# 18CEO407T RS & GIS App

# Unit I

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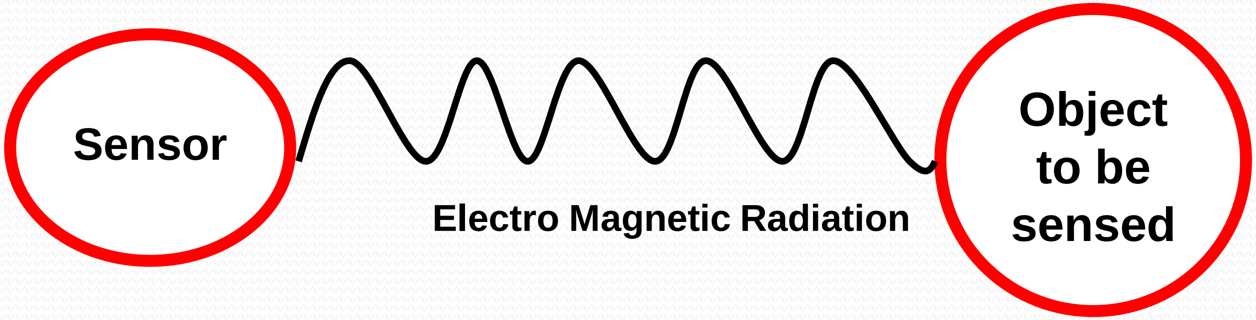
# REMOTE SENSING

"Remote sensing is the science of acquiring information about an object 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."

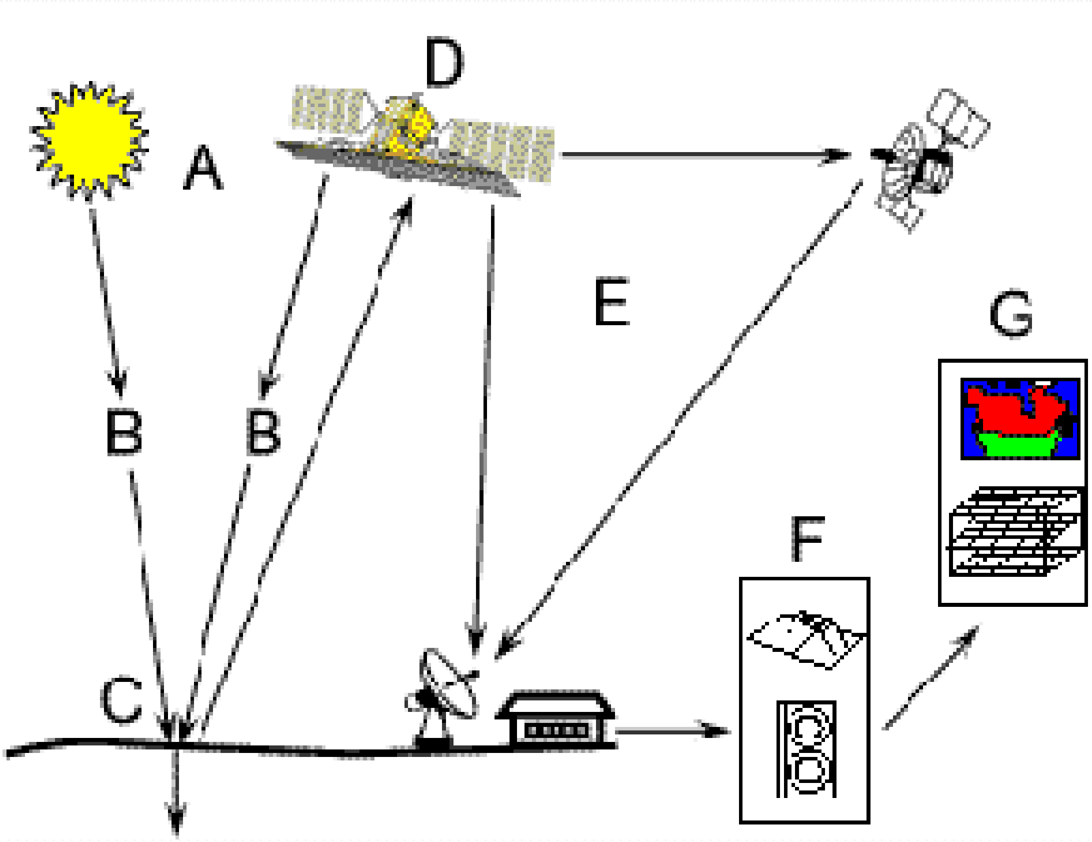
Three Essential Things for Remote Sensing

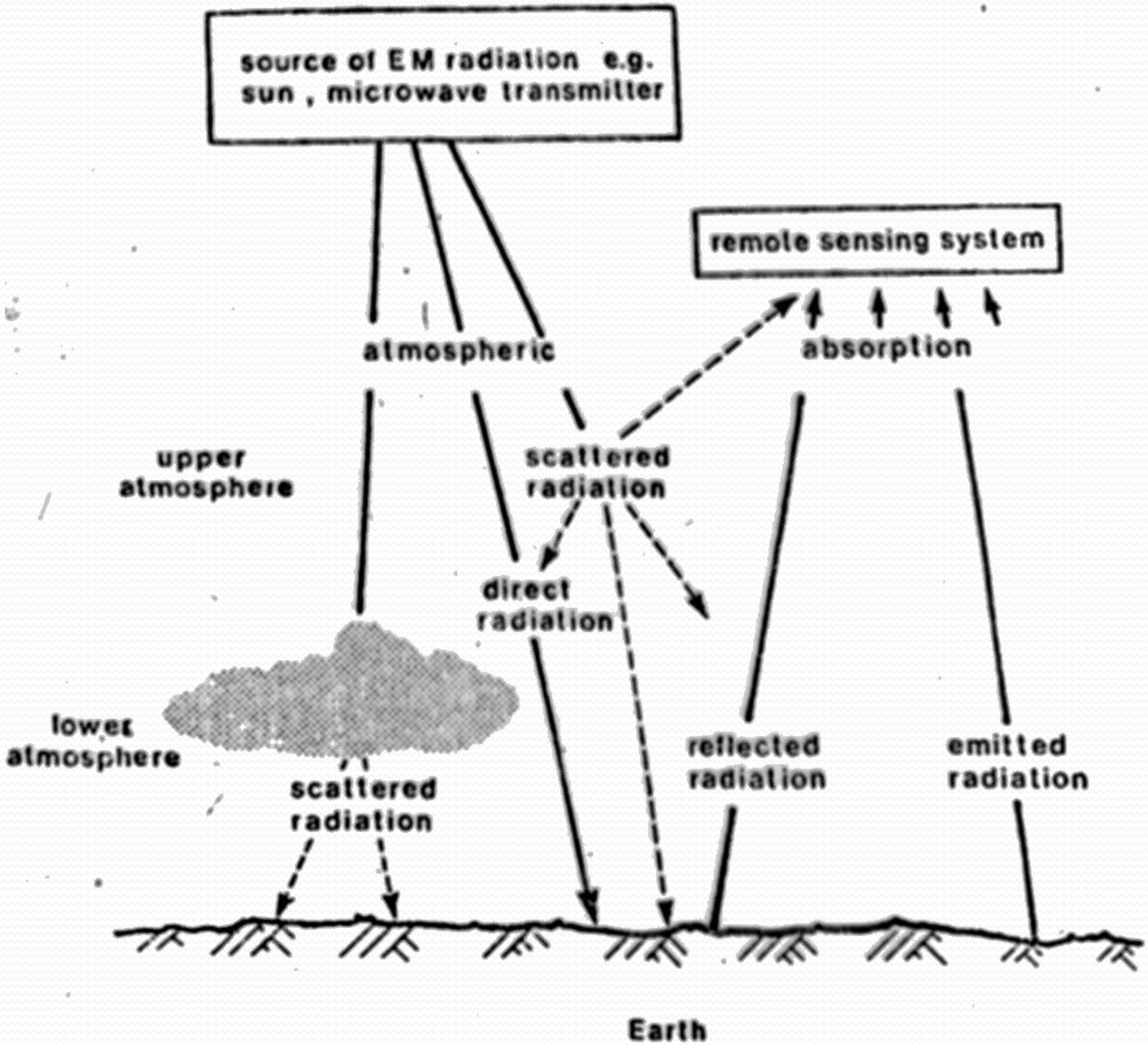


# Remote Sensing System andProcesses

**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**




source of E M radiation e.g. sun , microwave transmitter
remole sensing system
atmospheric
absorption
upper atmosphere
scattered radiation
direct radiation
lower atmosphere
scattered radiation
reflected radiation
emitted radiation
Earth

