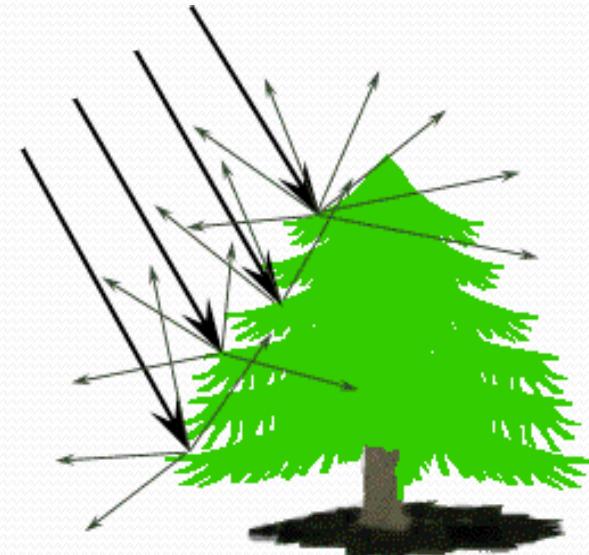
# SPECULAR REFLECTION

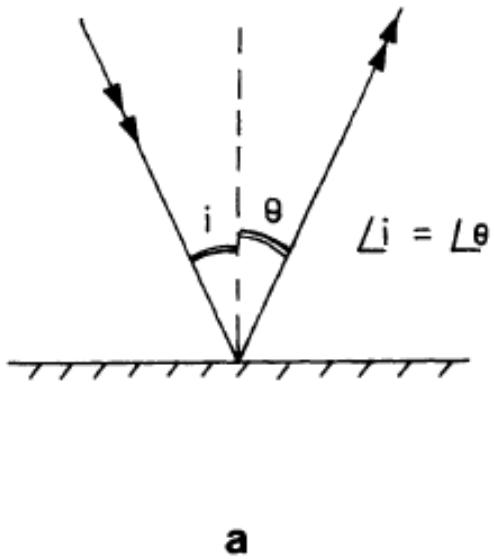
When a surface is smooth we get **specular** or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction.



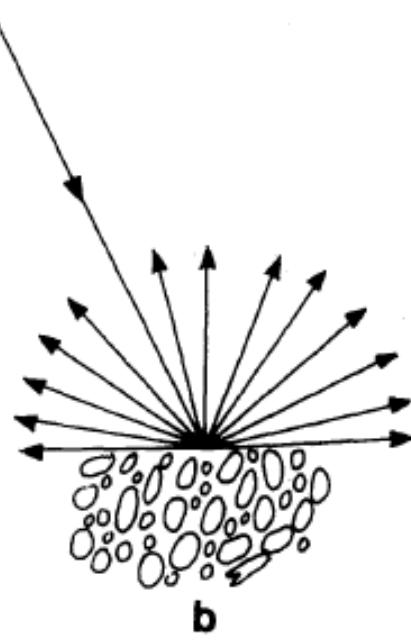
# DIFFUSE REFLECTION

When the surface is rough and the energy is reflected almost uniformly in all directions.

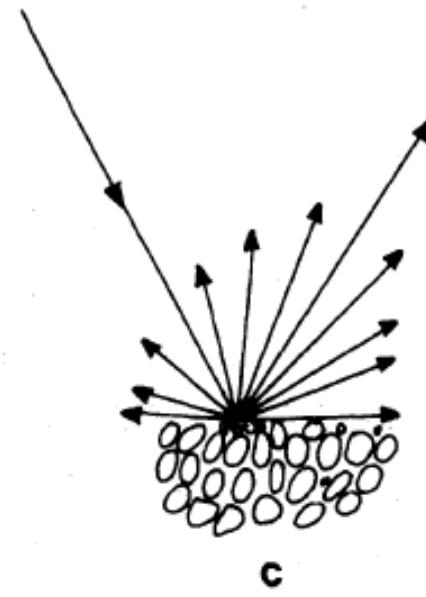




**a**



**b**



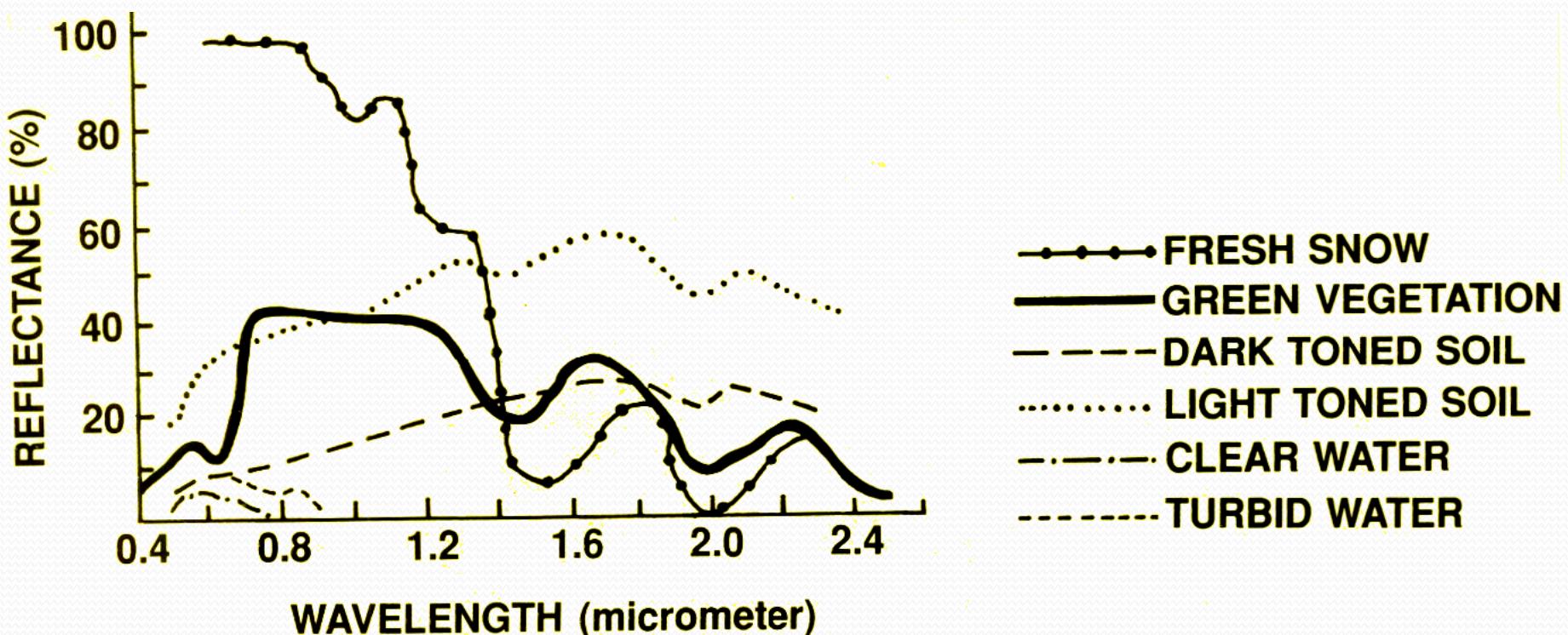
**c**

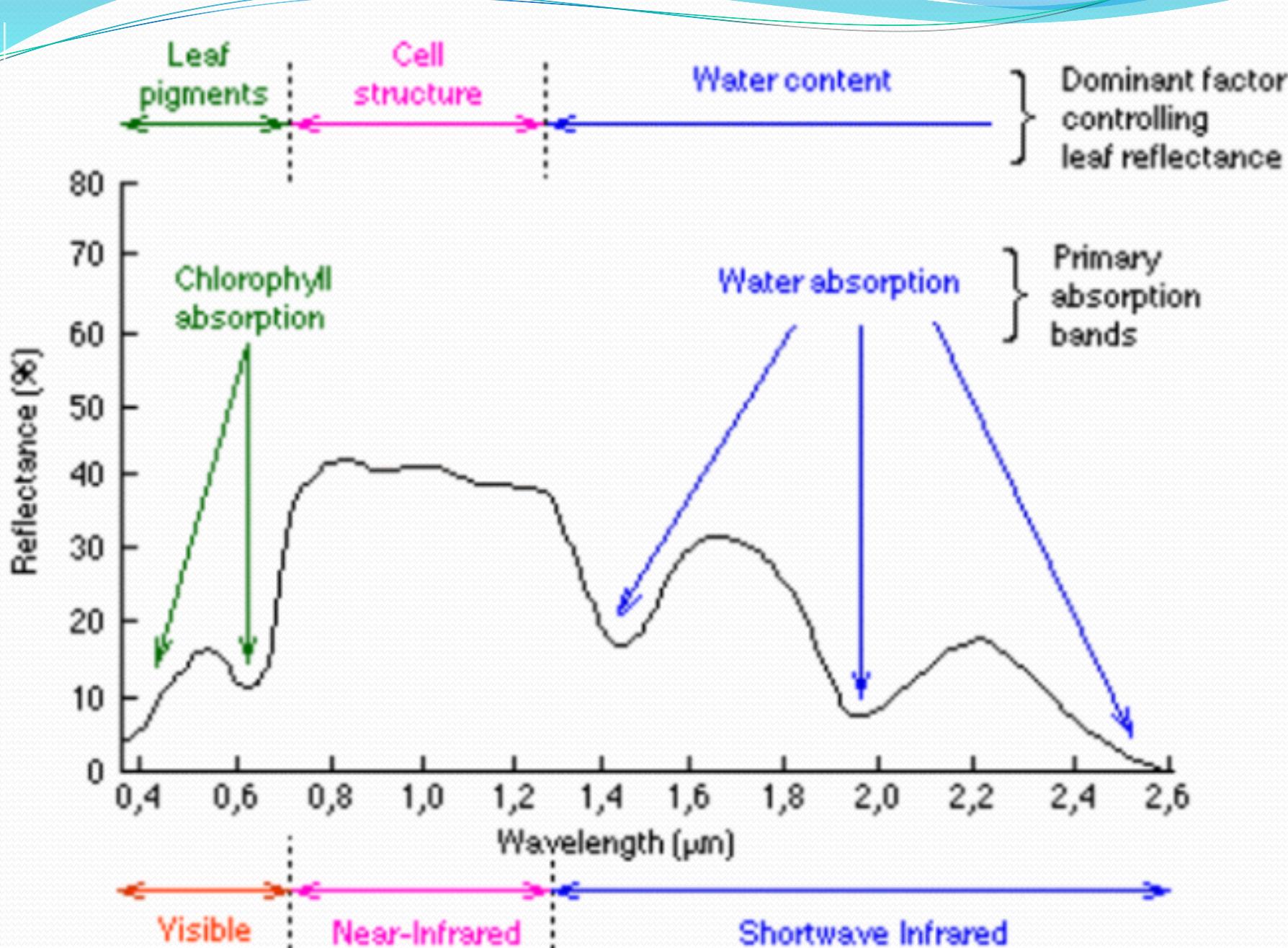
**Fig. 2.6a–c.** Reflection mechanisms. **a** Specular reflection from a plane surface; **b** Lambertian reflection from a rough surface (diffuse reflection); **c** semi-diffused reflection (natural bodies)

# SPECTRAL REFLECTANCE OF VEGETATION, SOIL AND WATER

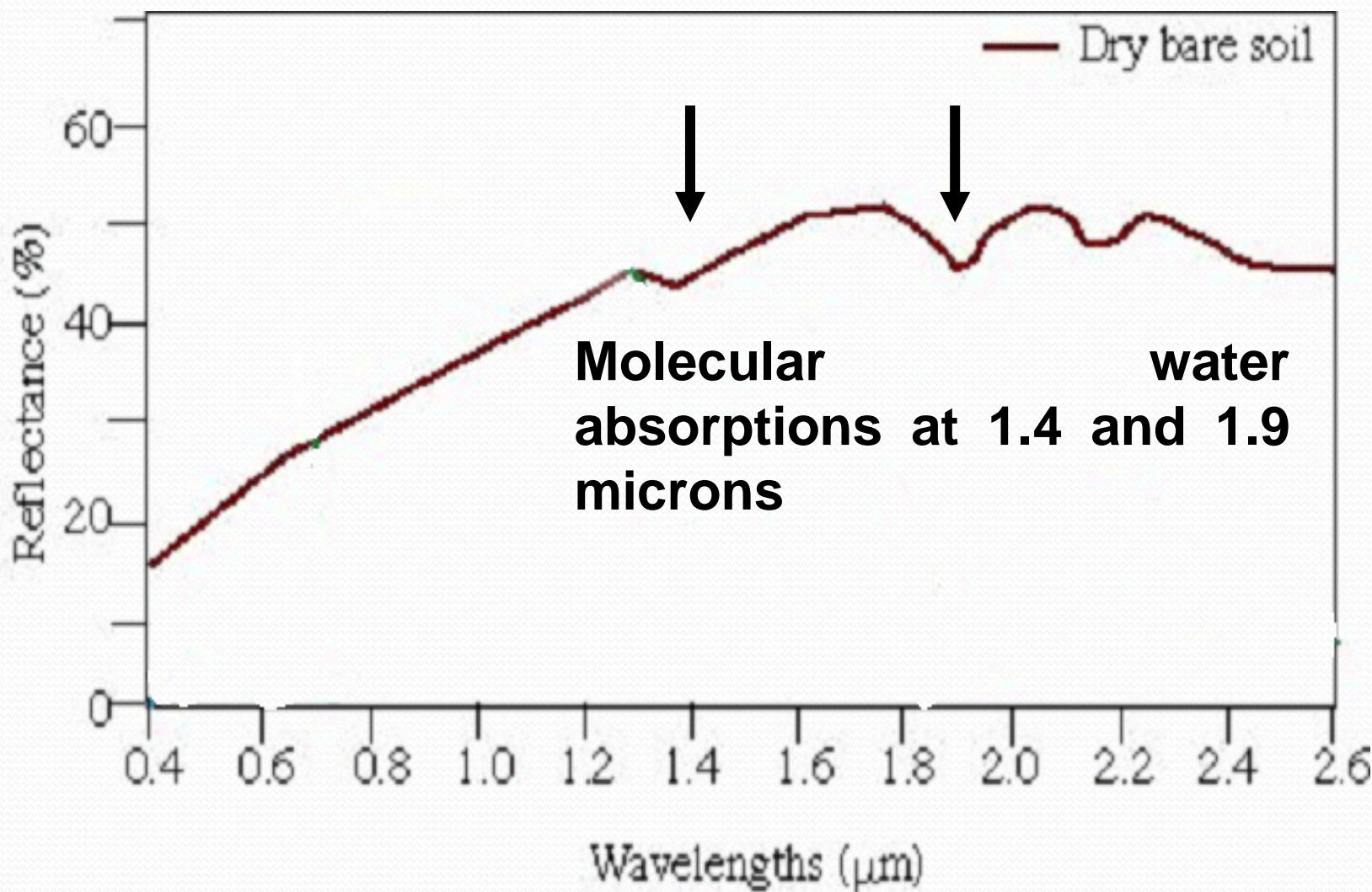
Key to feature identification from space imagery depends on the characteristic changes in the properties of the EM spectrum reflected/emitted from the target surface – referred ‘signature’

The graphical representation of the spectral response of an object over different wavelengths of the electromagnetic spectrum is termed as spectral reflectance curve.

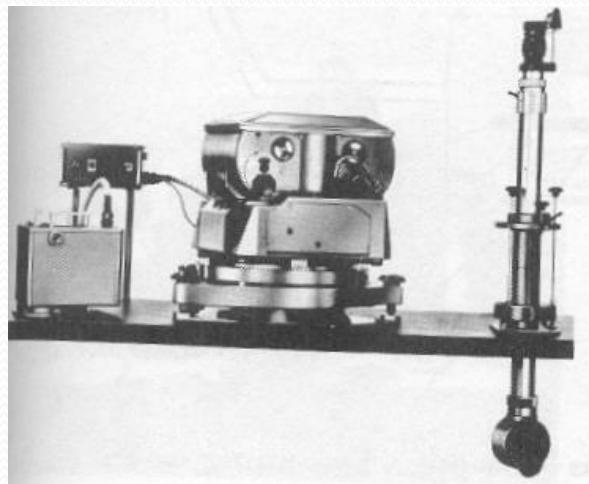




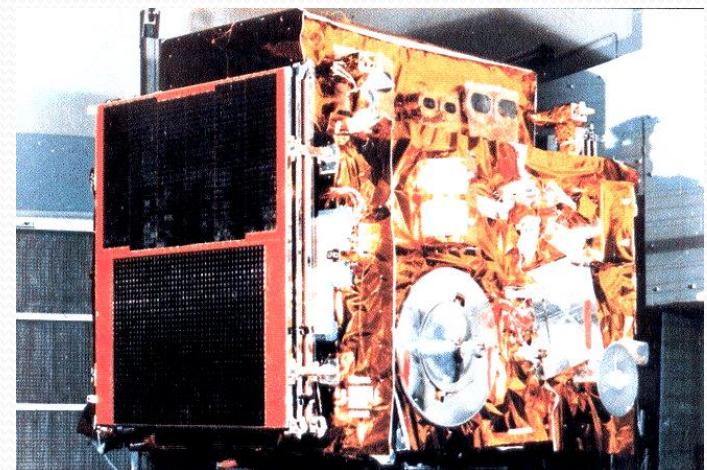
# SPECTRAL REFLECTANCE OF SOIL



# SENSORS

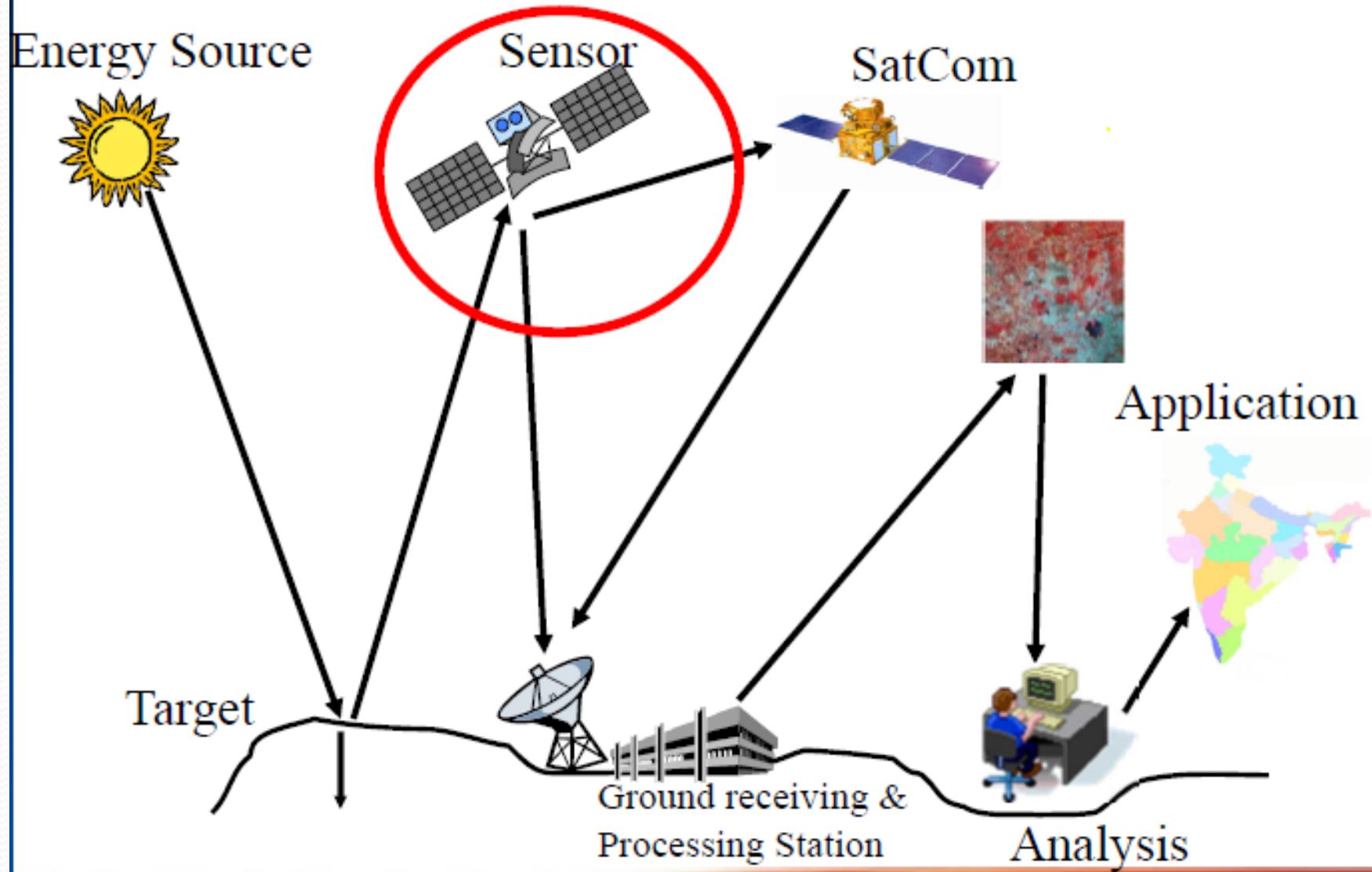


Camera



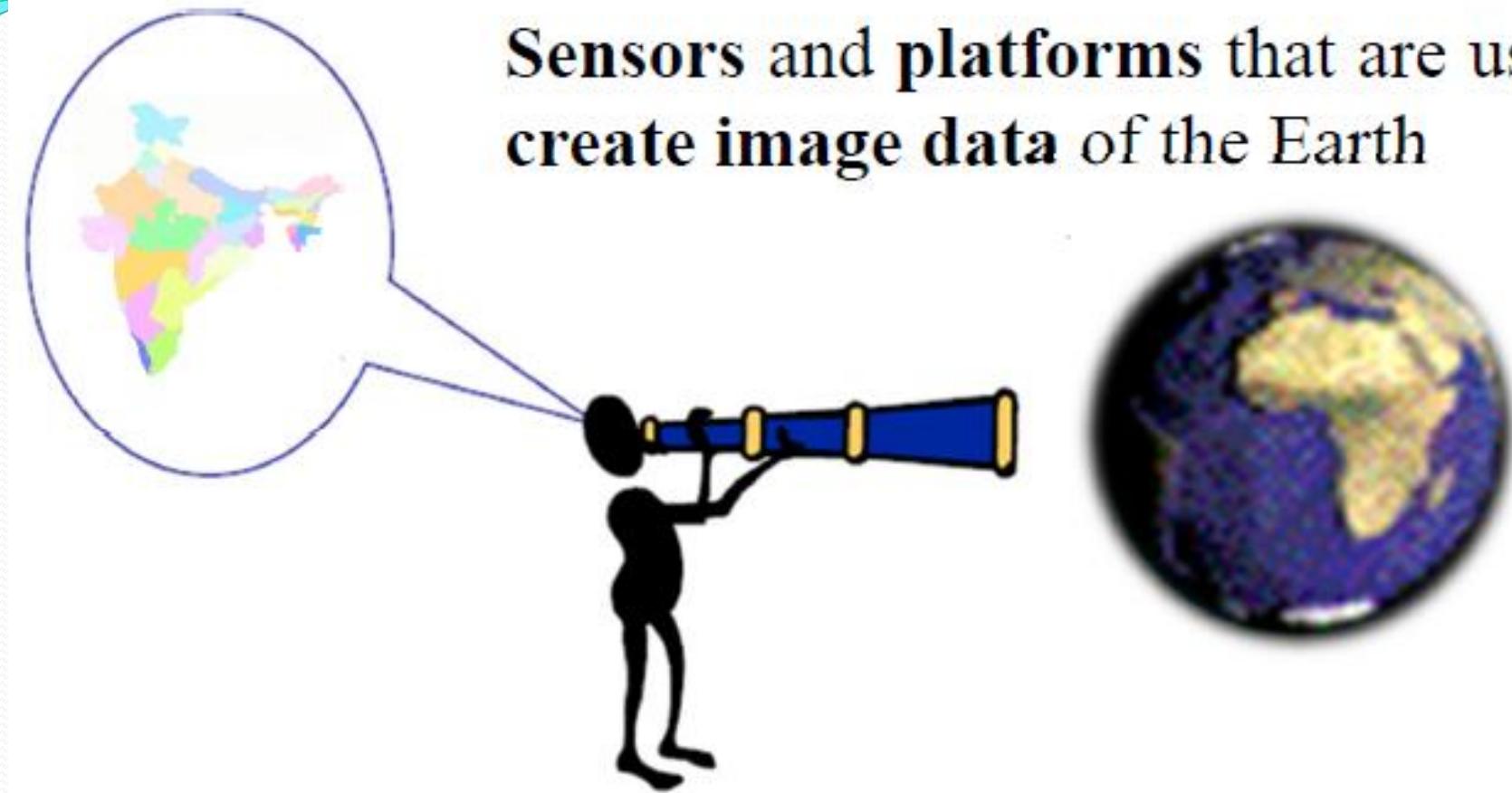
Scanner

# Remote Sensing Process



# Definition

**Sensors and platforms** that are used to create **image data** of the Earth



**Sensors**= a device that **records EM Energy**

**Platforms**= carrier bed used to **carry a sensor**

# Platforms

- Ground based
- Airborne
- Spaceborne



# Ground Based Platforms

- Used to **record detailed information** about the surface which is compared with **information collected from aircraft or satellite sensors**.
- In some cases, this can be used to **better characterize the target** which is being imaged by the other sensors, making it possible to **better understand the information in the imagery**.
- Sensors may be **placed on a ladder, scaffolding, tall building, crane, etc.**



# Airborne Platforms

- Are primarily **stable wing aircraft**, although **helicopters** are occasionally used.
- To collect **very detailed images** and facilitate the collection of data over **any portion of the Earth's surface at any time**.



# Spaceborne Platforms

- **Space remote sensing** is sometimes conducted from the
  - Space Shuttle**
  - Satellites** (more commonly)
- **Satellites** are objects which **revolve around another object** - in this case, the Earth.
- e.g: the **moon is a natural satellite**, whereas **man-made satellites** include those platforms launched **for remote sensing, communication, and telemetry (location and navigation) purposes**.



# **USUAL PLATFORMS**

- Aircraft
  - Helicopters
  - Microlites
  - Low altitude aircrafts
  - High altitude aircraft
- Satellites
  - Orbiting satellites
  - Geostationary satellites

# **CHARACTERISTICS OF PLATFORMS**

## **AIRCRAFT /Airborne Platform**

- Defence permission needed
- Imagery can be obtained at the time and place of our choice
- Expensive
- Usually used for cameras
- Narrow limited view
- Platform less stable
- Large scales
- Flexible repeat coverage
- High spatial resolution
- Less cost effective

# Satellite/Spaceborne platform

- Global coverage
- Defence permission not needed
- Wide, synoptic view
- Very stable platform
- Limited repeat coverage
- Highly cost effective

# **ORBIT**

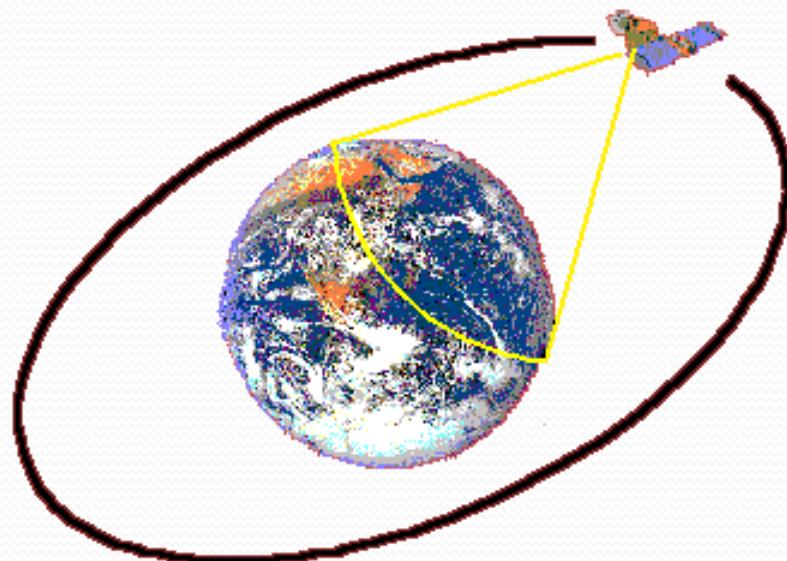
The path followed by a satellite

**Two types of Orbits are**

- 1) Geostationary Orbits
- 2) Near Polar Orbits

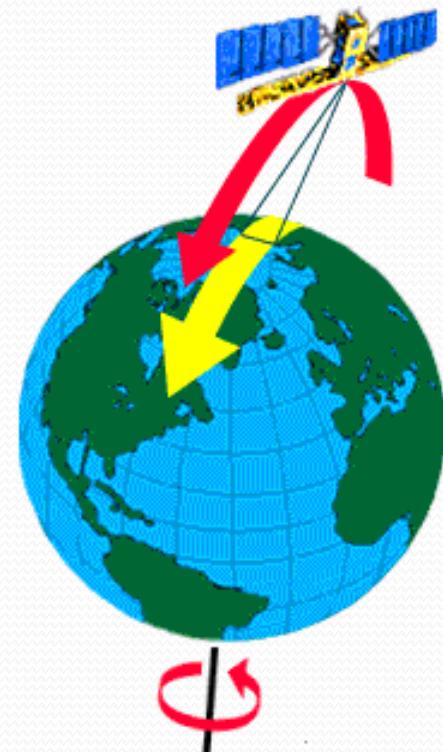
# GEOSTATIONARY ORBITS

- At altitudes of approximately 36,000 kilometres
- Revolve at speeds which match the rotation of the Earth so that they seem stationary, relative to the Earth's surface
- This allows the satellites to observe and collect information continuously over specific areas



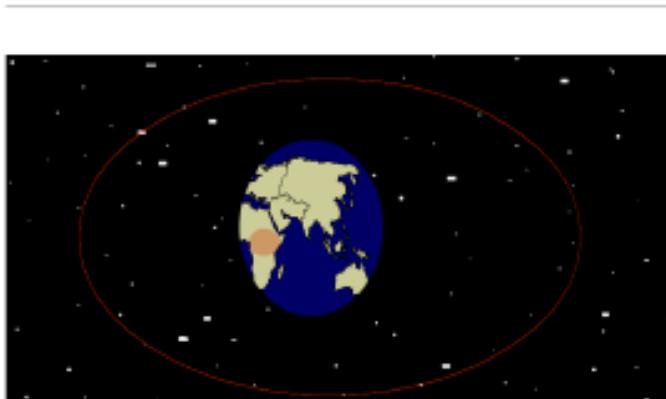
# NEAR-POLAR ORBITS

- The inclination of the orbit relative to polar axis.
- Some of these satellites' orbits are also **sun-synchronous**. This means that they cover each area of the world at a constant local time of day called **local sun time**.



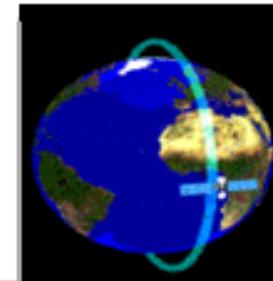
# Geostationary Satellite

- Altitude ~ 36,000 km,
- Orbit inclination ~ 0°
- Period of orbit = **24 hours**
- **Global coverage requires several geostationary satellite** in orbits at different latitudes
- Good for repetitive observations, **poor for spatially detailed data**
- Large distortions at high latitudes
- W-E satellite orbiting Earth
- Mainly used for communication and meteorological applications – **GOES, METEOSAT, INSAT etc.**

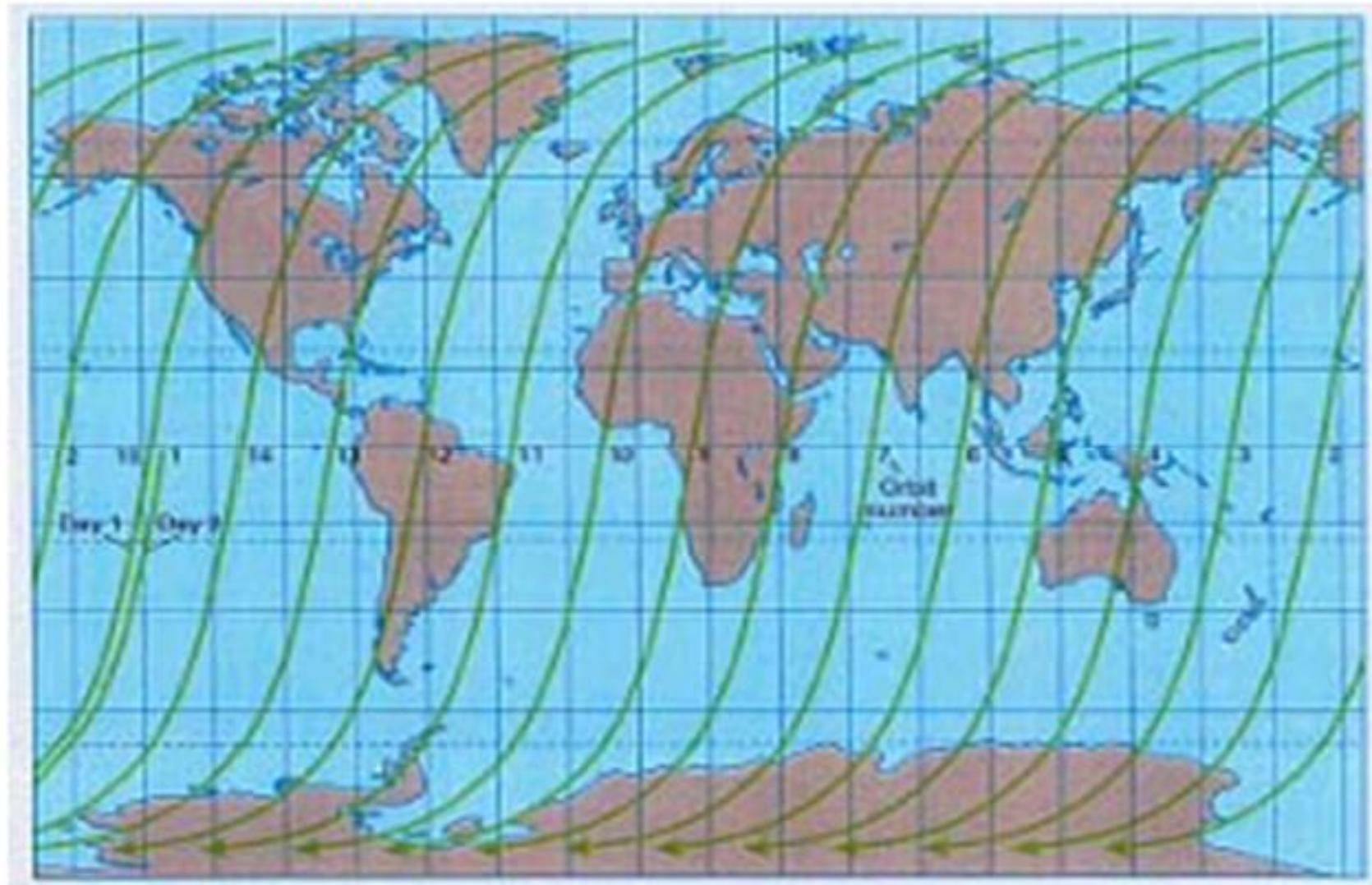


# Sun Synchronous Satellite

- Altitude ~700-800 km
- Orbit inclination ~ 98.7°
- Orbital period ~90 minutes
- Sun-synchronous, near-polar, near-circular
- Satellite orbit is fixed in space (basically **north-south**): Earth rotates beneath it (**west-east**)
- Cross the equator (N-S) at ~**10.30am local time**
- Satellite Orbital plane is near polar and the altitude is such that the satellite passes each place at same local sun-time.
- Cover entire globe – **LANDSAT, SPOT, NOAA, IRS etc.**



The satellite's orbit (North –South) and the rotation of the Earth (from west to east) work together to allow complete coverage of the Earth's surface, after it has completed one complete cycle of orbits

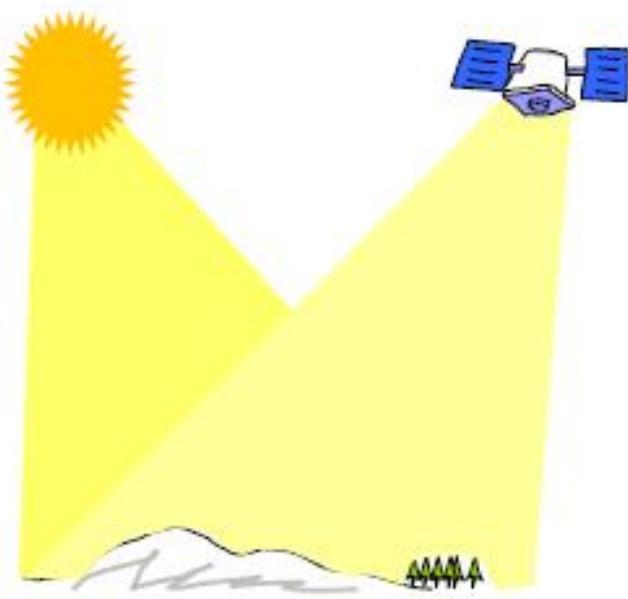


# SENSORS

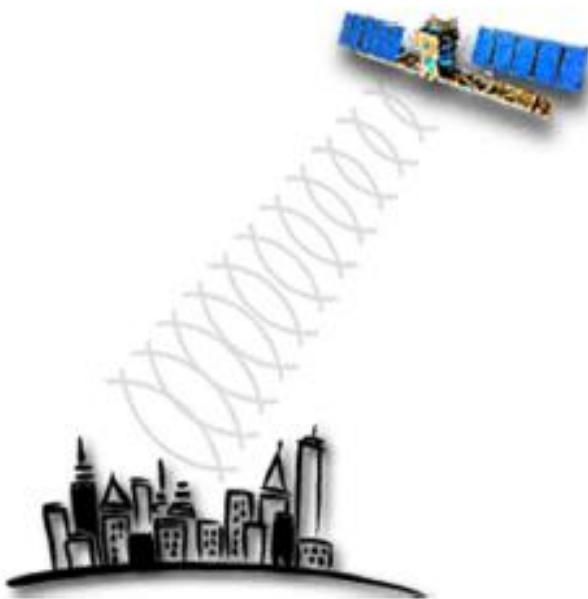


Passive

Active



Optical Remote Sensing



Microwave Remote Sensing

# Imaging Sensors

## Passive Sensors

1. Photographic Camera
2. The Optical Scanners
  - a) Across Track Scanners
  - b) Along Track Scanners
3. The Thermal Scanner