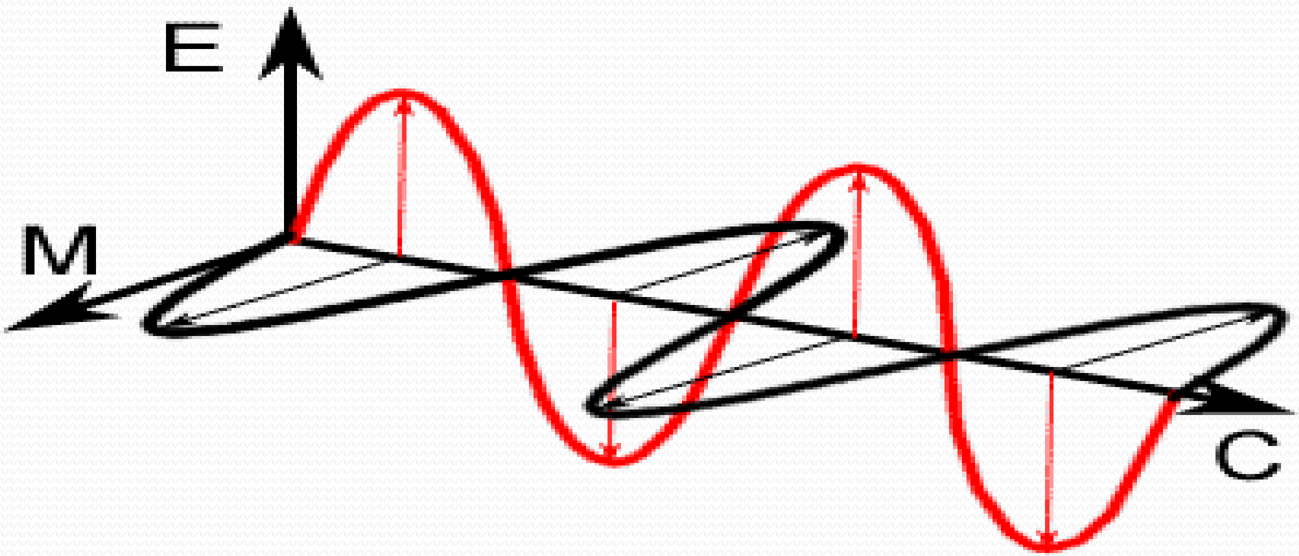
# The Process

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

- 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.