## Active Sensors

1. RADAR (Radio Detection and Ranging)
2. LiDAR (Light Detection and Ranging)

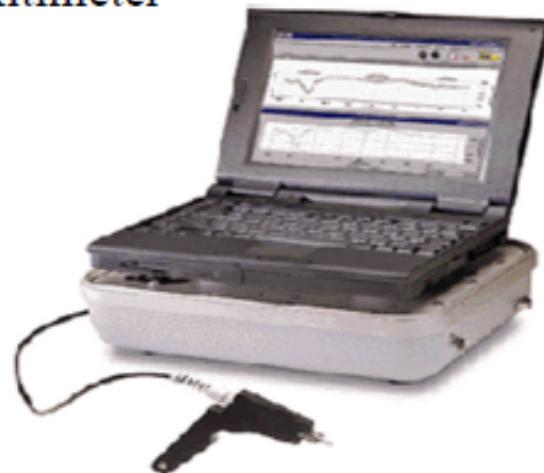
# Non-imaging Sensors

## Passive Sensors

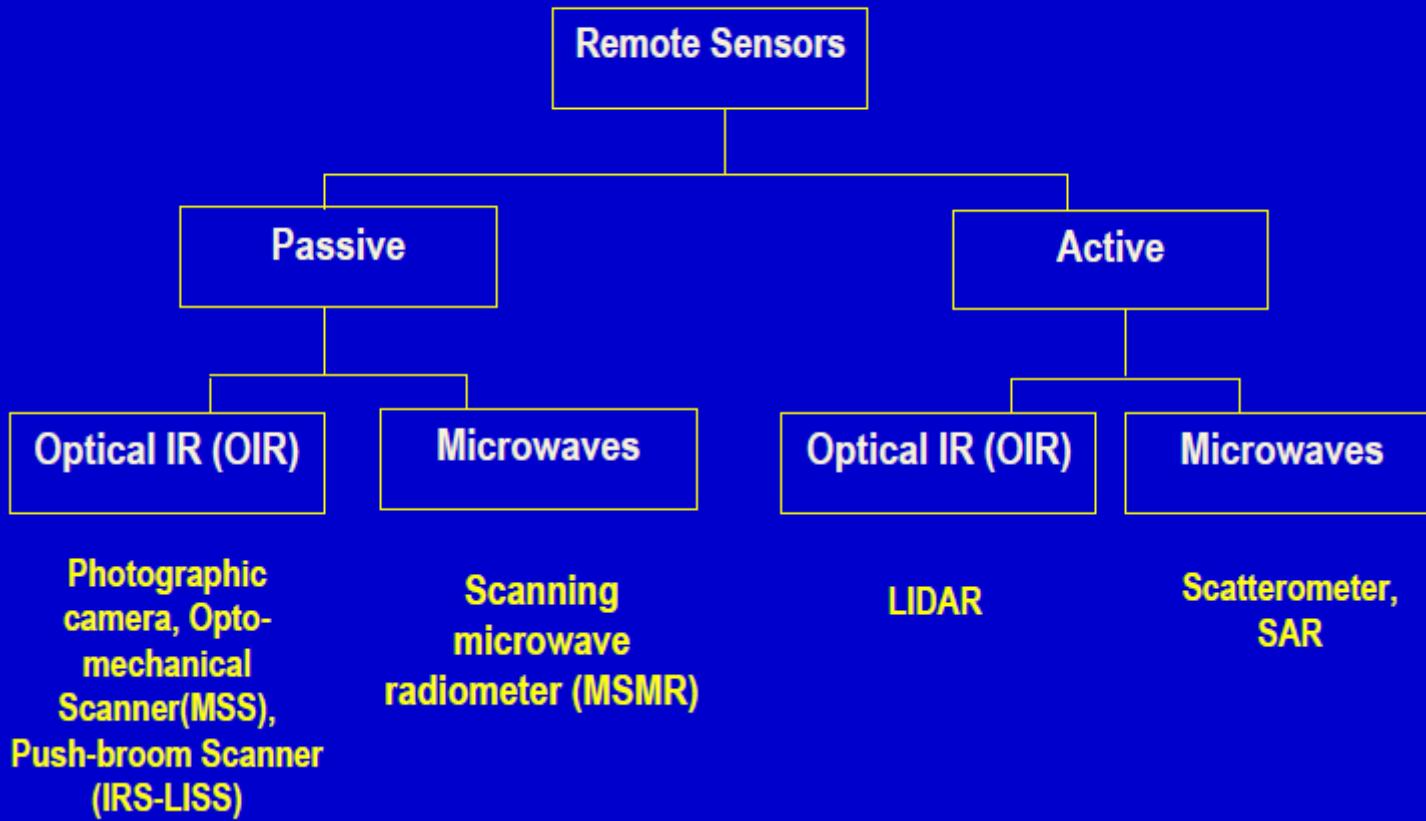
1. Spectro-radiometers

## Active Sensors

1. Laser Distance Meter
2. Laser Water Depth Meter
3. Microwave Altimeter



# CLASSIFICATION OF REMOTE SENSORS



- **IMAGING SENSORS**

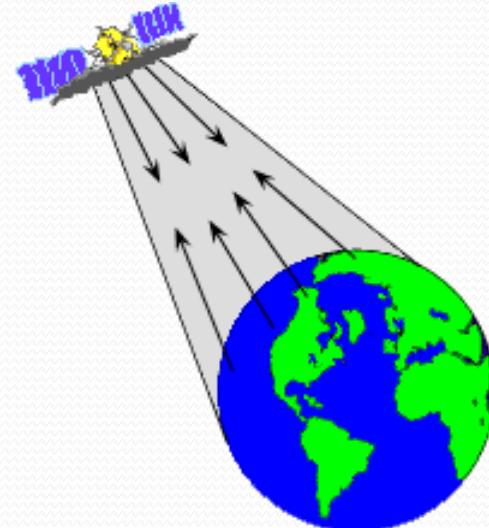
- Sensors which provide output to create an image
- Eg : LISS I, LISS II, LISS III etc.

- **NON IMAGING SENSORS**

- Sensors which provide numerical output with respect to the quantum of radiation
- Eg: Radiometer, Scatterometer etc.

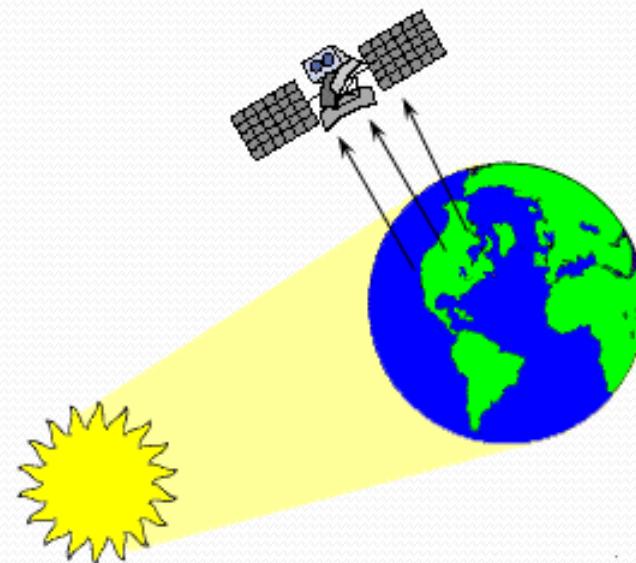
# **ACTIVE SENSORS**

- **Active sensors**, on the other hand, provide their own energy source for illumination.
- The sensor emits radiation which is directed toward the target to be investigated. Eg: RADAR



# PASSIVE SENSORS

- Remote sensing systems which measure energy that is naturally available are called **passive sensors**.
- Passive sensors can only be used to detect energy when the naturally occurring energy is available.



# **COMMON SENSORS USED IN REMOTE SENSING**

- Cameras
- Scanners
- Radar

# **CHARACTERISTICS OF CAMERA**

- Passive Remote Sensing
- Very high resolution imagery
- Stereo-capability
- Films - black & white, Colour, Colour Infrared
- Central perspective
- Well-defined geometry.

# **CHARACTERISTICS OF SCANNER**

- Output in digital form
- Highly amenable for computer processing
- No consumables
- Flexible w.r.t. radiometric and spectral resolutions

## **CHARACTERISTICS OF RADAR**

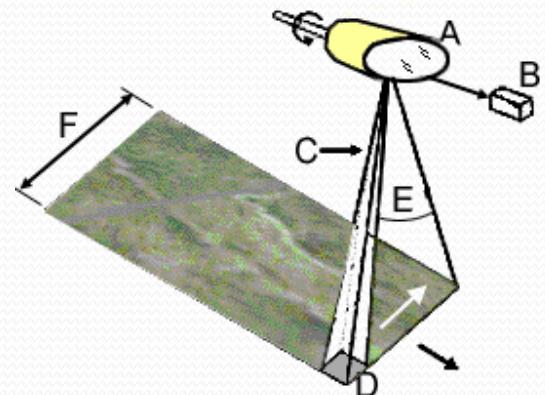
- All weather capability, day and night observing capability
- Sensitive to moisture
- Soil depth penetration to certain extent

- **Photographic Cameras** – Conventional Camera System.
- **Return Beam Videocon** – Image formed over semi transparent film as charge or potential.  
Similar to Television Cameras.
- **Thermal System** – Measures the emitted radiation from an object.
- **Optical Mechanical Scanners** – Employs filters and Detector combinations.
- **RADAR and Microwave Sensors (SLAR/SAR)**

# **SCANNERS**

# ACROSS-TRACK SCANNERS

- Scan the Earth in a series of lines.
- The lines are oriented perpendicular to the direction of motion of the sensor platform (i.e. across the swath).
- Each line is scanned from one side of the sensor to the other, using a **rotating mirror (A)**, also called **whiskbroom**.



# Across Track Multispectral Scanning

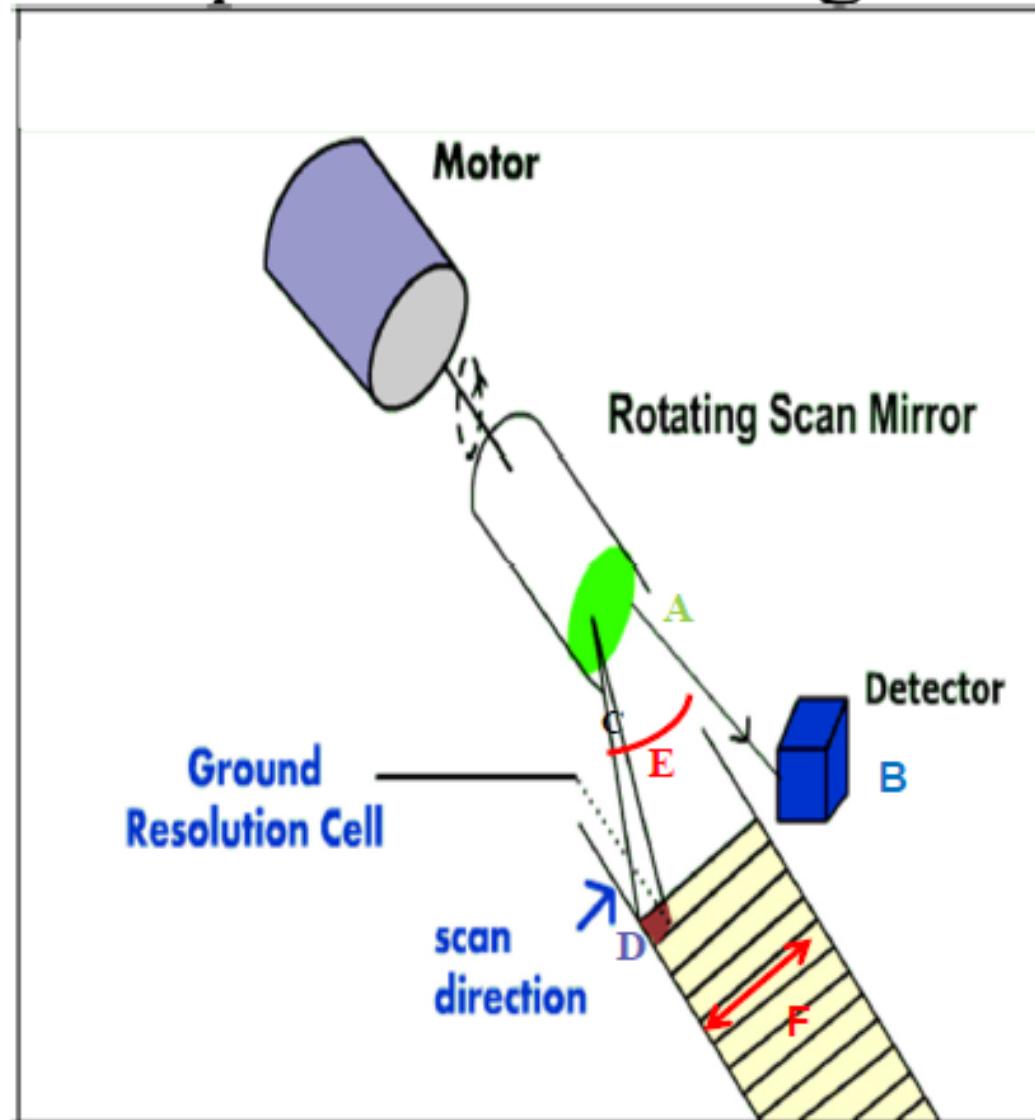
Whisk broom scanning

Scan the Earth in a series of lines.

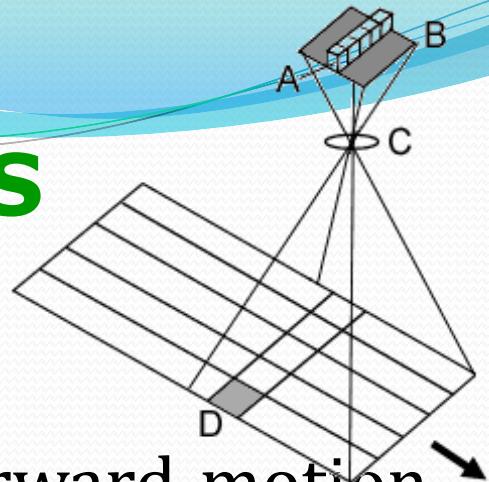
The lines are oriented perpendicular to the direction of motion of the sensor platform (i.e. across the swath).

Data are collected within an arc below the system typically of some **90° to 120°**

Multispectral scanner (MSS) and thematic mapper (TM) of LANDSAT, and Advanced Very High Resolution Radiometer (AVHRR) of NOAA are the examples of Whisk Broom scanners



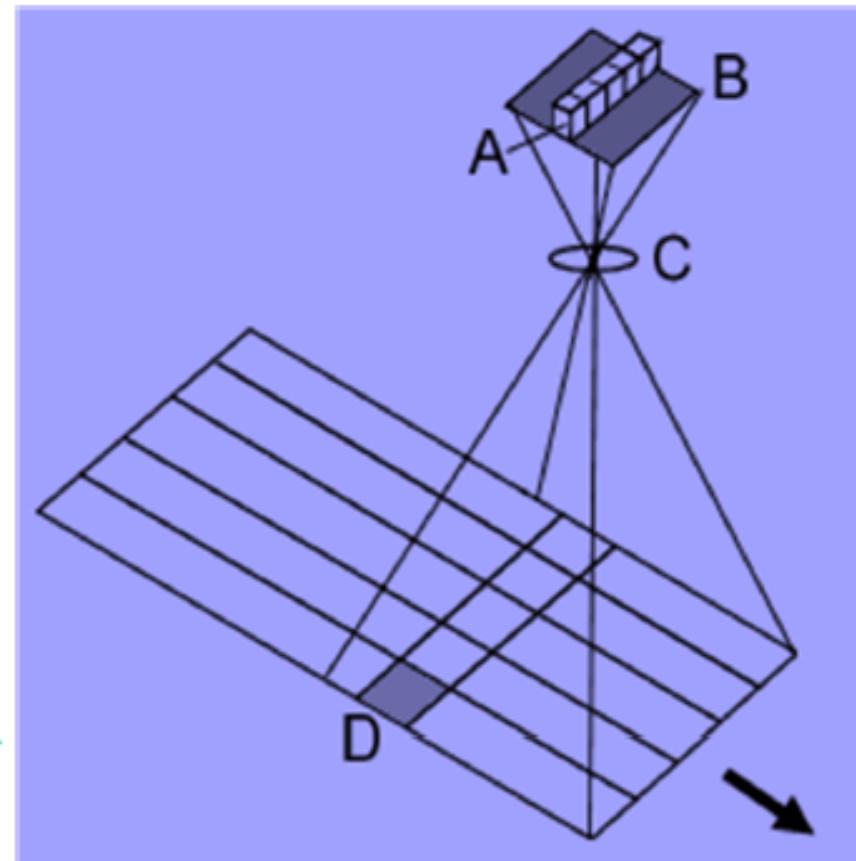
# ALONG-TRACK SCANNERS



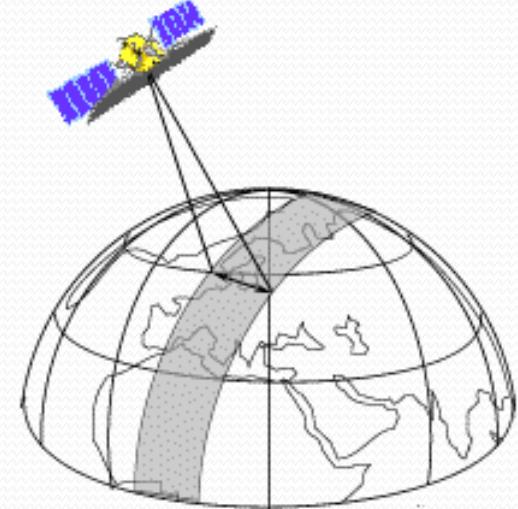
- **Along-track scanners** also use the forward motion of the platform to record successive scan lines and build up a two-dimensional image, perpendicular to the flight direction.
- Instead of a scanning mirror, they use a linear array of detectors (A) located at the focal plane of the image (B) formed by lens systems (C), which are "pushed" along in the flight track direction (i.e. along track).
- Also referred to as **pushbroom scanners**

# Along Track Multispectral Scanning

- Push broom scanning
- Scan the Earth in a series of lines.
- This also uses the forward motion of the platform to record successive scan lines and build up a two-dimensional image, perpendicular to the flight direction.
- Linear arrays normally consist of numerous **charge-coupled devices (CCDs)** positioned end to end.
- Linear imaging self scanning (LISS) and Wide Field Sensor (WiFS) of IRS Series, and High Resolution Visible (HRV) of SPOT-1 are the examples of Push broom scanners