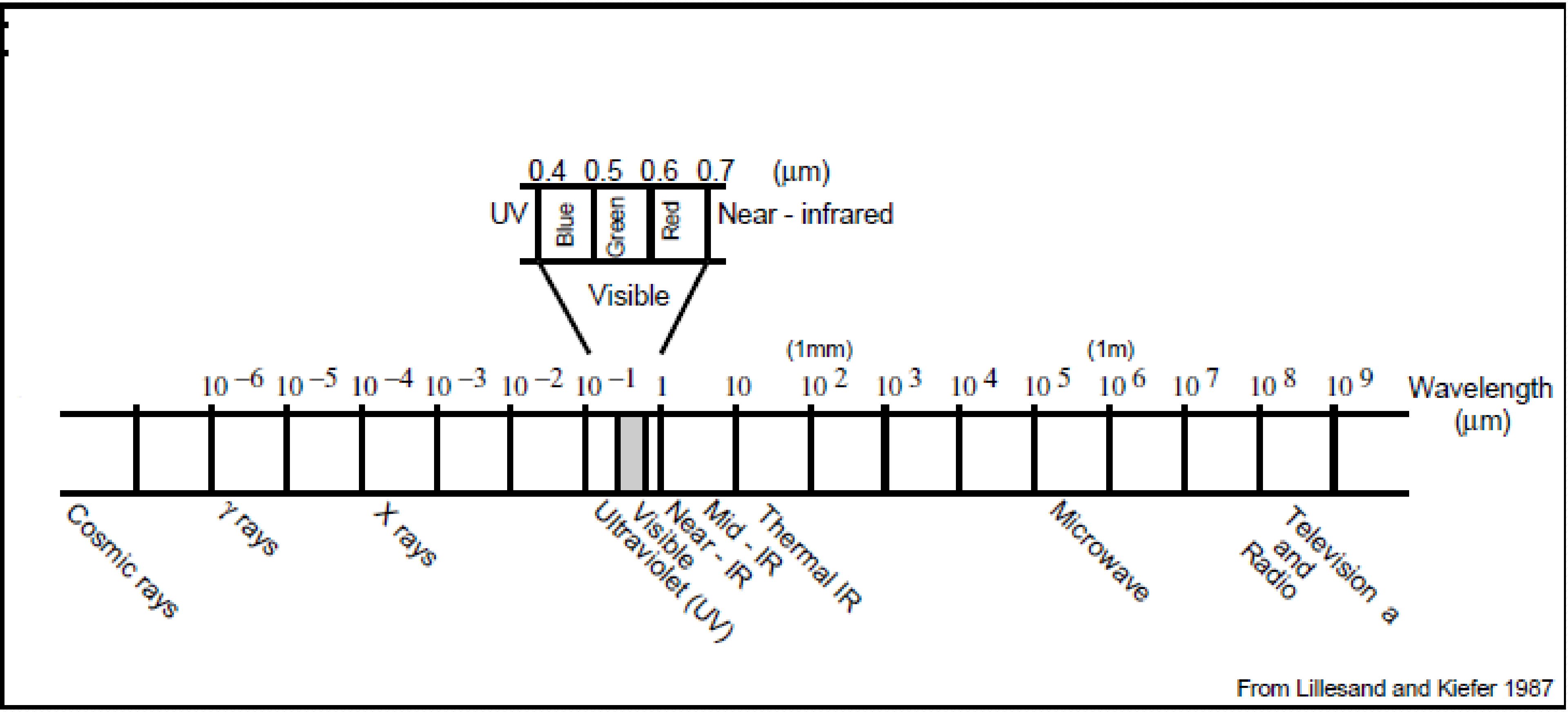
# Electromagnetic Radiation

# AN ELECTROMAGNETIC WAVE




**Electromagnetic radiation** consists of an electrical field(E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c).

# THE ELECTROMAGNETIC SPECTRUM

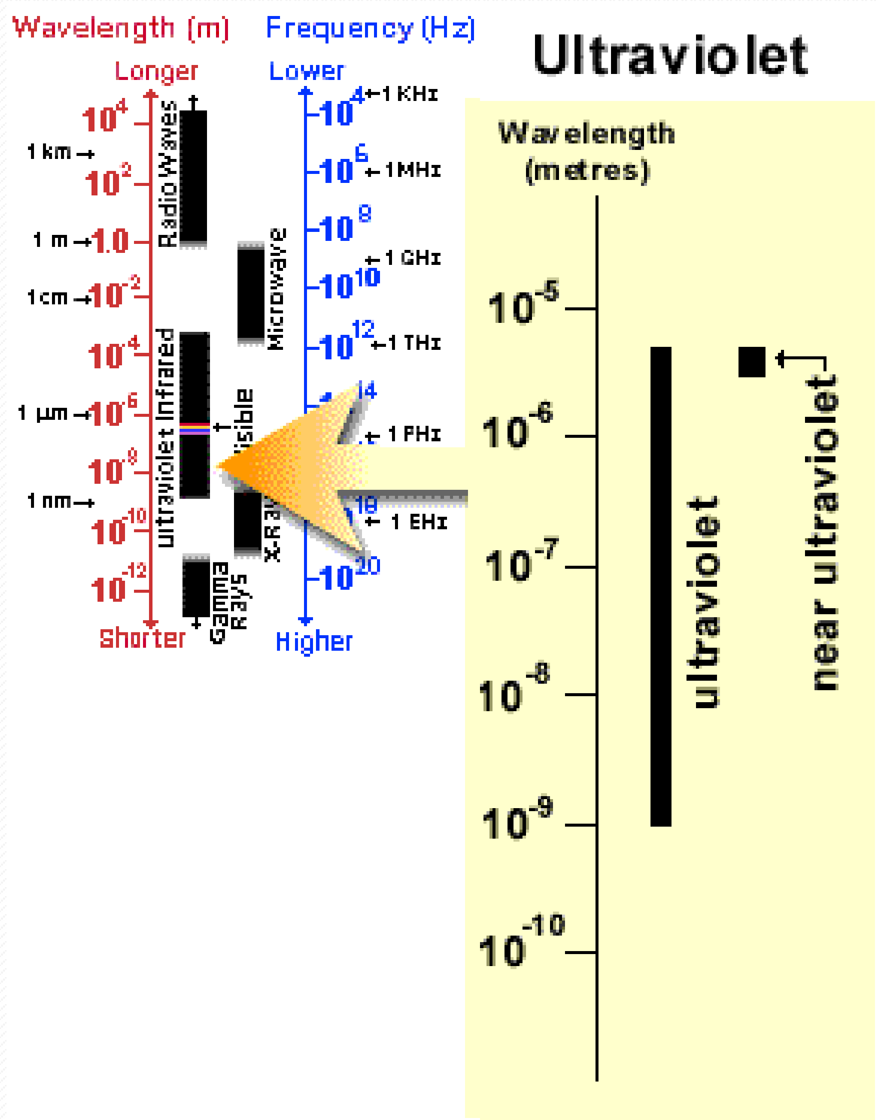


# Ultraviolet Spectrum (UV)

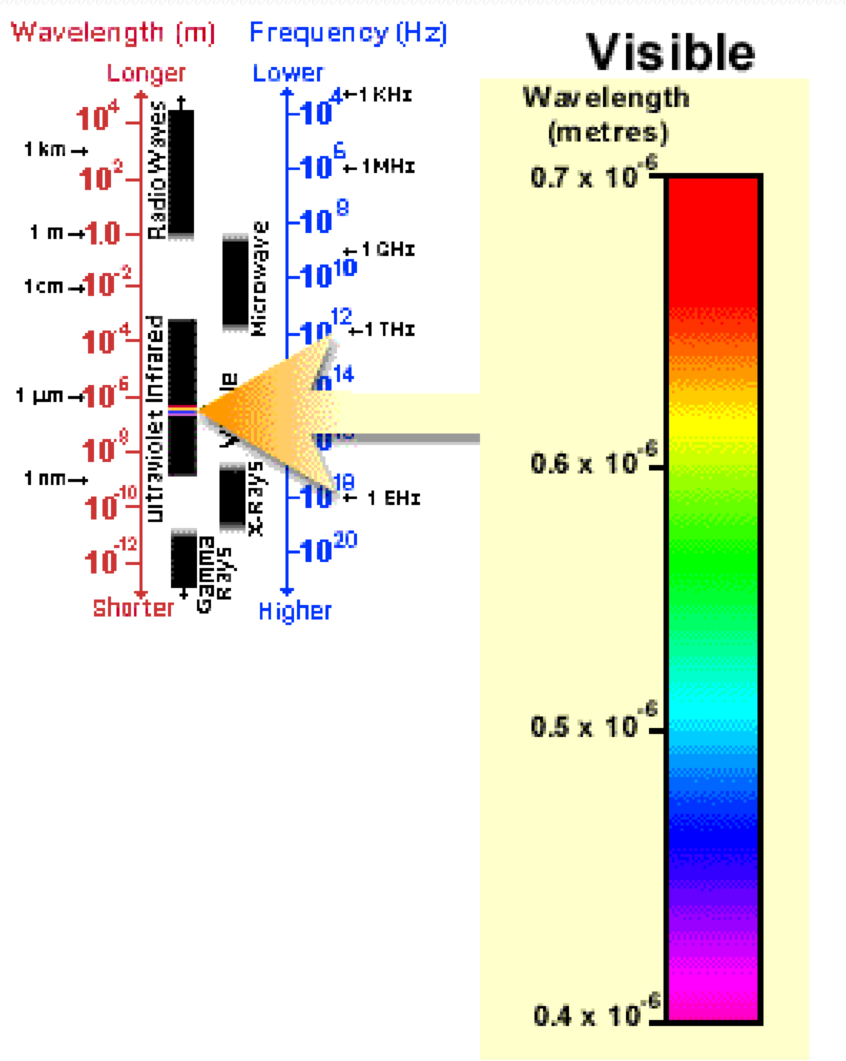
**UV** portion of the spectrum has the shortest wavelengths which are practical for remote sensing.

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

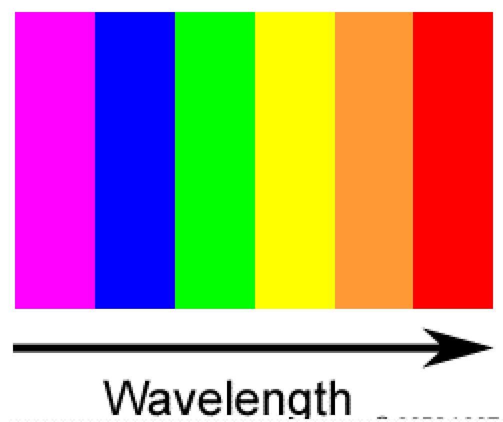
Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.