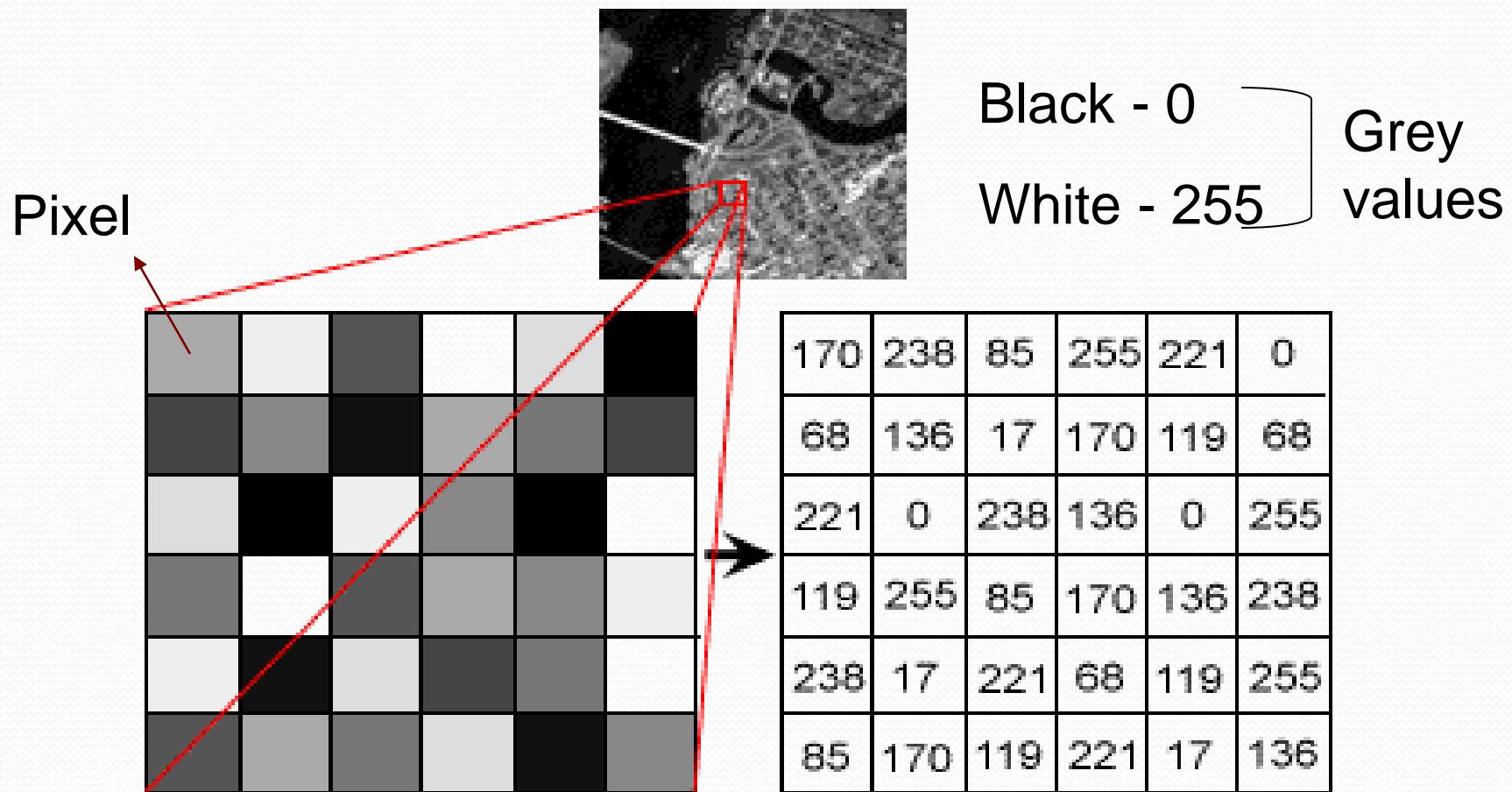


# SWATH



- As the satellite revolves around the Earth, the sensor "sees" a certain portion of the Earth's surface.
- The width of the strip imaged is referred to as the **swath width**.

# PIXELS (Picture + elements)



# **FOUR TYPES OF RESOLUTION**

**Spatial Resolution**

**Spectral Resolution**

**Radiometric Resolution**

**Temporal Resolution**



# Spatial Resolution

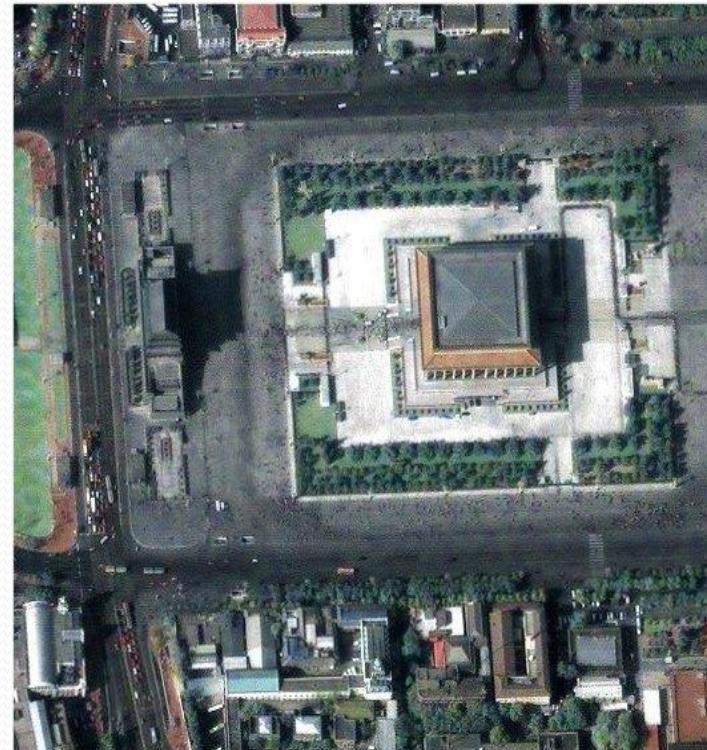
- Refers to the size of the smallest possible feature that can be sensed

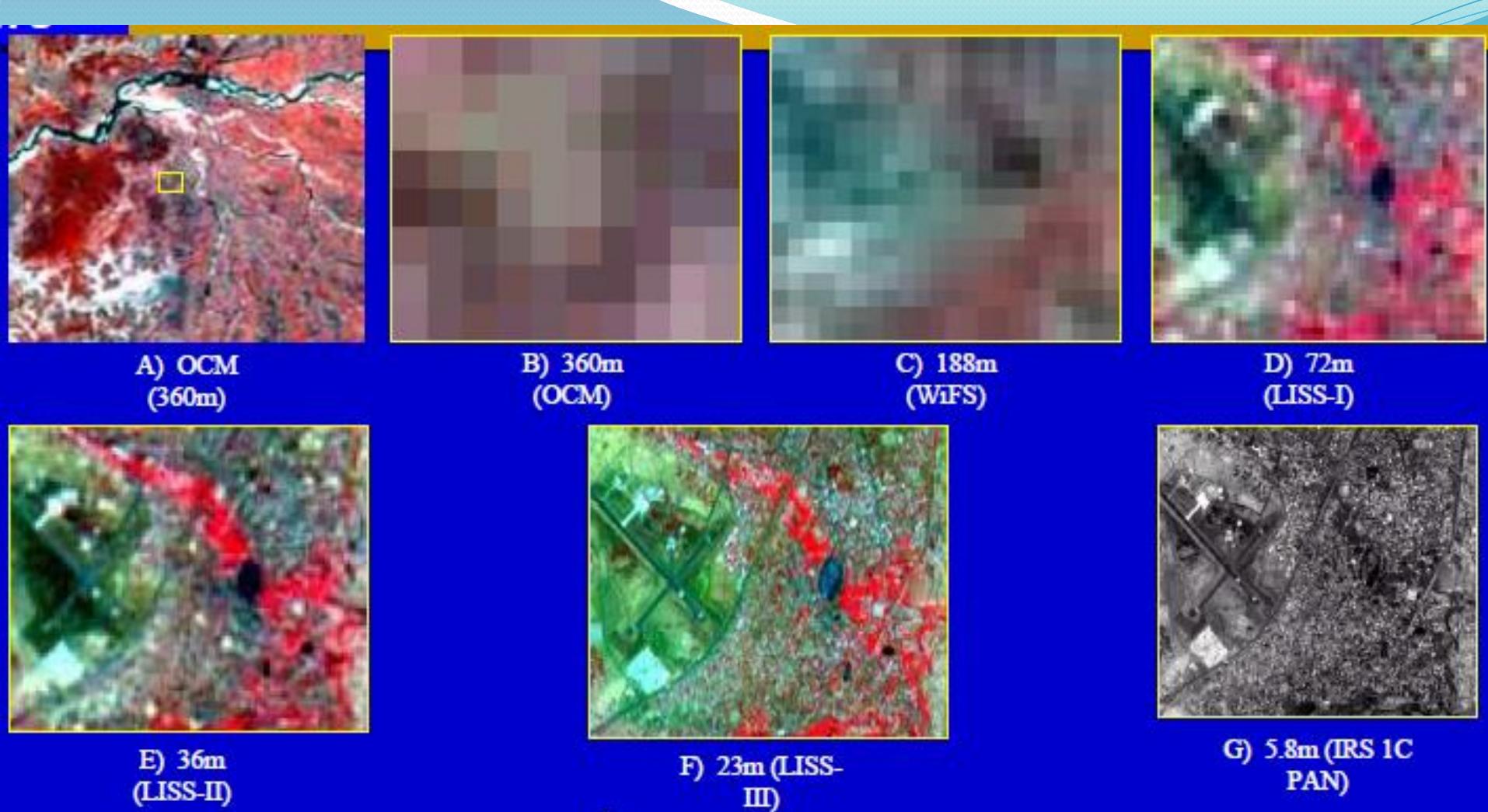
IRS 1C/D – 5.8m

(PAN)

IKONOS – 1m (PAN)

RESOURCESAT – 5.8m  
MULTISPECTRAL





Information content Vs resolution. 'A' is from a scene from IRS Ocean Colour Monitor (OCM). The area in the small square marked ( $\approx 4\text{km} \times 4\text{km}$ ) is shown in various resolutions from B to G. The feature showing airport runway is not at all discernable at 360 and 188 meter resolution; can be barely identified at 72 meters and the details one can discern increases as the resolution improves. At 5.8m even marking on the runway can be identified.

SPOT 2.5m



Shanghai, China  
SPOT 2.5m





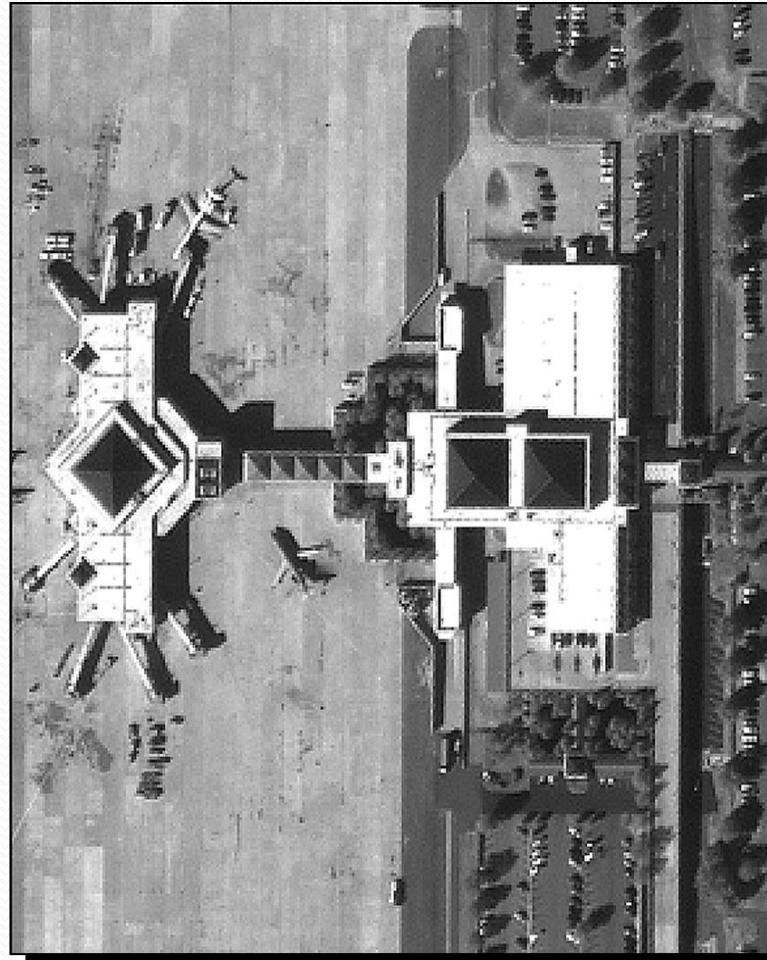
1 x 1 m spatial resolution

IKONOS  
Panchromatic Images  
of Washington, DC



Jensen, 2000

# IKONOS Panchromatic Stereopair of Columbia, SC Airport



Jensen, 2000



November 15,  
2000

## IKONOS Imagery of Columbia, SC Obtained on October 28, 2000

Panchromatic 1 x 1 m



# Spectral Resolution

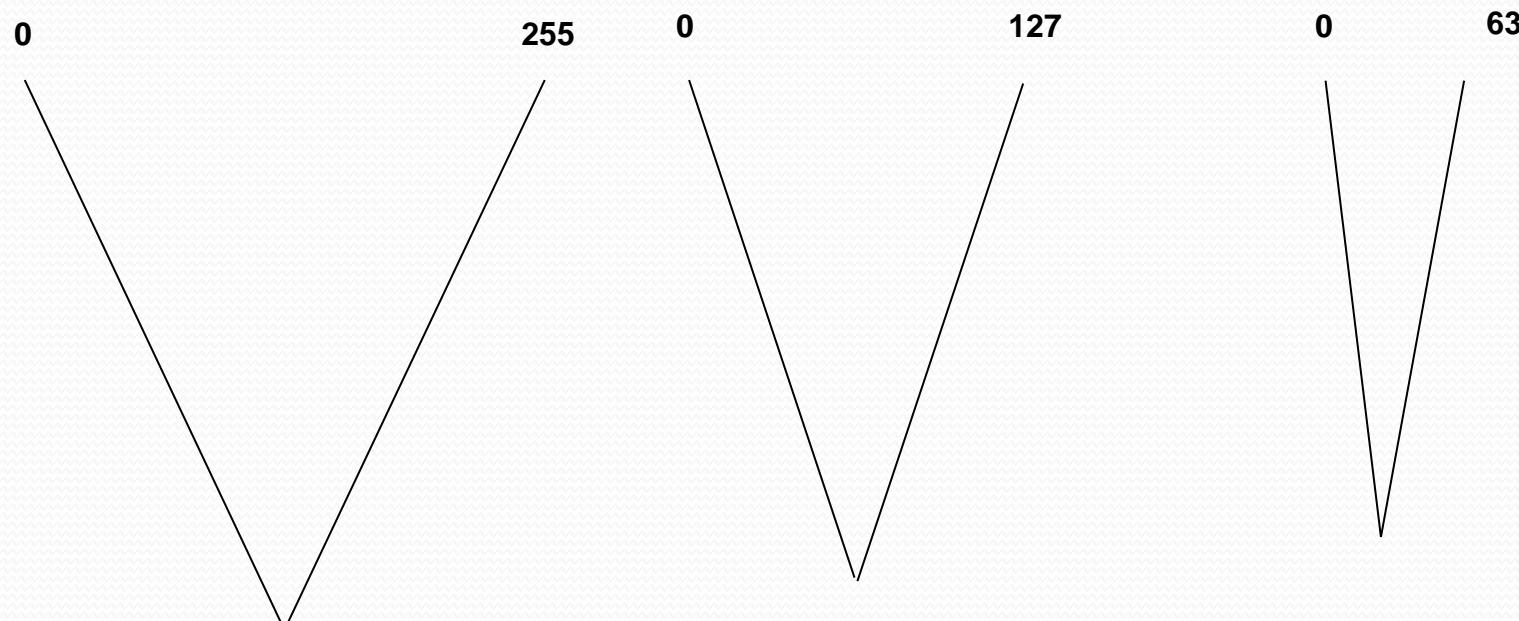


- Ability of a sensor to define fine wavelength intervals.
- The finer the spectral resolution, the narrower is the wavelength range for a particular channel or band.



# Radiometric Resolution

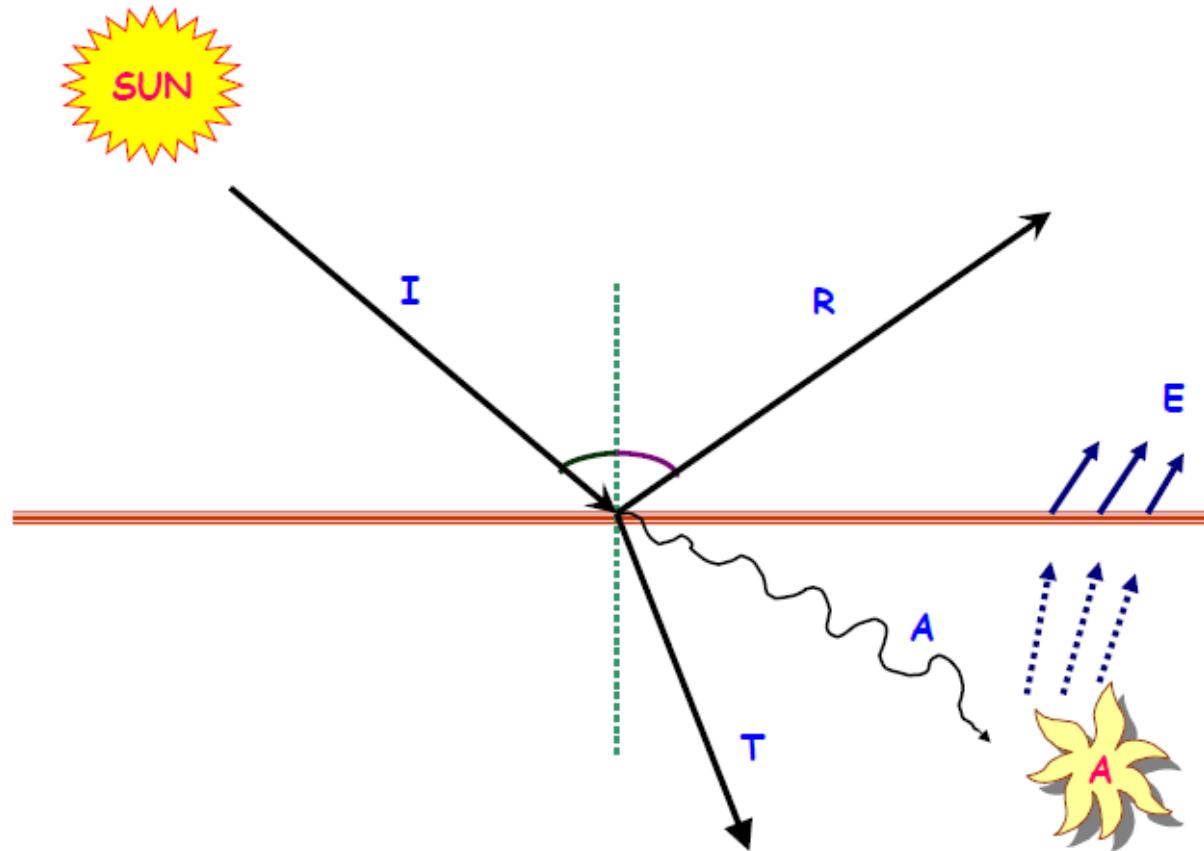
- Ability of the sensor to discriminate very slight differences in energy.
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.



# **Temporal Resolution**

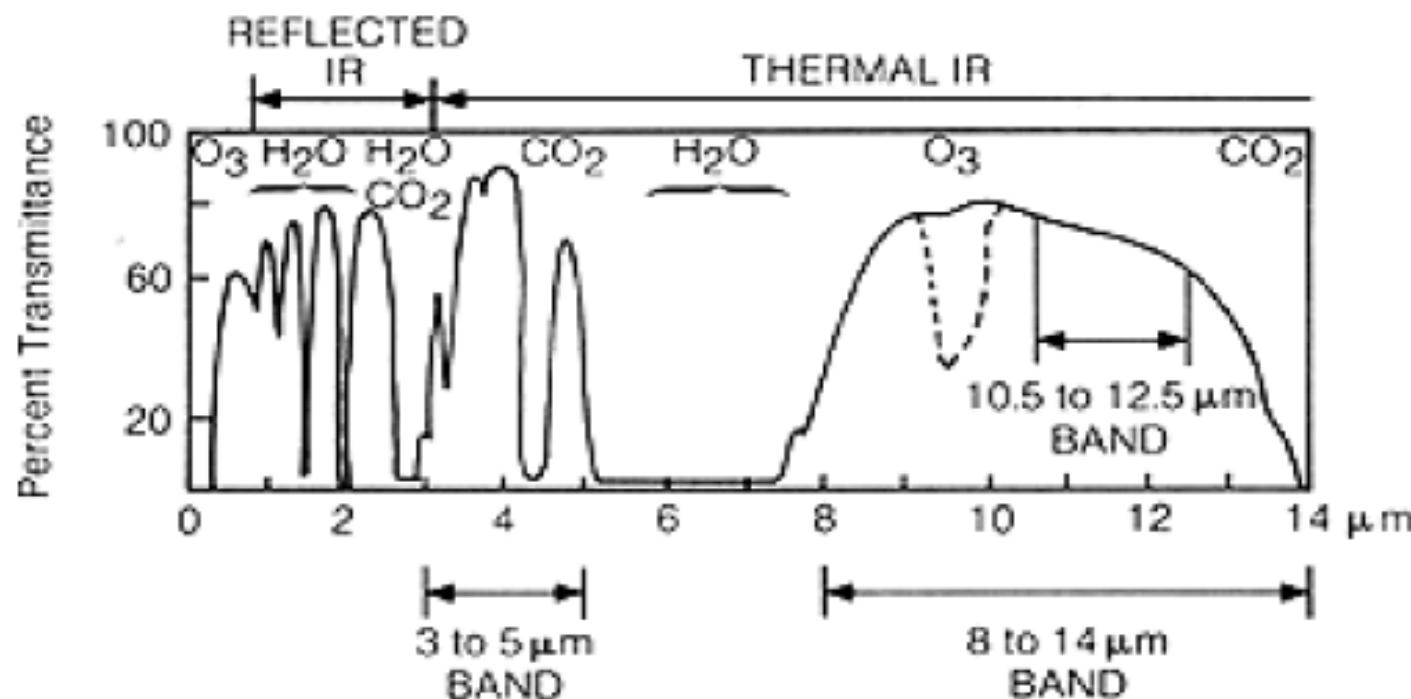
- Time interval between two successive visits of the satellite for the same place.
- Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing multi-temporal imagery.

# Thermal remote sensing



- Sensors that measure emitted radiation in the thermal region (infrared region) of the spectrum can produce very informative data about earth features.
- *Thermal Remote Sensing* can be defined as ‘detection of remote objects by recording amount of thermal radiation emitted from various surfaces’.
- All materials having a temperature above absolute zero (0 K or  $-273^{\circ}\text{C}$ ) emit thermal energy both day and night.

# Thermal Spectrum



- Thermal IR radiation is absorbed by glass lenses of conventional cameras and can't be detected by photographic films.
- Special optical-mechanical or electronic scanners are used to detect and record images in thermal IR region.

# **THERMAL PROPERTIES OF MATERIALS**

The primary objective of temperature measurements and related thermal response is to infer something about the nature, composition and other physical attributes of materials at the earth's surface and in its atmosphere.

**Emissivity ( $\epsilon$ )**

**Thermal Inertia (P)**

**Heat capacity (C)**

**Thermal Conductivity (K)**

**Thermal Diffusivity ( $\Gamma$ )**

# **ACQUISITION OF TIR INFORMATION**

Several instruments are available for the remote acquisition of surface information in TIR region. The majority of them are either Airborne or Spaceborne with a few field instruments.



**Heat Capacity mapping Mission (HCMM)** 10.5 - 12.5  $\mu\text{m}$ ; resolution 600 m

**Thermal Infrared Multispectral Scanner (TIMS)**

6 bands between 8-12  $\mu\text{m}$

**NOAA AVHRR**

5 bands; resolution 1.1 km



## Landsat Thematic Mapper (TM) band 6

10.4 - 12.5  $\mu\text{m}$ ; 60 m resolution

## Advanced Spaceborne Thermal Emission Reflectance Radiometer (ASTER) (Terra)

High resolution multispectral imager

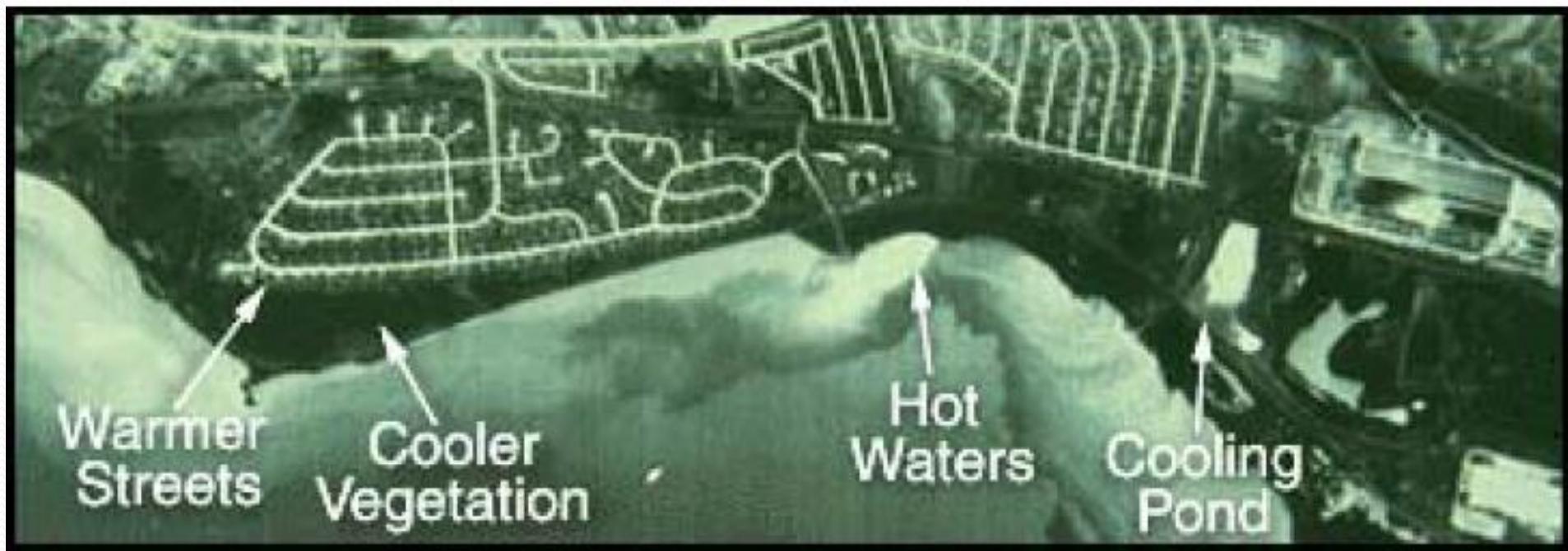
3 bands in VNIR (0.5 - 1.0  $\mu\text{m}$ ); 15 m resolution

6 bands in SWIR (1.0-2.5  $\mu\text{m}$ ); 30 m resolution

5 bands in TIR (8-12  $\mu\text{m}$ ); 90 m resolution

# Night-time (TM-6) thermal image of Lake Ontario and Erie





# Microwave remote sensing

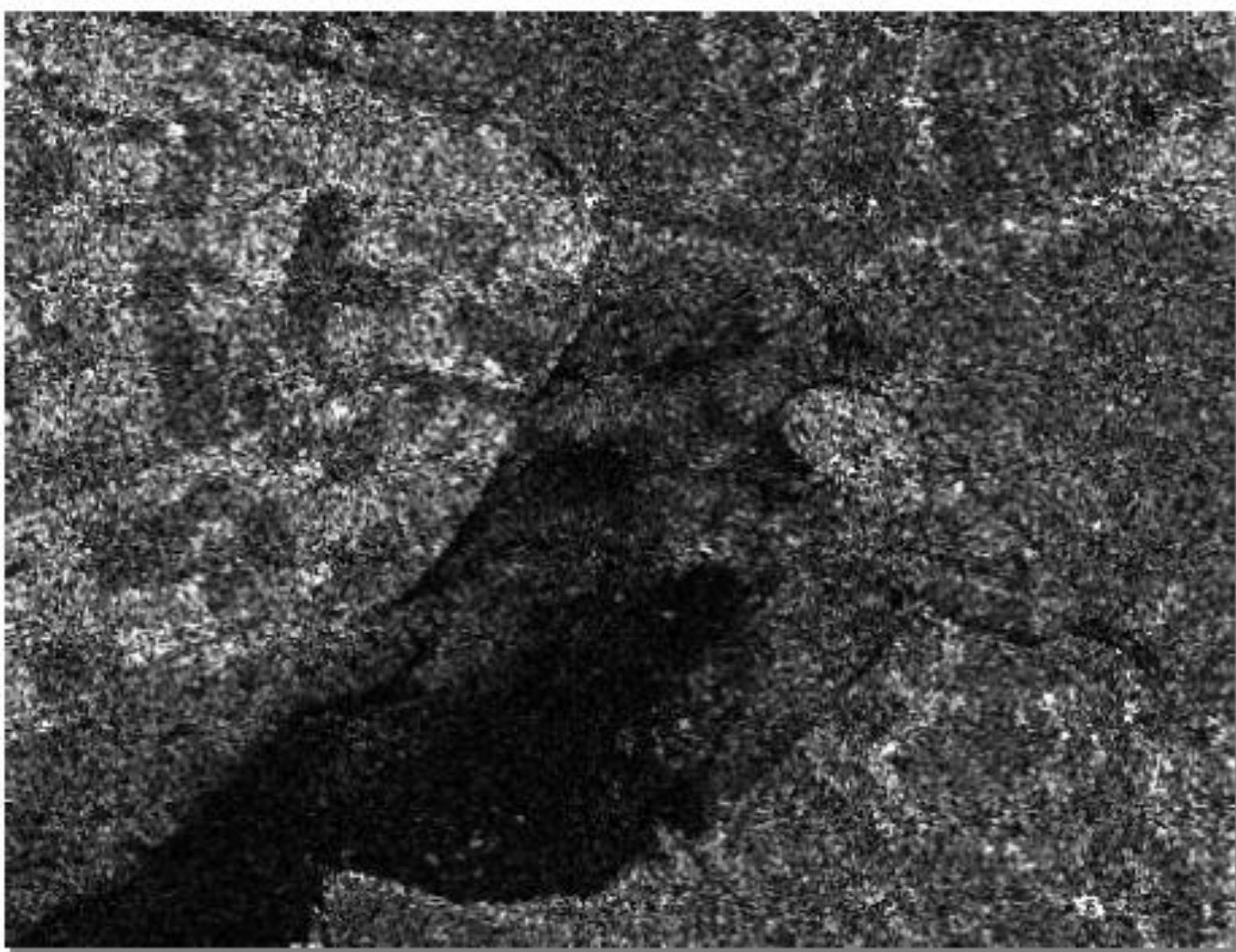
# Introduction

Analyzing the information collected by the sensors that operate in the *microwave portion* of the electromagnetic spectrum is called as **Microwave Remote Sensing**.

1mm to 1m

These longer waves have capability of penetrating through the clouds thus overcoming the atmospheric effects

**Microwave reflection (backscattering) - in active mode  
emission - in passive mode,**

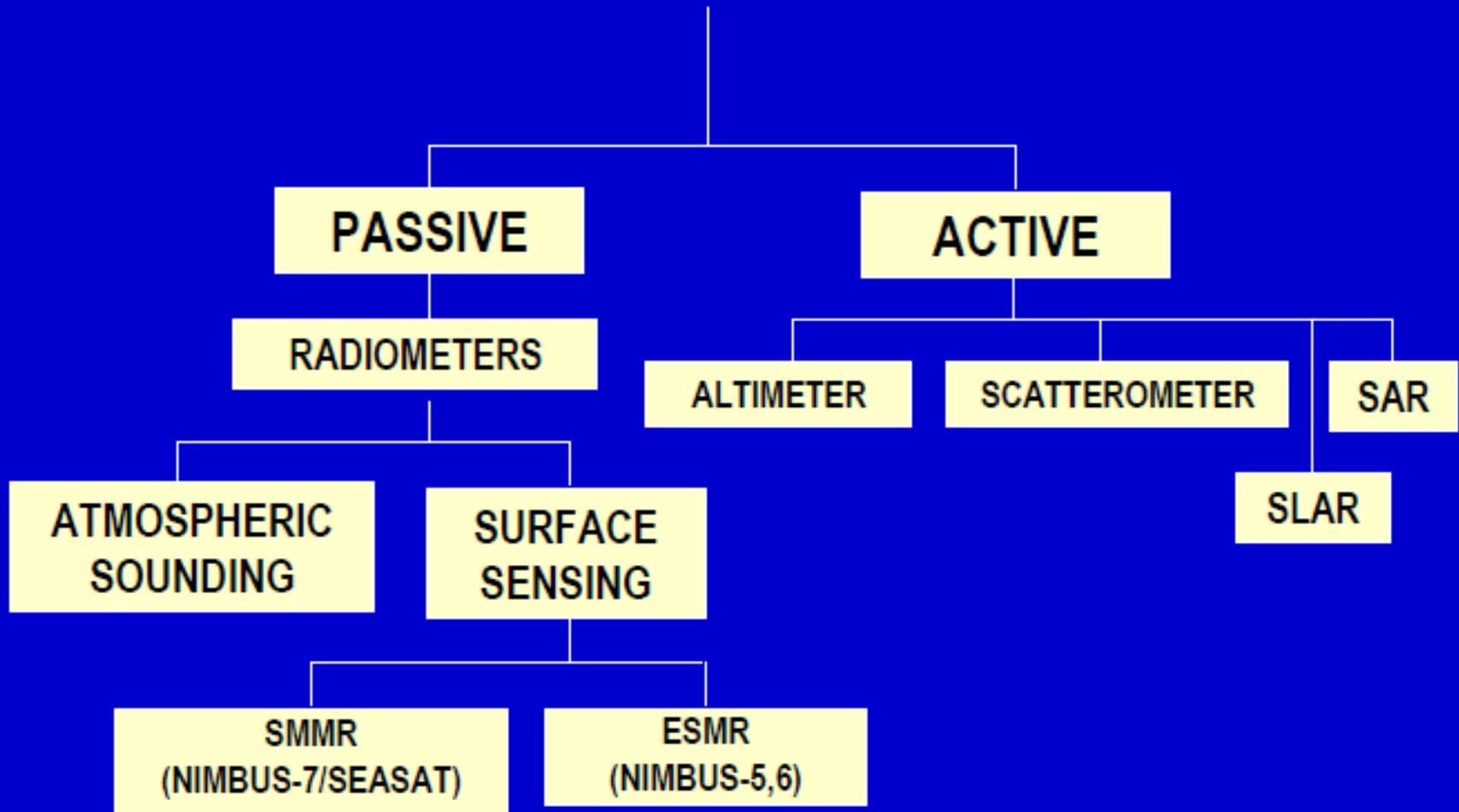


The amount and nature of backscattered electromagnetic radiation can provide information about the size, shape, configuration and electrical properties, etc of the surfaces and objects irradiated.

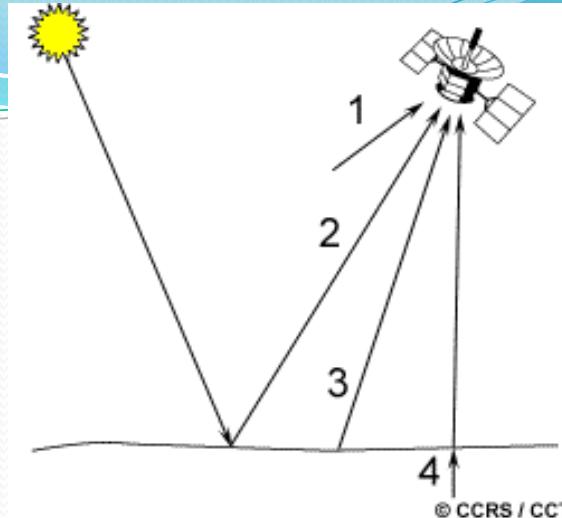
### **Advantages over remote sensing in the other regions of EMR.**

1. Time independent.
2. Weather independent.
3. Sensitive to moisture in soil, vegetation and snow.
4. Enhancement of surface roughness / relief.
5. Penetration of soil and vegetation cover.
6. Ability to collect data which are far away from flight path.

# MICROWAVE SENSORS



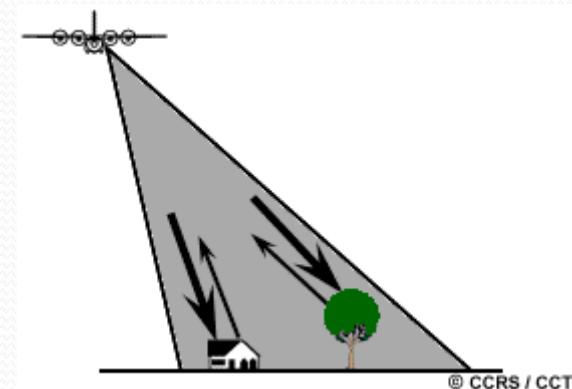
**Passive microwave** sensor detects the naturally emitted microwave energy within its field of view. This emitted energy is related to the temperature and moisture properties of the emitting object or surface. Passive microwave sensors are typically radiometers or scanners and operate in much the same manner as systems discussed previously except that an antenna is used to detect and record the microwave energy .