# Visible Spectrum




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




longer

higher frequency

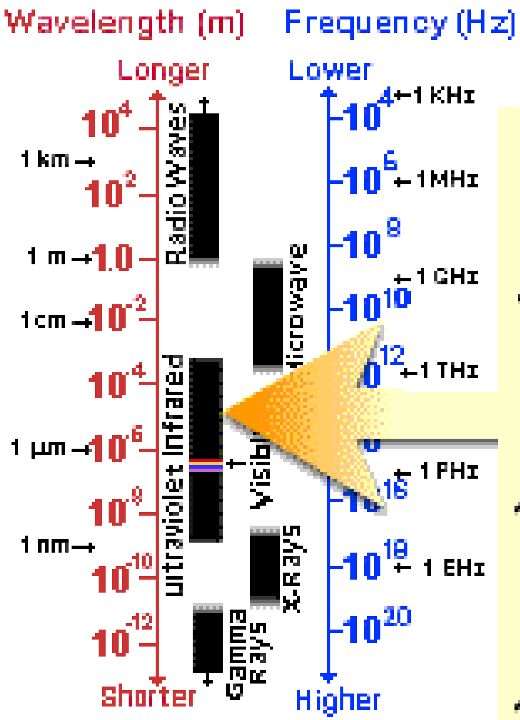
# Visible Spectrum

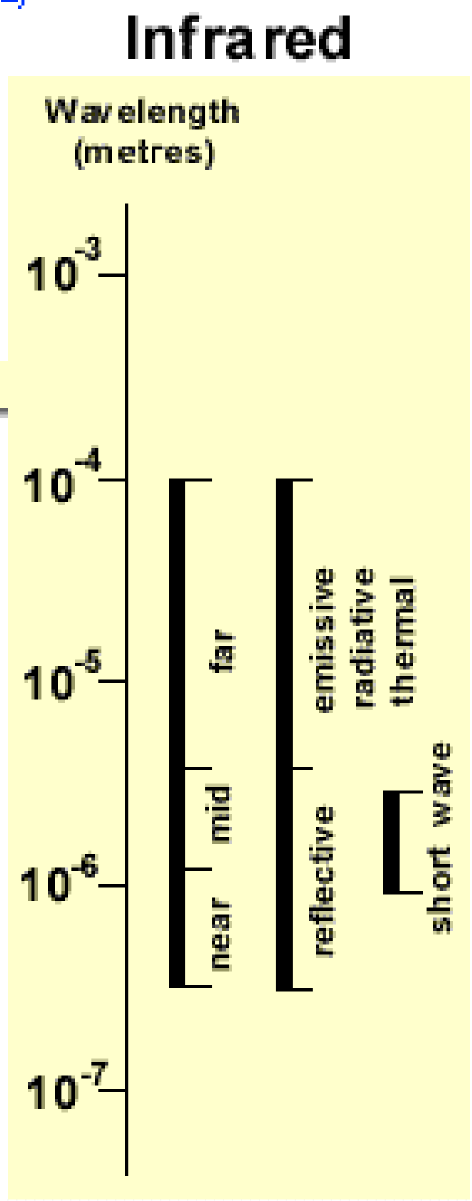
- It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage.
- The visible wavelengths cover a range from approximately 0.4 to 0.7 µm. 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

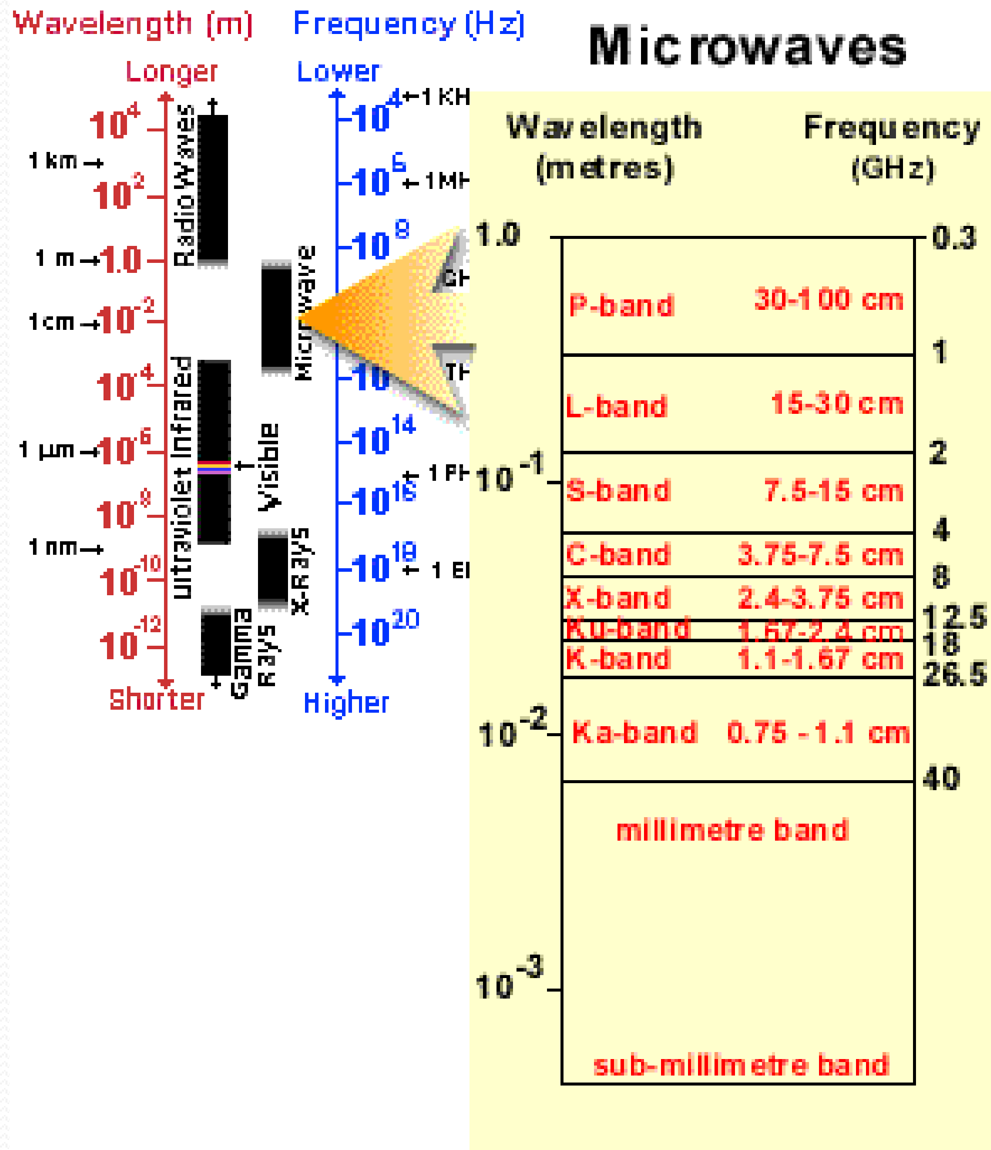
- Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion.
- The reflected IR covers wavelengths from approximately ***0.7 μm to 3.0 μm***.
- The thermal IR region is quite different than the visible and reflected IR portions, 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.

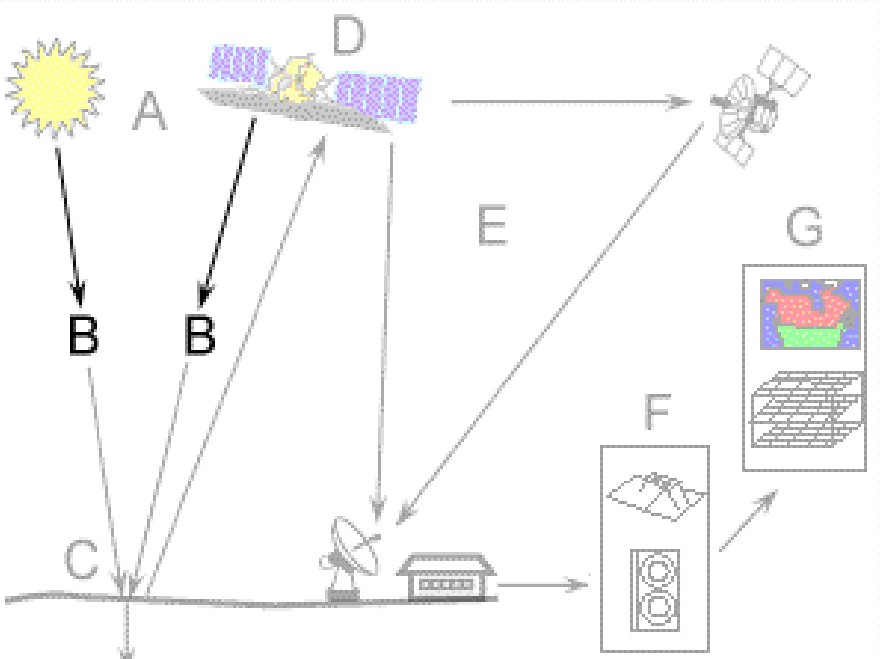


# INTERACTION WITH THE ATMOSPHERE

# Interactions with Atmosphere

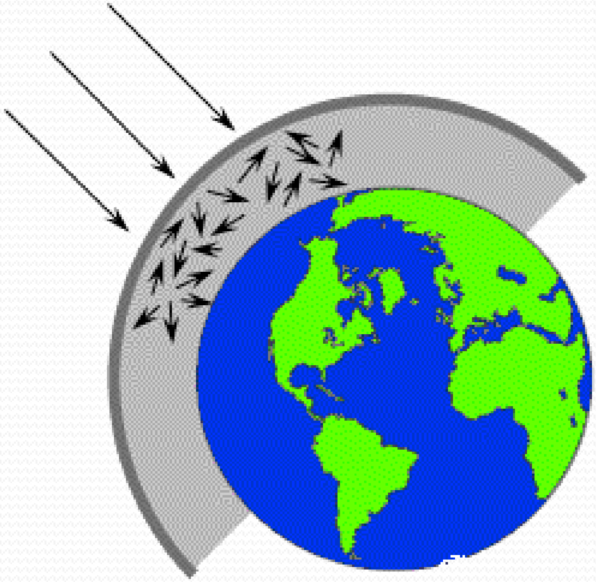
Before radiation used for remote sensing reaches the Earth's surface, it has to travel through some distance of the Earth's atmosphere.

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

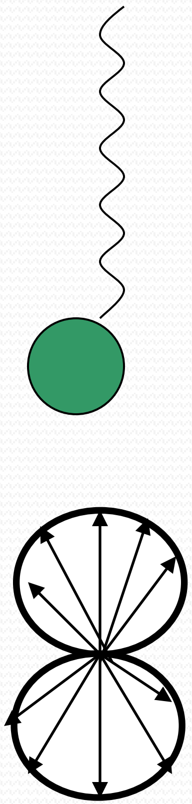


# SCATTERING

- **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.



# RAYLEIGH SCATTERING

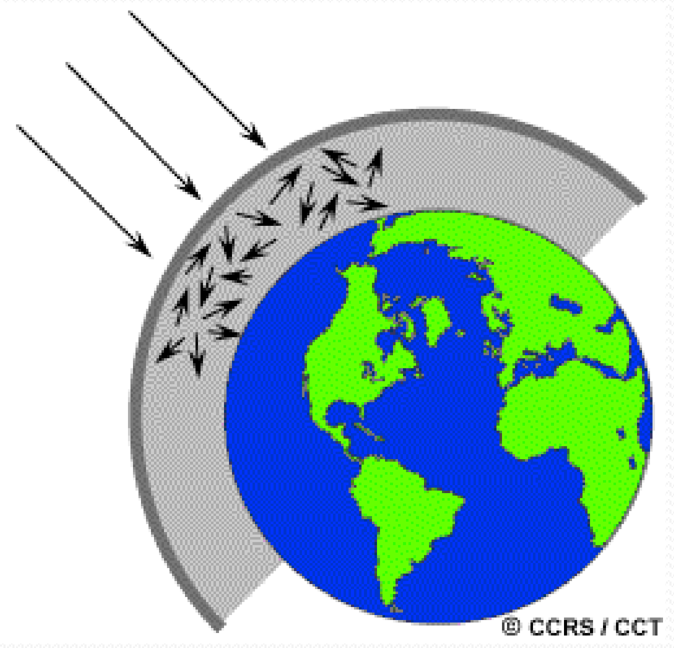


- **Rayleigh scattering** occurs particles are very small compared to the wavelength of the radiation
- Small specks of dust or nitrogen and oxygen molecules
- The fact that the sky appears "blue" during the day and red sunset is because of this phenomenon.
- Rayleigh **Scattering** $\propto$ **$1/\lambda^4$**

# 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.**

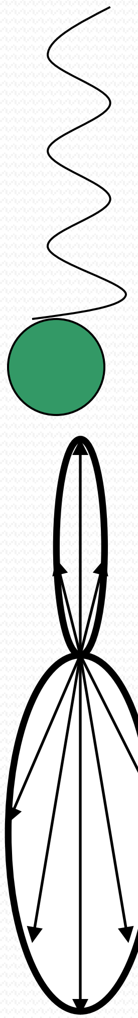
Shorter wavelengths are scattered more Negligible at wavelengths beyond micro meter.

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

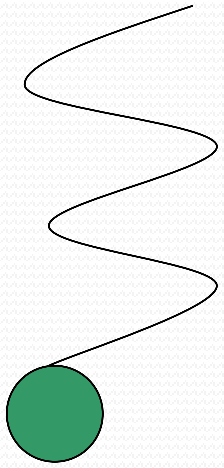
- **Mie Scattering ∝ 1/ λ to 1/λ²**



# 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)

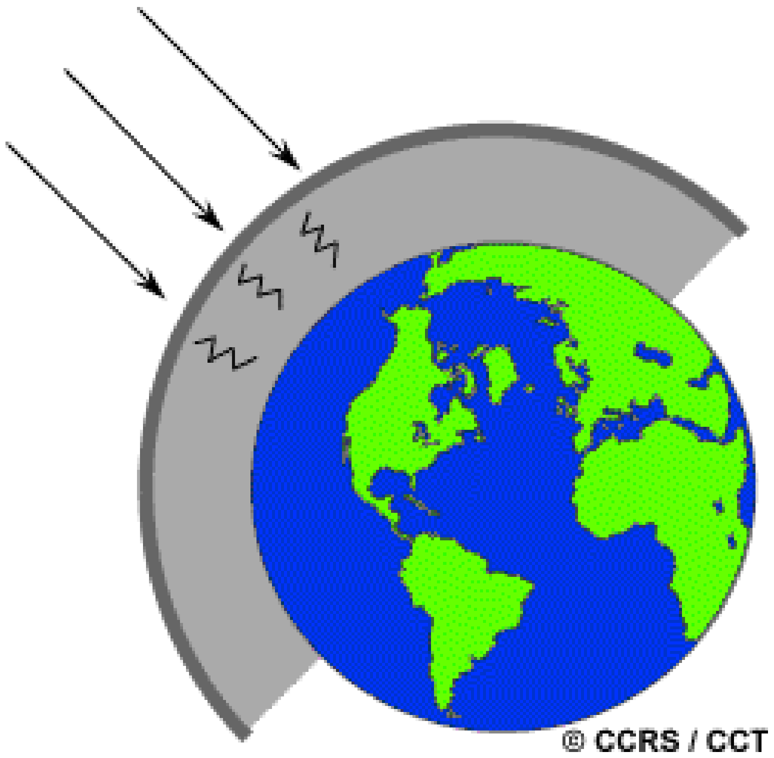
| Type of Scatter of particles | Size of effective atmospheric particles | Type of effective atmospheric particles | Scatter of particles | Effect of scatter on visible and near visible wavelength |
|---|---|---|---|---|
| Rayleigh | Smaller than the wavelength of radiation. | Gas molecules | Molecule 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 |