**Active microwave** sensors provide their own source of microwave radiation to illuminate the target. Active microwave sensors are generally divided into two distinct categories: **imaging and non-imaging**.

The most common form of imaging active microwave sensors is RADAR.

**RADAR** is an acronym for **R**Adio **D**etection **A**nd **R**anging, which essentially characterizes the function and operation of a radar sensor.



Non-imaging microwave sensors include **altimeters** and **scatterometers**.

## Radiometers

Radiometers are basically high sensitive receivers operating in different frequencies depending on the application. Radiometers receive the natural electromagnetic radiation emitted by the target in the desired frequency and process it to provide the geophysical information. The **data is used for studying the soil moisture and snow cover on land, salinity and surface wind speeds in oceans and water vapour and liquid water content in atmosphere.** Radiometers also can be used for generating imageries of the target/terrain of interest.

**Scatterometer** is also a Side Looking Radar, but configured to measure the Radar cross section/scattering co-efficient of the target accurately rather than mapping it. Ground based scatterometers are used to collect the Radar cross section of various targets of interest as a function of the sensor and target parameters. From spaceborne platforms, the scatterometer is mainly used to **measure the ocean surface wind speed and direction**. This can generate this wind data over a wide area (500 - 800 Km.) with good accuracy.

### **Altimeter**

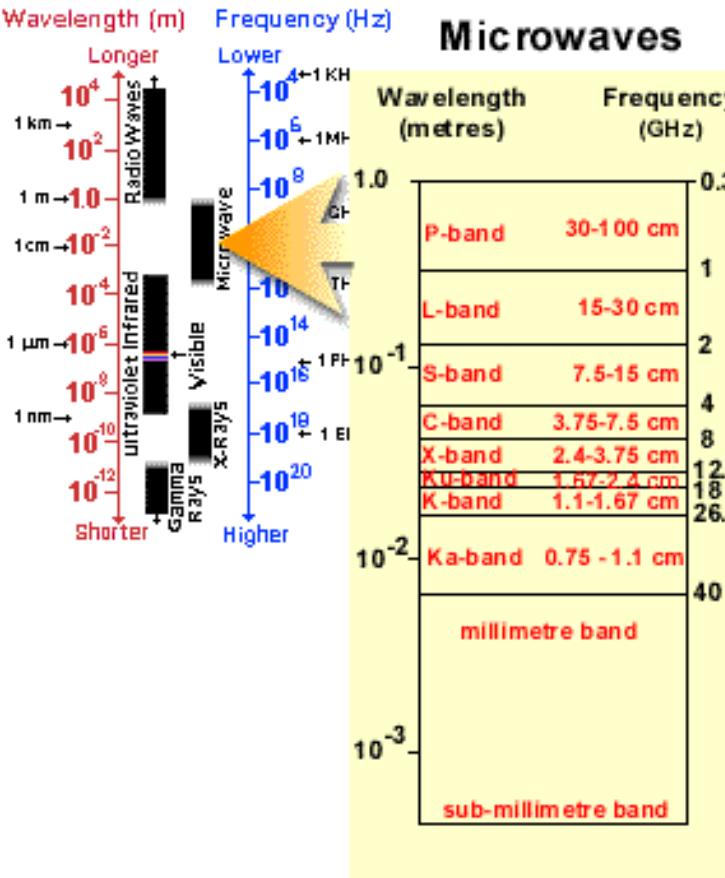
It measures the **ocean surface topography, significant wave height and surface wind speed**. It can also be configured to measure the terrain evaluation on land. It operates in nadir looking mode.

### **Rain mapping Radar**

It is meant for **measuring the rainfall** in the tropical region. The Radar transmits coherent high energy pulses at microwave frequencies and receives the back-scattered power from rain drop and processes to provide information on the rain rate, vertical distribution etc. It can measure rainfall rate upto 0.5 mm/hr.

### **Side Looking Radar**

Real Aperture Radars are less complex. But the resolution is directly linked to the physical length of the antenna and distance to the target. This is overcome by the Synthetic Aperture Radar, though a complex system, using signal processing techniques.



The **microwave region of the spectrum** is quite large, relative to the visible and infrared, and there are several wavelength ranges or bands commonly used which given code letters during World War II, and remain to this day.

**Ka, K, and Ku bands:** very short wavelengths used in early airborne radar systems but uncommon today.

**X-band:** used extensively on airborne systems for military reconnaissance and terrain mapping.

**C-band:** common on many airborne research systems (CCRS Convair-580 and NASA AirSAR) and spaceborne systems (including ERS-1 and 2 and RADARSAT).

**S-band:** used on board the Russian ALMAZ satellite.

**L-band:** used onboard American SEASAT and Japanese JERS-1 satellites and NASA airborne system.

**P-band:** longest radar wavelengths, used on NASA experimental airborne research system.

Band code	Wavelength ( $\lambda$ ) in cm	Frequency( $\nu$ ) GHz
Ka	0.8 - 1.1	40 - 26.5
K	1.1 - 1.7	26.5 - 18.0
Ku	1.7 - 2.4	18.0 - 12.5
X	2.4 - 3.8	12.5 - 8.0
C	3.8 - 7.5	8.0 - 4.0
S	7.5 - 15.0	4.0 - 2.0
L	15.0 - 30.0	2.0 - 1.0
P	30.0 - 100.0	1.0 - 0.3

## RADAR Return and Image Signatures

Energy reflected from the terrain to the radar antenna is called radar return. The following parameters strongly affect the radar return.

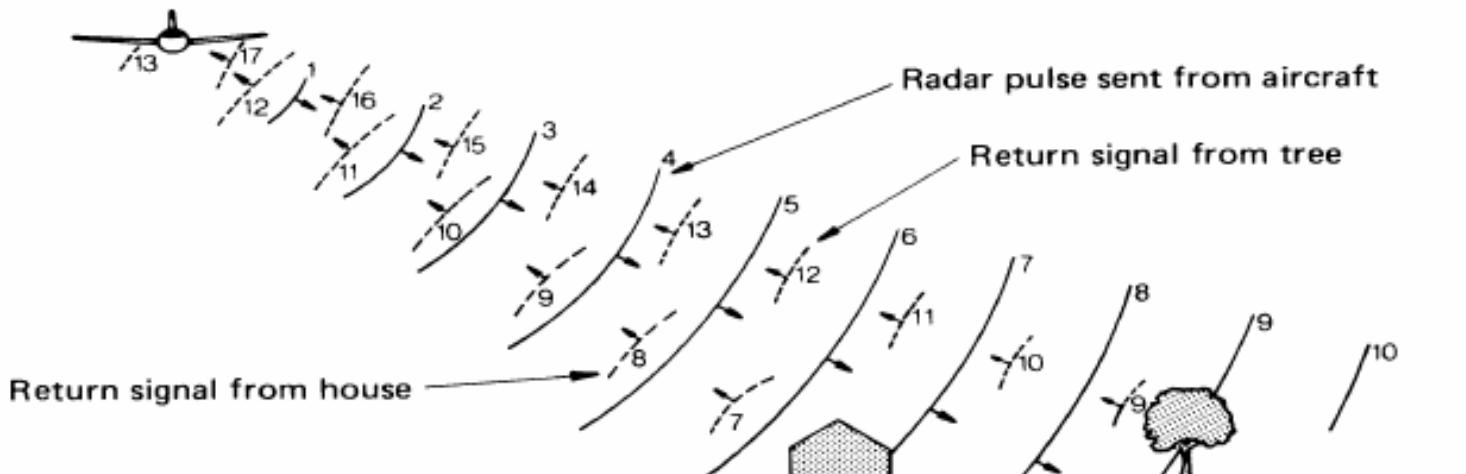
a) System properties

- i) Wavelength / frequency
- ii) Polarization
- iii) Incidence angle

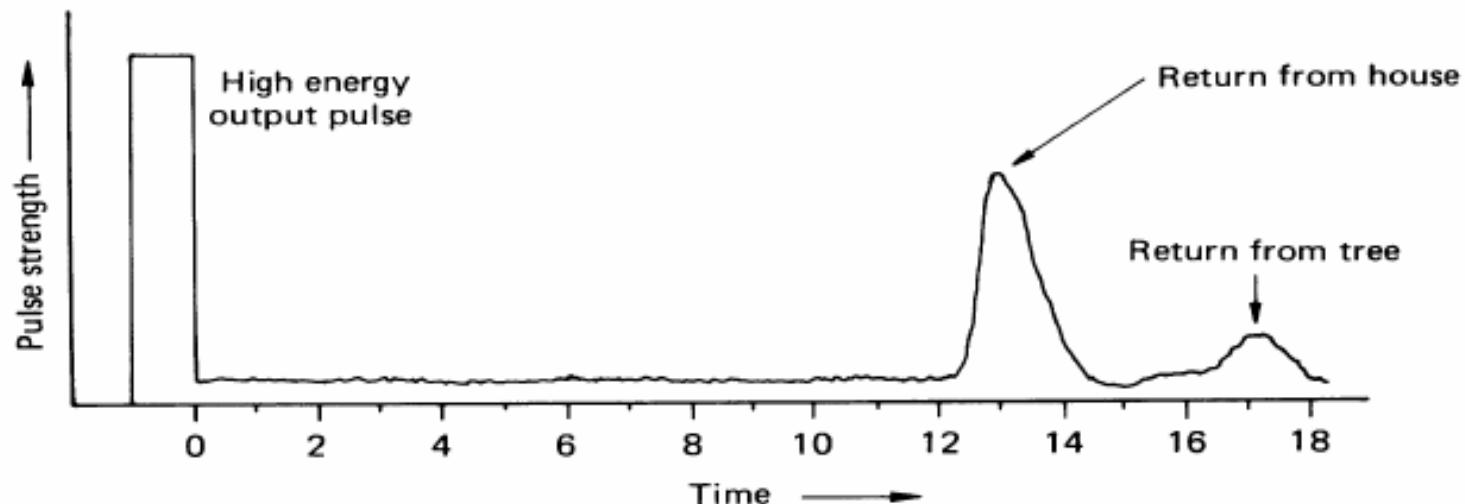
b) Terrain properties

- i) Dielectric constant
- ii) Surface roughness
- ii) Feature orientation

# Radar pulse propagation and reflection

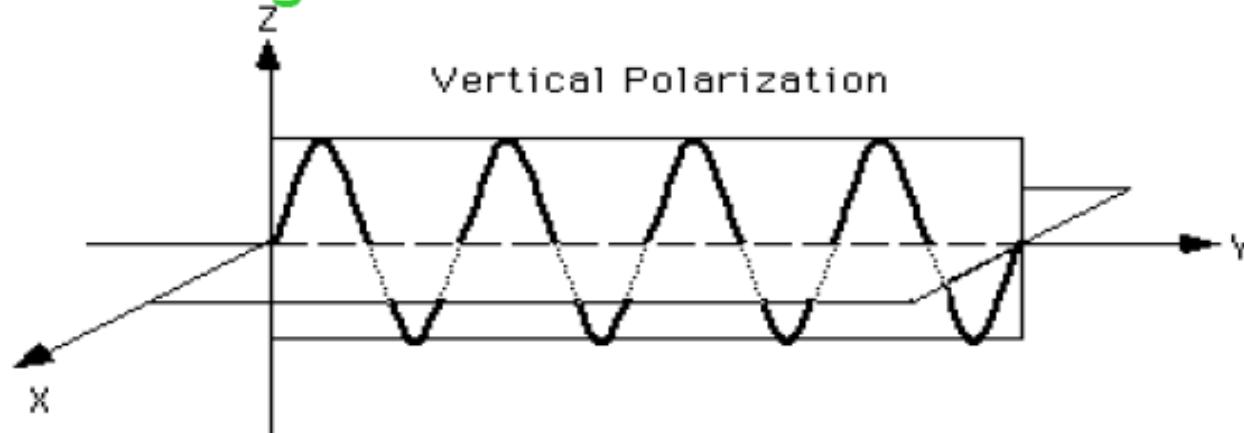


(a) Propagation of one radar pulse (indicating the wavefront location at time intervals 1–17)



# Polarisation

Resolving the EMR into its horizontal and vertical component

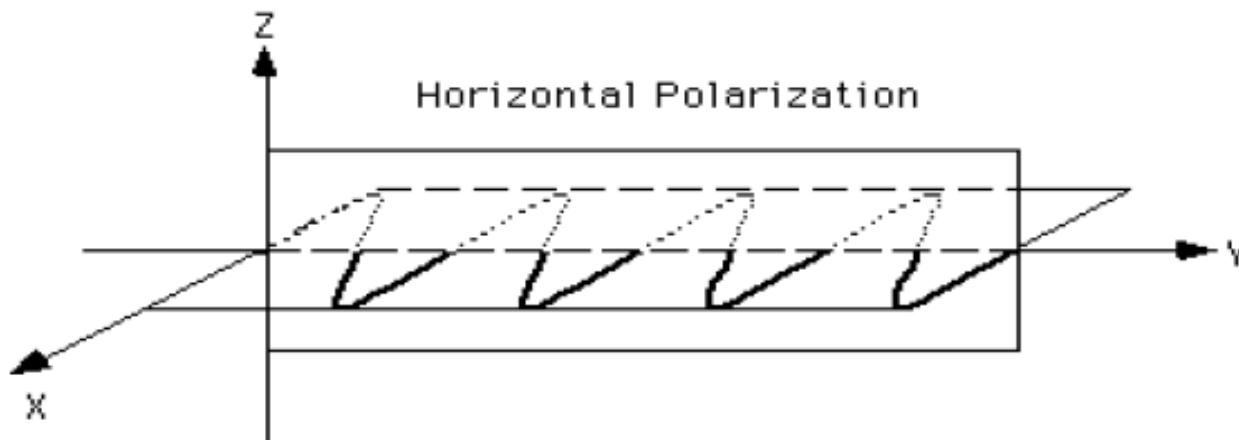


VV

HH

VH

HV



# Polarization

HH image and VV image - like polarized images

VH image and HV image - cross-polarized images

Radar system containing **single antenna** can receive only one image type i.e. either of the *like polarized* or either of the *cross polarized*. If Radar system contains **two antenna** it can receive two image types simultaneously i.e. either both *like polarized* or both *cross polarized* or one *like polarized* and one *cross polarized*.

A comparison of like and cross-polarized returns might reveal differences leading to terrain identification.

**Water and trees appear same in like and cross-polarized images while swamps appear brighter in like polarized and darker in cross-polarized imagery.**

**Grasslands appear darker in like polarized image and brighter in cross-polarized image.**

# Polarised images

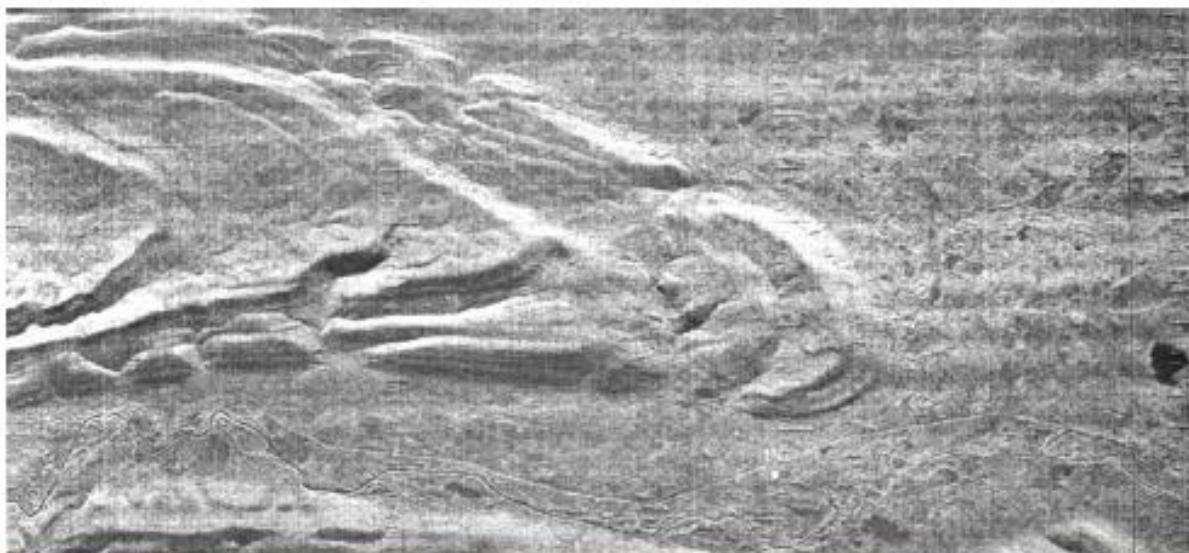


SLAR system

Oklahoma

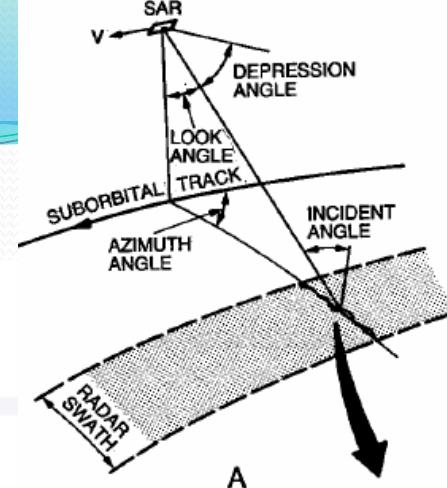
Scale 1:160,000

K band (3.2cm)



HH polarization

HV polarization



# Incidence angle

Incidence angle is defined as the angle between the radar beam and a perpendicular to the surface. For flat terrain incidence angle is same as the look angle.

Rough surfaces produce relatively uniform radar return irrespective of the incidence angle. Smooth surfaces give a stronger return at very high depression angles (near vertical) but little or no return occurs at lower depression angles.

# The di-electric constant

The electrical properties of matter influence the interaction with electromagnetic energy and are called the complex dielectric constant.

**Dielectric constant can be stated as the ‘ability of the material to get depolarized when electromagnetic field is applied’.**

If the material has very high dielectric constant, it will depolarize the incident EMR better and hence the intensity of received signal will also be more which gives rise to brighter tone.

Dielectric constant for some common targets e.g. **water**, **dry rocks & soils**, **metals**, **vacuum** is **87.8**; **3 to 8**; **2 to 5**; **1.0** respectively.

# Surface Roughness

Surfaces can be either smooth or rough or intermediate.

**Smooth surfaces** reflect all the energy away from the antenna and will be resulted in dark tone.

**Rough surfaces** diffusely scatter the energy equally in all directions irrespective of the angle of incidence.

**Intermediate surfaces** scatter the energy diffusely but not equally since a portion of energy is specularly reflected and the rest diffusely scattered.

# Feature Orientation

Orientation of the linear features with respect to the look direction affects the Radar return

If the feature is oriented perpendicular to the look direction then the identification of the same becomes possible since it gives strong return.

If the linear feature is oriented parallel to the look direction, then identification of the same becomes very difficult because of the weak return and poor contrast with the neighbouring features.

# Landsat Missions: Imaging the Earth Since 1972



Landsat is a part of the USGS National Land Imaging (NLI) Program. Landsat data is processed and hosted at the USGS Earth Resources Observation and Science (EROS) Center.