# 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).***

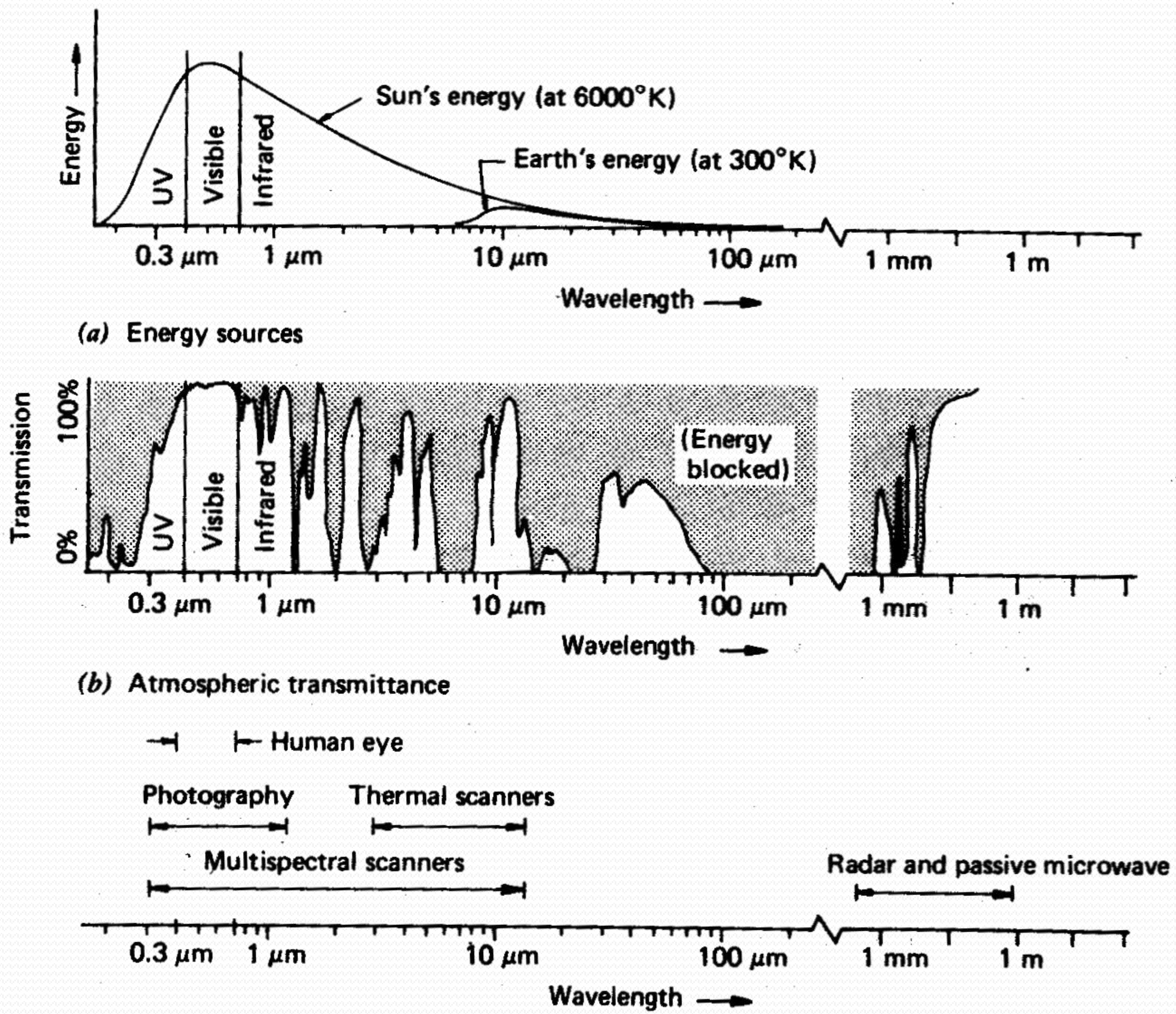
# Atmospheric Window

- 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 | **0.30–0.75 μm** | Optical |
| Near-IR | **0.77–0.91 μm** | Optical |
| Short-wave-IR | 1.00–1.12 μm | Optical |
| | 1.19–1.34 μm | |
| | **1.55–1.75 μm** | |
| | **2.05–2.4 μm** | |
| Mid-IR (Thermal-IR) | 3.50–4.16 μm | Optical |
| | 4.50–5.0 μm | |
| | **8.00–9.2 μm** | |
| | **10.20–12.4 μm** | |
| | (**8–14 μm** for aerial sensing) | |
| | 17.00–22.0 μm | |
| Microwave | 2.06–2.22 mm | Microwave |
| | **7.50–11.5 mm** | |
| | 20.0 + mm | |

# ENERGY INTERACTIONS WITH EARTH SURFACE FEATURES



# 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)

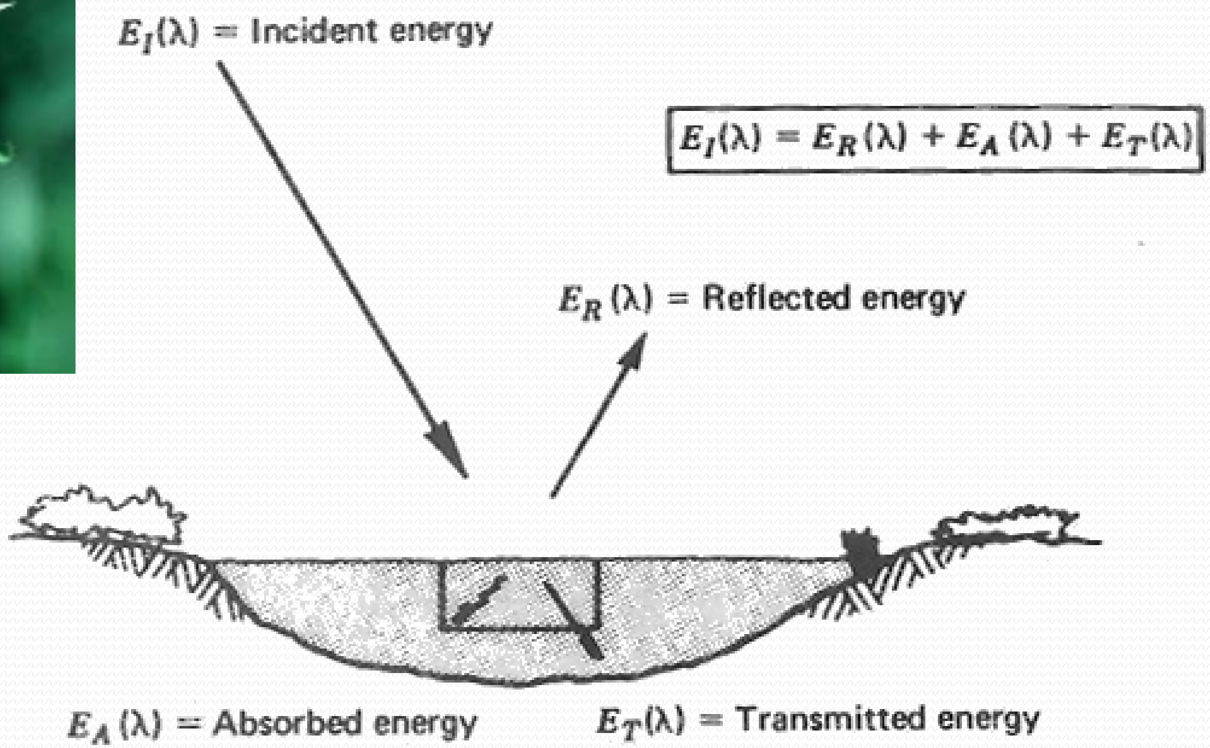
Reflection (R).

**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

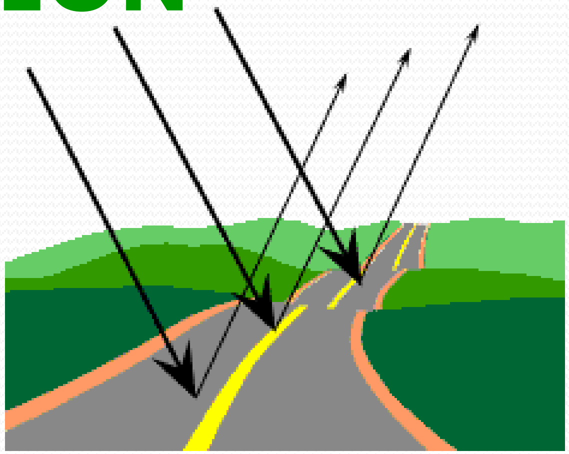
**Reflection (R)** occurs when radiation "bounces" off the target and is redirected.

# TWO TYPES OF REFLECTION

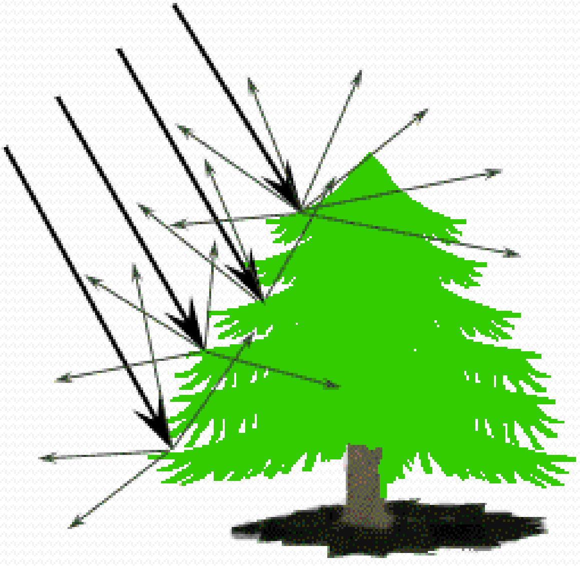
# SPECULAR REFLECTION

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.



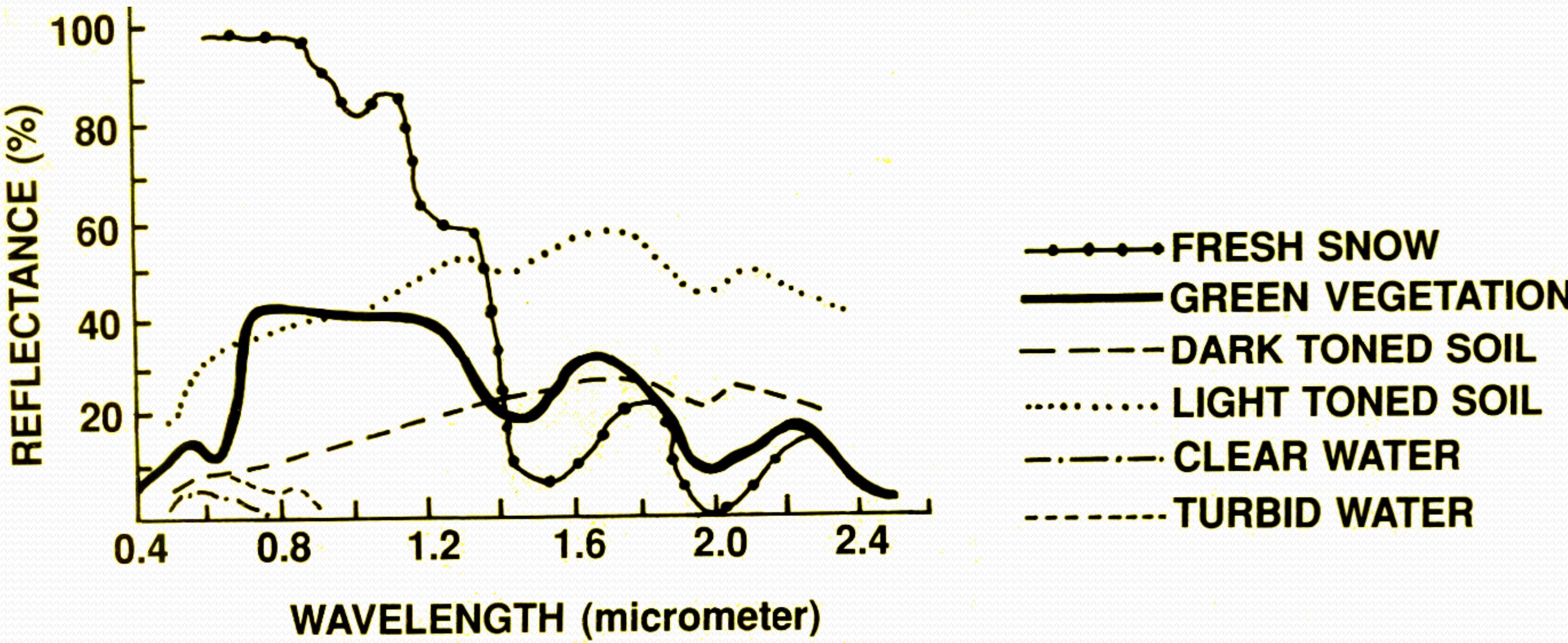
# DIFFUSE REFLECTION

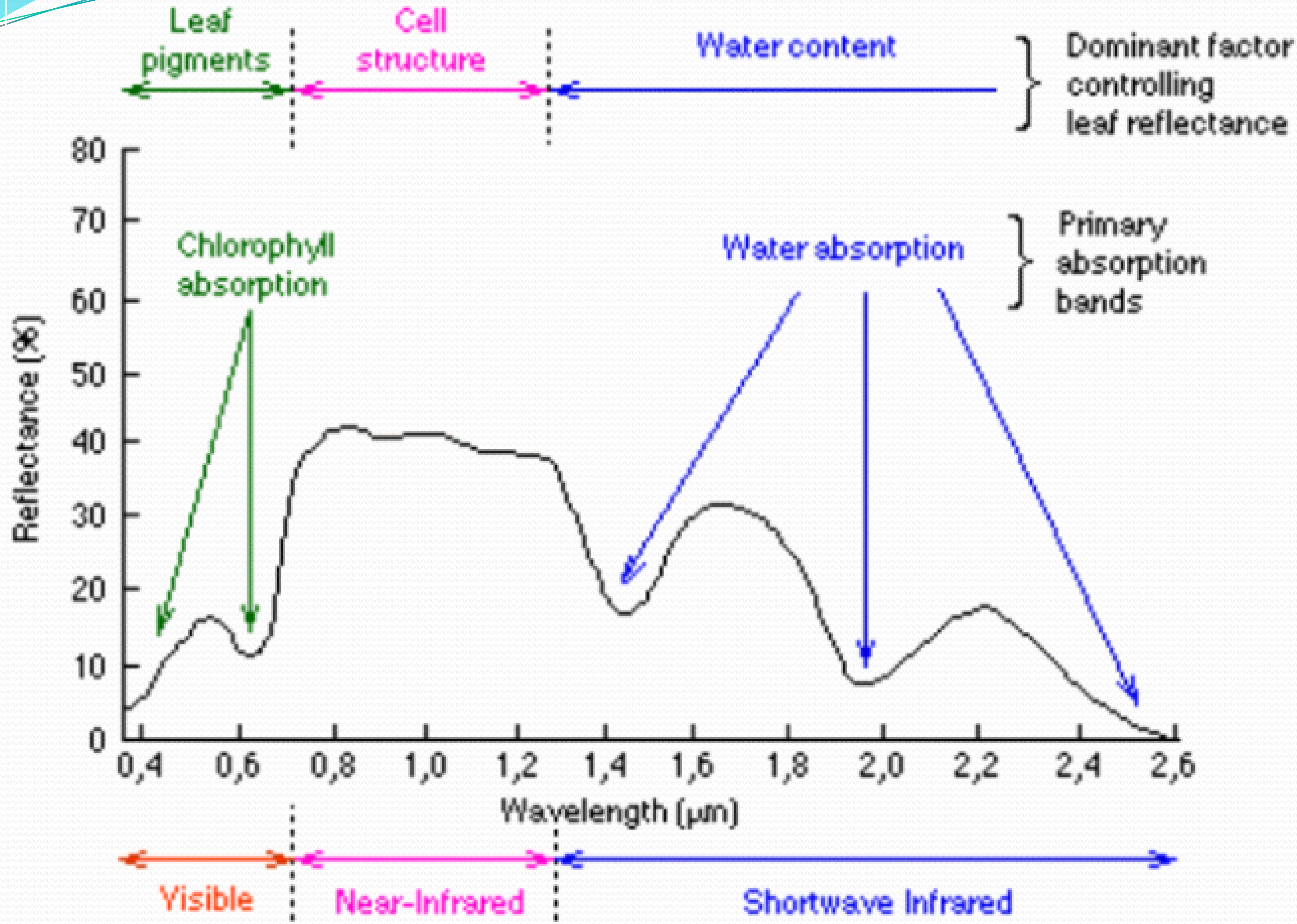
When the surface is rough and the energy is reflected almost uniformly in all directions.