Since 1972, the joint NASA/ U.S. Geological Survey Landsat series of Earth Observation satellites have continuously acquired images of the Earth's land surface, providing uninterrupted data to help land managers and policymakers make informed decisions about natural resources and the environment.

# Landsat series of satellite

	Landsat 1	Landsat 2	Landsat 3	Landsat 4	Landsat 5	Landsat 7
Operators	NASA (National Aeronautics and Space Administration)	NASA (National Aeronautics and Space Administration)	NASA (National Aeronautics and Space Administration)	NASA (National Aeronautics and Space Administration)	NASA (National Aeronautics and Space Administration)	NASA (National Aeronautics and Space Administration)
Launch Dates	July 23, 1972	Jan. 22, 1975	Mar. 5, 1978	July 16, 1982	March 1, 1984	April 15, 1999
End of Service	Jan. 6, 1978	Removed from operations Feb. 25, 1982. Decommissioned on July 27, 1983	Standby mode on March 31, 1983 and decommissioned on September 7, 1983.	Standby Dec. 93. Decommissioned on June 15, 2001	Decommissioned on June 5, 2013	Still operational
Orbit Height	907 km	908 km	917 km	705 km	705 km	705 km
Orbit Type	Sun-synchronous near-polar	Sun-synchronous near-polar	Sun-synchronous near-polar	Sun-synchronous near-polar	Sun-synchronous near-polar	Sun-synchronous polar
Inclination	99.2°	99.2°	99.2°	98.2°	98.2°	98.2°
Repeat Cycle	18 days	18 days	18 days	16 days	16 days	16 days
Equatorial Crossing Time	9:30 a.m.	9:45 a.m.	9:30 a.m.	9:45 a.m.	9:45 a.m.	10:00 a.m.
Onboard sensors provided under TPM	Multispectral Scanner (MSS)	Multispectral Scanner (MSS)	Multispectral Scanner (MSS)	Multispectral Scanner (MSS) Thematic Mapper (TM)	Multispectral Scanner (MSS) Thematic Mapper (TM)	ETM+ (Enhanced Thematic Mapper Plus)

# Band Designation of Landsat 7 and 8

Landsat-7 ETM+ Bands ( $\mu\text{m}$ )		Landsat-8 OLI and TIRS Bands ( $\mu\text{m}$ )		
		30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue 0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green 0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red 0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR 0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1 1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR 10.31 - 12.36	<i>100 m TIR-1</i>	<i>10.60 – 11.19</i>	Band 10
		<i>100 m TIR-2</i>	<i>11.50 – 12.51</i>	Band 11
Band 7	30 m SWIR-2 2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan 0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
		30 m Cirrus	1.363 - 1.384	Band 9

# About SPOT Series

The SPOT (from French "Satellite pour l'Observation de la Terre") series has been supplying high-resolution, wide-area optical imagery since 1986. Five satellites were launched between 1986 and 2015, and in revealing Earth's surface in detail they led to new applications in mapping, vegetation monitoring, land use and land cover, and the impacts of natural disasters.

All of the SPOT satellites provide imagery in Panchromatic and Multispectral bands with a swath of 60 km. The latest satellites in the series, SPOT 6 and SPOT 7, are commercial satellites owned by Airbus Defence and Space, and assure data continuity through to 2024.

The SPOT series is part of ESA's Third Party Missions Programme, in which ESA has an agreement with Airbus Defence and Space to distribute data products from the mission.

# Spot series of satellite

	SPOT 1	SPOT 2	SPOT 3	SPOT 4	SPOT 5	SPOT 6	SPOT 7
<b>Operators</b>	CNES (owner), Spot Image (operator)					Airbus DS	
<b>Launch dates</b>	22 February 1986	22 January 1990	26 September 1993	24 March 1998	4 May 2002	9 September 2012	30 June 2014
<b>EOL</b>	November 2003	July 2009	November 1996	29 June 2013	March 2015	operating nominally	operating nominally
<b>Orbit Height</b>	832 km					694 km	
<b>Orbit Type</b>	Near-polar, sun-synchronous phased orbit local equator crossing time 10:30 on descending orbit at an altitude of 830 km completing over 14 revolutions per day						
<b>Orbit Period</b>	101 minutes					98.79 minutes	
<b>Inclination</b>	98.7°					98.2°	
<b>Repeat Cycle</b>	26 days						
<b>Onboard sensors provided under TPM</b>	HRV	HRV	HRV	HRVIR, VEGETATION	HRG, HRS, VEGETATION	NAOMI	NAOMI
<b>Resolution</b>	HRV: 10 m (PAN), 20 m			HRVIR: 10 m (PAN), 20 m	HRG: 2.5 m (PAN), 10 m (MS), 20 (SWIR) HRS: 10 m (cross track), 5 m (along-track)	1.5 m (PAN), 6 m (MS)	
<b>Swath Width</b>	HRV: 117 (60 + 60) km			HRVIR: 117 (60 + 60) km	HRG: 117 (60 + 60) km HRS: 120 km	60 km	

# Spot 7 band designation

## SPOT 7 NAOMI Instrument Details

Type	High-resolution optical pushbroom imager	
Ground Sample Distance	Panchromatic: 1.5 m at nadir Multispectral: 6 m at nadir	
Swath Width	60 km	
Field of Regard	±30° (spacecraft tilting capability about nadir for event monitoring)	
Bands	PAN	0.45-0.75 µm
	Blue	0.45-0.52 µm
	Green	0.53-0.60 µm
	Red	0.62-0.69 µm
	NIR (Near Infrared)	0.76-0.89 µm

Following the successful demonstration flights of Bhaskara-1 and Bhaskara-2 - experimental Earth observation satellites developed and built by ISRO (Indian Space Research Organization) - and launched in 1979 and 1981, respectively, India began the development of an **indigenous IRS** (Indian Remote Sensing Satellite) program.

[IRS-1A](#), the first of the series of indigenous state-of-art operating remote sensing satellites, was successfully launched into a polar sun-synchronous orbit on March 17, 1988

IRS is the integrated **LEO (Low Earth Orbit) element** of India's NNRMS (National Natural Resources Management System) with the objective to provide a long-term spaceborne operational capability to India for the observation and management of the country's natural resources (applications in agriculture, hydrology, geology, drought and flood monitoring, marine studies, snow studies, and land use).

# IRS series of satellite

Satellite	Launch date	Sensor complement	Spectral Bands (µm)	Spatial resolution (m)	Swath width (km)	Repeat cycle (days)
IRS-1A	17.03.1988	LISS-I, and LISS-II A/B (3 sensors)	0.45-0.52 0.52-0.59 0.62-0.68 0.77-0.86	72.5 m LISS-I 36 m LISS-II	148 74 x 2 (swath of 148 km)	22
IRS-1B	29.08.1991	LISS-I and LISS-II A/B	same as for IRS-1A		148 74 x 2	22
IRS-P2	15.10.1994	LISS-II M	0.45-0.52 0.52-0.59 0.62-0.68 0.77-0.86	32 m x 37 m	66 x 2 (131 km for combined swaths)	24
IRS-1C	28.12.1995	LISS-III	0.52-0.59	23.5	142	24
			0.62-0.68	23.5	142	
			0.77-0.86	23.5	142	
		PAN	1.55-1.70	70	148	
			0.50-0.75	5.8	70	24 (5)
			WiFS	188	804	5
IRS-P3	21.03.1996	WiFS	0.62-0.68	188	804	5
			0.77-0.86			
			1.55-1.70			
		MOS-A	0.75-0.77	1500	195	
		MOS-B	0.41-1.01	520	200	
		MOS-C	1.595-1.605	550	192	Ocean surface

# IRS series of satellite

IRS-1D	29.09.1997	Satellite and instruments are identical to those of IRS-1C					
IRS-P4 (OceanSat-1)	26.05.1999	OCM MSMR	0.4-0.9 6.6, 10.65, 18, 21 GHz (frequencies)	360 x 236 105x68, 66x43, 40x26, 34x22 (km for frequency sequence)	1420 1360	2	2
IRS-P6 ResourceSat-1	17.10.2003	LISS-IV	0.52-0.59 0.62-0.68 0.77-0.86	5.8 5.8 5.8	70	24 (5)	
		LISS-III*	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	23.5 23.5 23.5 23.5	140	24	
		AWIFS	0.62-0.68 0.77-0.86 1.55-1.70	70 70 70	740	5	
IRS-P5 CartoSat-1	05.05.2005	PAN-F PAN-A	0.50-0.75 0.50-0.75	2.5 2.5	30 30	2-line stereo camera	
CartoSat-2	10.01.2007	PAN camera	0.50-0.85	< 1	9.6		
OceanSat-2	23.09.2009	OCM SCAT ROSA	0.40-0.90 8 bands 13.515 GHz GPS occultation	360 x 236 25 km x 25 km	1420 1400	2	
RISAT	2011	SAR instrument	5.350 GHz (C- band)	< 2 m to 50 m	100 - 600		

	IRS 1C/1D			RESOURCESAT			OCEANSAT
	LISS III	PAN	WiFS	LISS III	LISS IV	AWifs	OCM (Ocean Colour Monitor)
No of Spectral bands	4	1	2	4	3	3	8
Spectral Bands (microns)	B2 0.52-0.59 B3 0.62-0.68 B4 0.77-0.86 B5 1.55-1.70	0.50 -0.75	B3 0.62-0.68 B4 0.77-0.86	0.52-0.59 0.62-0.68 0.77-0.86	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	0.402-0.422 0.433-0.453 0.480-0.500 0.500-0.520 0.545-0.565 0.660-0.680 0.745-0.785 0.845-0.885
Spatial Resolution (m)	23.5 for B2,B3,B4 and 70.5 for B5	Better than 10	188	23.5	5.8	56	360
Swath	142 km for B2, B3,B4 and 148 km for B5	70 km, nadir Steering Range $\pm 26^\circ$	774 km	141km	23.9 (MX mode) 70.3 (PAN mode)	740 km	1420 km
Radiometric levels	128	64	128	7 bits	7 bits	10 bits	

Parameter	LISS-I	LISS-II A/B
Focal length	162.2 mm	324.4 mm
FOV, IFOV	9.4°, 80 µrad	4.7°+ 4.7°, 40 µrad
Spectral bands (µm)	0.46 - 0.52 (blue) 0.52 - 0.59 (green) 0.62 - 0.68 (red) 0.77 - 0.86 (NIR)	0.46 - 0.52 (blue) 0.52 - 0.59 (green) 0.62 - 0.68 (red) 0.77 - 0.86 (NIR)
Integration time	11.2 ms	5.6 ms
Ground resolution	72.5 m (each band)	36.25 m (each band)
Swath width	148 km	2 x 74 km
Radiometric resolution	7 bit	7 bit
Detector, elements	CCD, 2048	CCD, 2048
Data rate	5.2 Mbit/s	2 x 10.4 Mbit/s
Instrument mass, power	38.5 kg, 34 W	2 x 80.8 kg, 2 x 34 W

<https://directory.eoportal.org/web/eoportal/satellite-missions/i/irs>

## **METEOROLOGICAL SATELLITE**

GSAT: Geo Stationary satellites:

INSAT: Indian National Satellite system

GOES: Geostationary Operational Environmental Satellites

POES: Polar Operational Environmental Satellites

## **HIGH RESOLUTION SATELLITE**

CARTOSAT 3

IKONOS

QUICKBIRD

WORLDVIEW

ORBVIEW

The **GSAT satellites** are India's indigenously developed communications satellites, used for digital audio, data and video broadcasting.

**The Indian National Satellite (INSAT)** system is one of the largest domestic communication satellite systems in Asia-Pacific region with nine operational communication satellites placed in Geo-stationary orbit. Established in 1983 with commissioning of INSAT-1B, it initiated a major revolution in India's communications sector and sustained the same later. GSAT-17 joins the constellation of INSAT System consisting 15 operational satellites, namely - INSAT-3A, 3C, 4A, 4B, 4CR and GSAT-6, 7, 8, 9, 10, 12, 14, 15, 16 and 18.

The **Geostationary Operational Environmental Satellite (GOES)**, operated by the United States' National Oceanic and Atmospheric Administration (NOAA)'s National Environmental Satellite, Data, and Information Service division, supports weather forecasting, severe storm tracking, and meteorology research.

The **Polar-orbiting Operational Environmental Satellite (POES)** was a constellation of polar orbiting weather satellites funded by the National Oceanic and Atmospheric Administration (NOAA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) with the intent of improving the accuracy and detail of weather analysis and forecasting.

**Cartosat-3** is an advanced Indian Earth Observation satellite built and developed by Indian Space Research Organisation (ISRO), which replaces the Indian Remote Sensing Satellite (IRS) series. It has a panchromatic resolution of 0.25 metres making it one of the imaging satellite with highest resolution in the world at the time of launch and MX of 1 metre with a high quality resolution which is a major improvement from the previous payloads in the Cartosat series.

Cartosat-3 will address the increased user's demands for large scale urban planning, rural resource and infrastructure development, coastal land use and land cover etc

The **IKONOS satellite sensor** was successfully launched as the first commercially available high resolution satellite sensor on September 24, 1999 at Vandenberg Air Force Base, California, USA.

The IKONOS satellite sensor is a high-resolution satellite operated by DigitalGlobe. Its capabilities include capturing a 3.2m multispectral, Near-Infrared (NIR) 0.82m panchromatic resolution at nadir. Its applications include both urban and rural mapping of natural resources and of natural disasters, tax mapping, agriculture and forestry analysis, mining, engineering, construction, and change detection. It can yield relevant data for nearly all aspects of environmental study

# QuickBird was a high-resolution commercial Earth observation satellite, owned by DigitalGlobe, launched in 2001.

## Resolution

Pan: 65 cm (nadir) to 73 cm (20° off-nadir)

MS: 2.62 m (nadir) to 2.90 m (20° off-nadir)

## Image Bands

Pan: 450-900 nm

Blue: 450-520 nm

Green: 520-600 nm

Red: 630-690 nm

Near IR: 760-900 nm

**OrbView-3** is a high-resolution imaging minisatellite owned and operated by Orbital Imaging Corporation (ORBIMAGE) of Dulles, VA, a commercial provider of Earth imagery acquired from a family of imaging satellites that it owns and operates.

Instrument type	Body-scanning whiskbroom imager (in PAN and MS)	
Imaging Mode	Panchromatic	Multispectral (MS)
Spatial resolution	1 m	4 m
Imaging bands	1	4 MS
Spectral range	Pan: 450 - 900 nm	MS1: 450-520 nm (blue) MS2: 520-600 nm (green) MS3: 625-695 nm (red) MS4: 760-900 nm (NIR)
Silicon detector size (linear array)	8000 pixels	2000 x 4
Pixel size of detectors	6.0 $\mu\text{m}$ x 5.4 $\mu\text{m}$ (cross x along)	
Swath width	8 km	
Data quantization of imagery	11 bit (compressed in downlink to 2 bit/pixel)	

**WorldView-3** is the first multi-payload, super-spectral, high-resolution commercial satellite sensor operating at an altitude of 617 km.

WorldView-3 satellite provides 31 cm panchromatic resolution, 1.24 m multispectral resolution, 3.7 m short wave infrared resolution (SWIR) and 30 m CAVIS resolution. The satellite has an average revisit time of <1 day and is capable of collecting up to 680,000 km<sup>2</sup> per day.

Sensor Bands	Panchromatic: 450-800 nm 8 Multispectral: (red, red edge, coastal, blue, green, yellow, near-IR1 and near-IR2) 400 nm - 1040 nm 8 SWIR: 1195 nm - 2365 nm 12 CAVIS Bands: (desert clouds, aerosol-1, aerosol-2, aerosol-3, green, water-1, water- 2, water-3, NDVI-SWIR, cirrus, snow) 405 nm - 2245 nm
Sensor Resolution ( or GSD, Ground Sample Distance; off-nadir is geometric mean)	Panchromatic Nadir: 0.31 m GSD at Nadir 0.34 m at 20° Off-Nadir Multispectral Nadir: 1.24 m at Nadir, 1.38 m at 20° Off-Nadir SWIR Nadir: 3.70 m at Nadir, 4.10 m at 20° Off-Nadir CAVIS Nadir: 30.00 m
Dynamic Range	11-bits per pixel Pan and MS; 14-bits per pixel SWIR





# FIRST DAY IMAGE OF RESOURCESAT-1

AWIFS IMAGE OF MANASAROVAR & SURROUNDINGS ACQUIRED ON 25 - OCT - 2003

**nrsa**

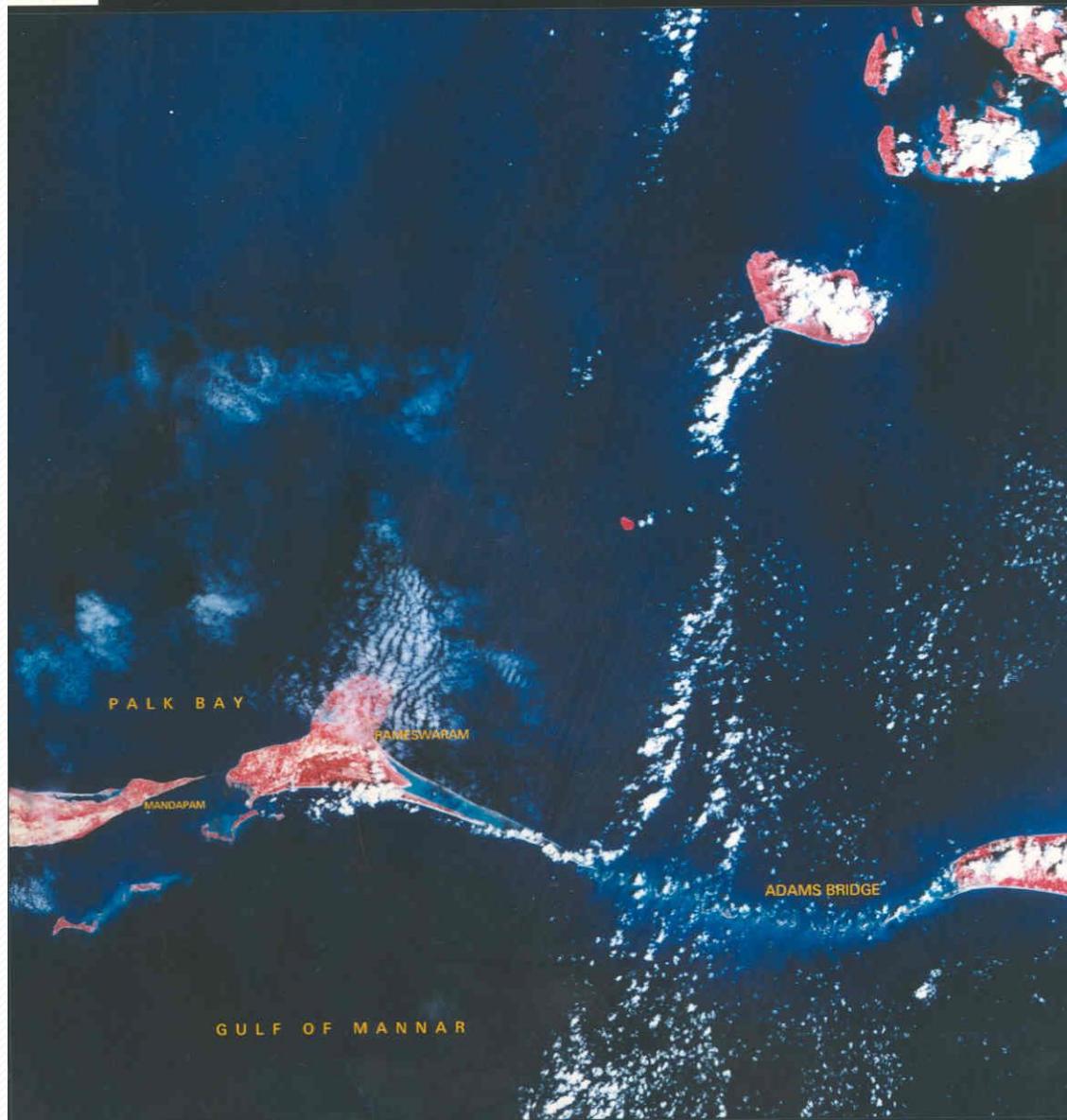




## INITIAL IMAGE OF RESOURCESAT-1

LISS-III IMAGE OF RAMESWARAM & SURROUNDINGS ACQUIRED ON 26-OCT-2003

nrsá



# Multispectral vs. Hyperspectral

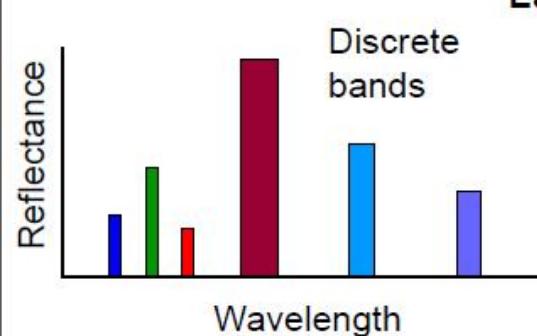
## Multispectral



## Hyperspectral

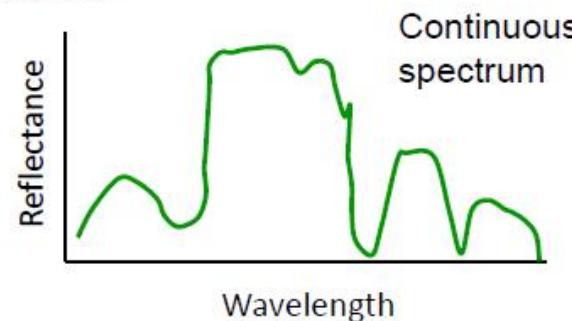


Each pixel



consists of hundreds or thousands of narrow-wavebands (as narrow as 1; but generally less than 5 nm) along the electromagnetic spectrum;

it is important to have narrowbands that are contiguous



## Bands

One      **Panchromatic**



Tens      **Multispectral**



Hundreds      **Hyperspectral**



<b>Multispectral</b>	<b>Hyperspectral</b>
Multispectral instruments can <i>discriminate</i> materials.	Hyperspectral imaging is required to actually <i>identify</i> materials
Multispectral data are used to detect the existence of various materials	Hyperspectral data allows the identification of many materials even in mixed materials
Greater accessibility due to the larger number of space-based multispectral sensors	Most current hyperspectral sensors are airborne, hence inaccessible (in the Indian context).

# Hyperspectral Sensors

## Airborne

- CASI (Canadian technology)
- HyMAP (Australian technology)
- AVIRIS (American NASA technology)
- HYDICE( US Naval research lab)
- DAIS (European technology)
- AIMS (Indian technology)
- AHySI (Indian technology)

## Spaceborne

- MODIS
- MERIS
- Hyperion
- CHRIS
- HySI
- ...

## Ground based

- Spectro-radiometer

## ISRO hyperspectral Missions (current & future)

- ISRO - NASA AVIRIS – NG Airborne flights
- GISAT (Future Mission)



TerraSpec HALO

350-2500nm



# **LiDAR remote sensing**

**LiDAR** or Light Detection and Ranging is an active remote sensing system that can be used to measure vegetation height across wide areas.

LiDAR, or light detection ranging (sometimes also referred to as active laser scanning) is one remote sensing method that can be used to map structure including vegetation height, density and other characteristics across a region. LiDAR directly measures the height and density of vegetation on the ground making it an ideal tool for scientists studying vegetation over large areas.

Ground based/ airborne/ spaceborne

**Lidar unit + GPS (for altitude and x y location)+**

**Inertial measurement unit (IMU) (for accurate elevation calculation)+**

**Computer system**

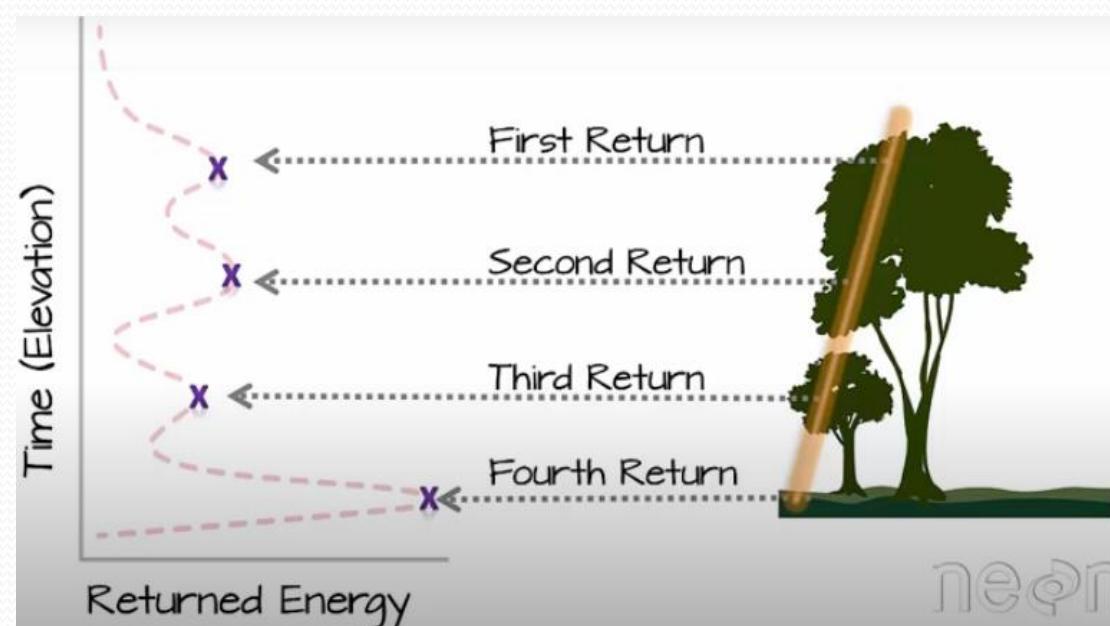
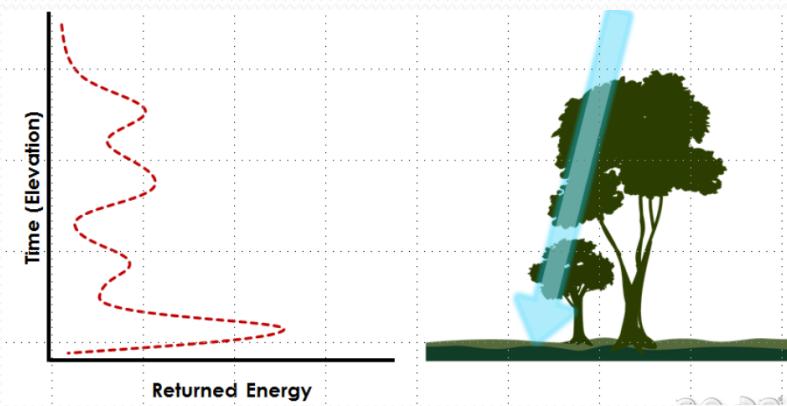
LiDAR is an **active remote sensing** system. An active system means that the system itself generates energy - in this case, light - to measure things on the ground. In a LiDAR system, light is emitted from a rapidly firing laser. This light travels to the ground and reflects off of things like buildings and tree branches. The reflected light energy then returns to the LiDAR sensor where it is recorded.

A LiDAR system measures the time it takes for emitted light to travel to the ground and back. That time is used to calculate distance traveled. Distance traveled is then converted to elevation. These measurements are made using the key components of a lidar system including a GPS that identifies the X,Y,Z location of the light energy and an Internal Measurement Unit (IMU) that provides the orientation of the plane in the sky.

Altitude – distance = elevation

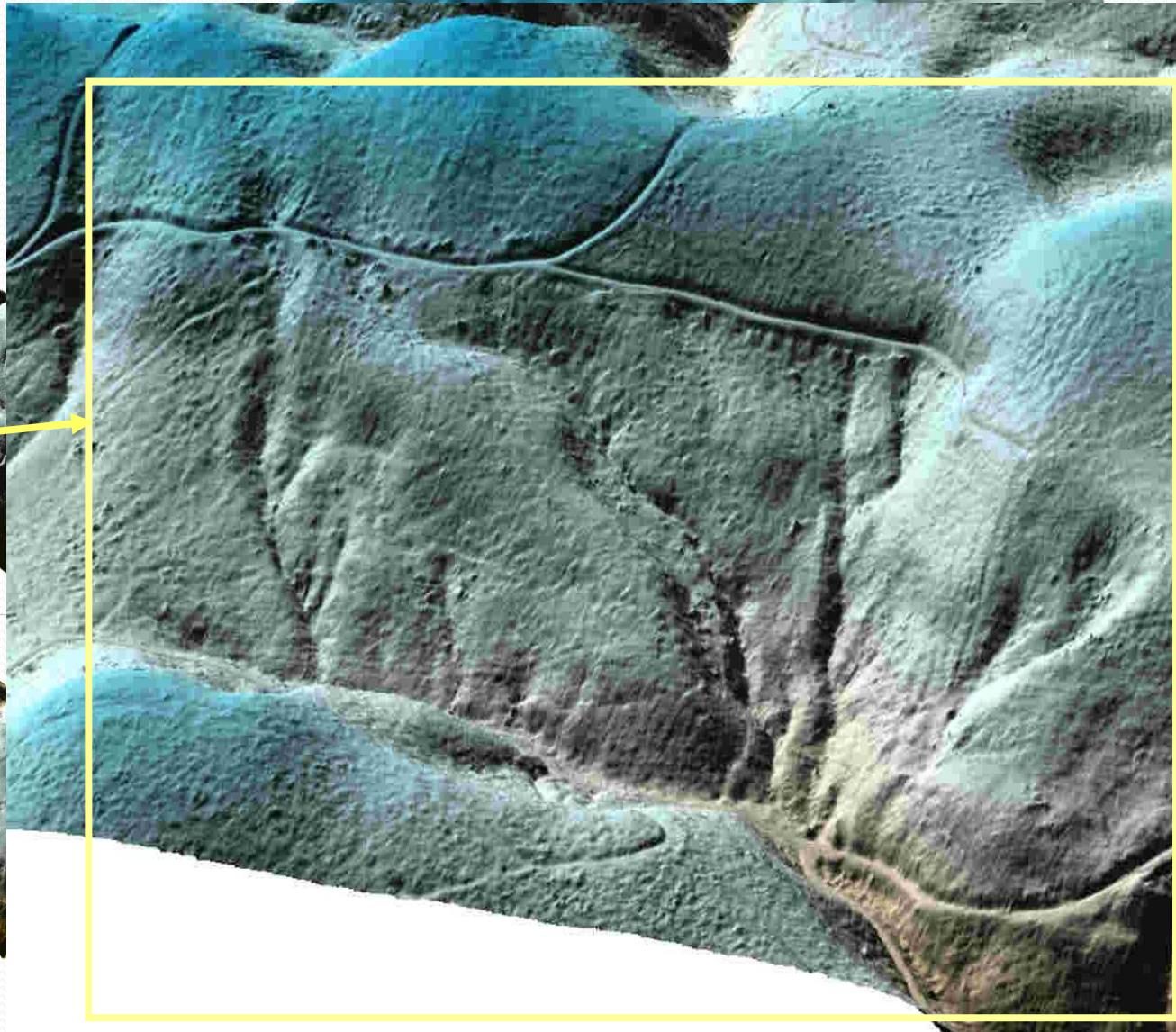
# How Light Energy Is Used to Measure Trees

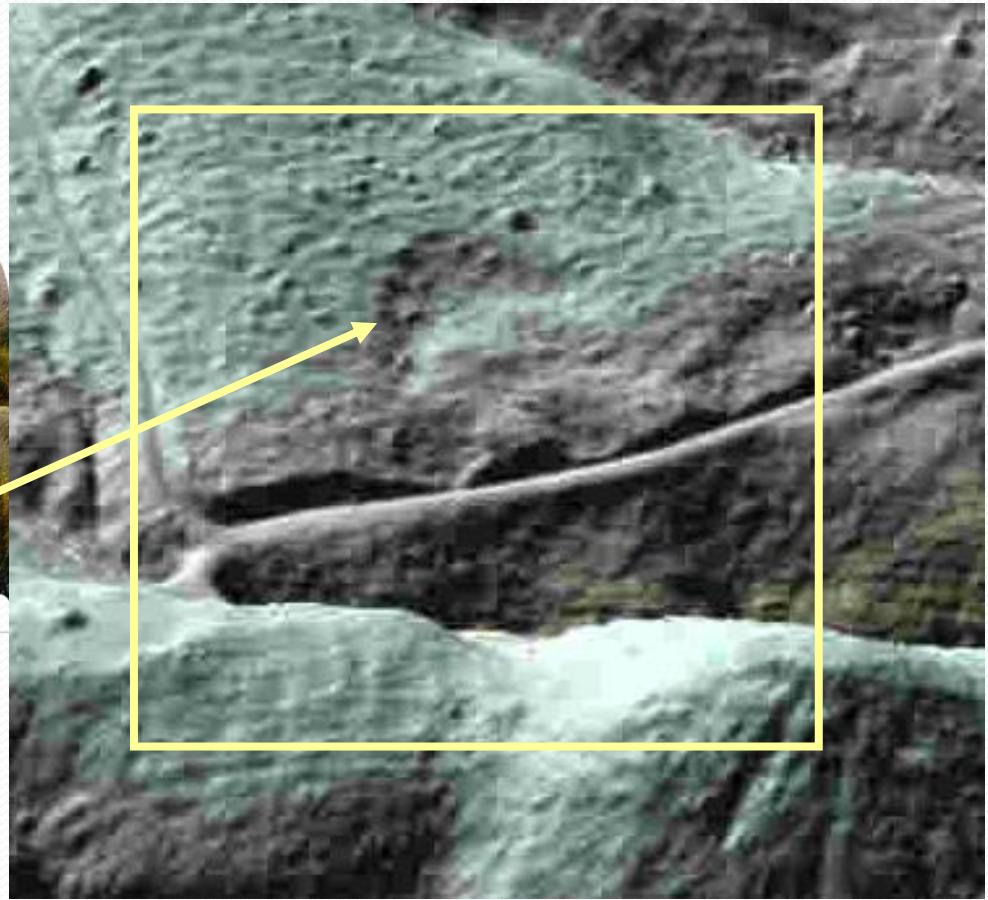
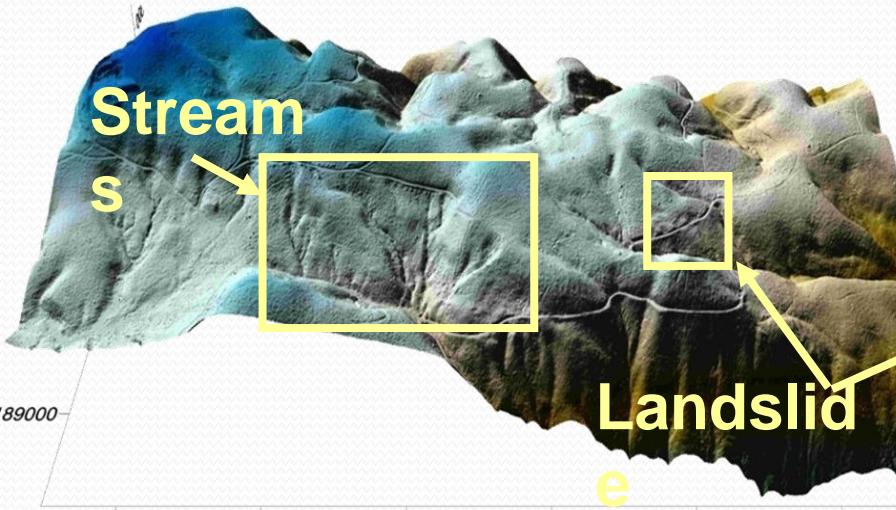
Light energy is a collection of photons. As photon that make up light moves towards the ground, they hit objects such as branches on a tree. Some of the light reflects off of those objects and returns to the sensor. If the object is small, and there are gaps surrounding it that allow light to pass through, some light continues down towards the ground. Because some photons reflect off of things like branches but others continue down towards the ground, multiple reflections may be recorded from one pulse of light.



10m USGS  
DEM

# DEM & Canopy Models





# Uses for LiDAR data

- LiDAR data classically have been used to derive high resolution elevation data
- LiDAR data have also been used to derive information about vegetation structure including
  - Canopy Height
  - Canopy Cover
  - Leaf Area Index
  - Vertical Forest Structure
  - Species identification (if a less dense forests with high point density LiDAR)

# Discrete vs. Full Waveform LiDAR

A waveform or distribution of light energy is what returns to the LiDAR sensor. However, this return may be recorded in two different ways.

1.A **Discrete Return LiDAR System** records individual (discrete) points for the peaks in the waveform curve. Discrete return LiDAR systems identify peaks and record a point at each peak location in the waveform curve. These discrete or individual points are called returns. A discrete system may record 1-4 (and sometimes more) returns from each laser pulse.

2.A **Full Waveform LiDAR System** records a distribution of returned light energy. Full waveform LiDAR data are thus more complex to process however they can often capture more information compared to discrete return LiDAR systems.

# **LiDAR File Formats**

Whether it is collected as discrete points or full waveform, most often LiDAR data are available as discrete points. A collection of discrete return LiDAR points is known as a **LiDAR point cloud**.

The commonly used file format to store LIDAR point cloud data is called **.las** which is a format supported by the American Society of Photogrammetry and Remote Sensing (ASPRS).

Recently, the **.laz** format has been developed by Martin Isenberg of LasTools.

**.laz is a highly compressed version of .las.**

Data products derived from LiDAR point cloud data are often raster files that may be **in GeoTIFF (.tif) formats**.

# Merits of remote sensing

- Remote sensing has many advantages over ground-based survey in that *large tracts of land can be surveyed at any one time*, and *areas of land (or sea) that are otherwise inaccessible can be monitored*.
- The advent of satellite technology and multispectral sensors has further enhanced this capability, with the ability to *capture images of very large areas of land in one pass*, and by collecting data about an environment that would normally not be visible to the human eye.



THANK YOU