# SPECTRAL REFLECTANCE OF VEGETATION,SOIL AND WATER

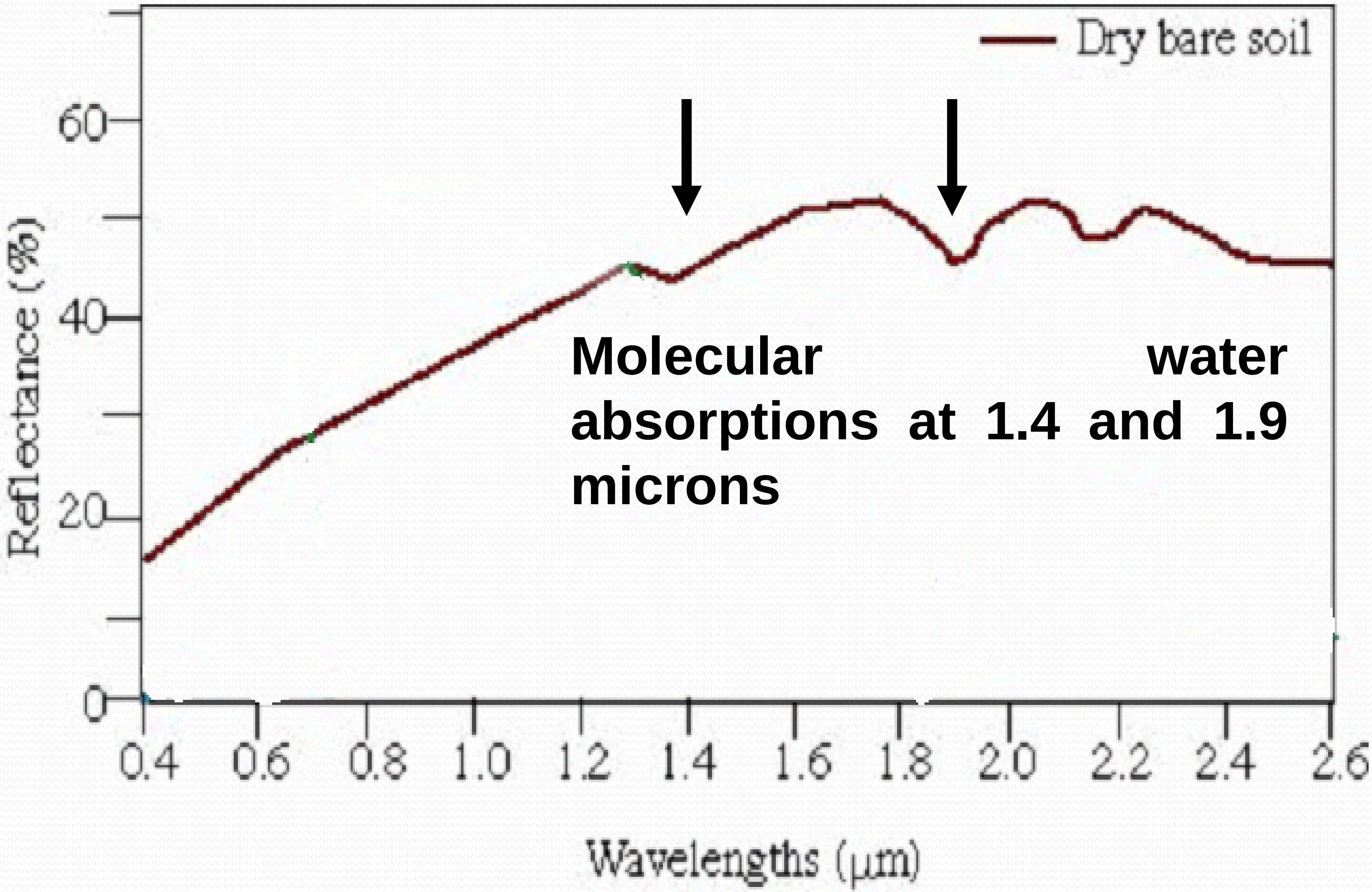
Key to feature identification from space imagery depends on the characteristic changes in the properties of the EM spectrum reflected/emitted from the target surface – **referred 'signature'**



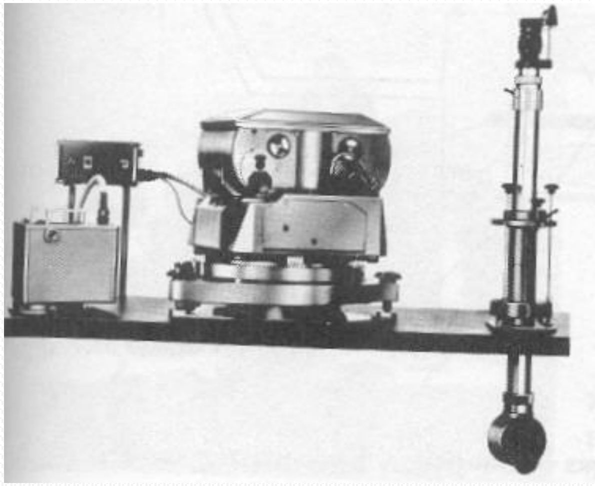


Leaf pigments
Cell structure
Water content
Dominant factor controlling leaf reflectance
Primary absorption bands
Chlorophyll absorption
Water absorption
Reflectance (%)
80
70
60
50
40
30
20
10
0
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
2,0
2,2
2,4
2,6
Wavelength (μm)
Visible
Near-Infrared
Shortwave Infrared

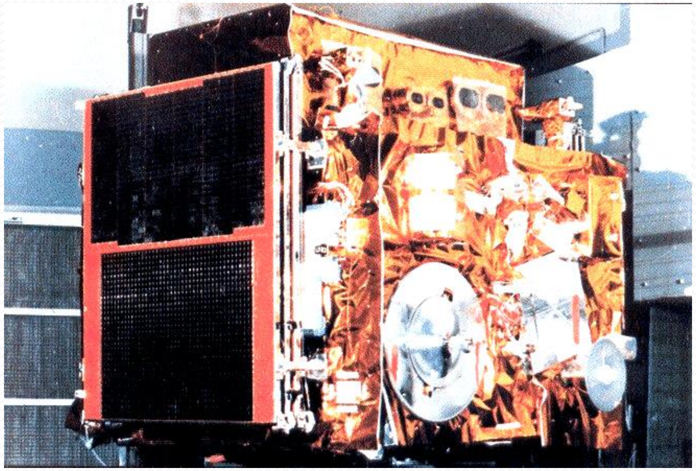
# SPECTRAL REFLECTANCE OF SOIL



# SENSORS



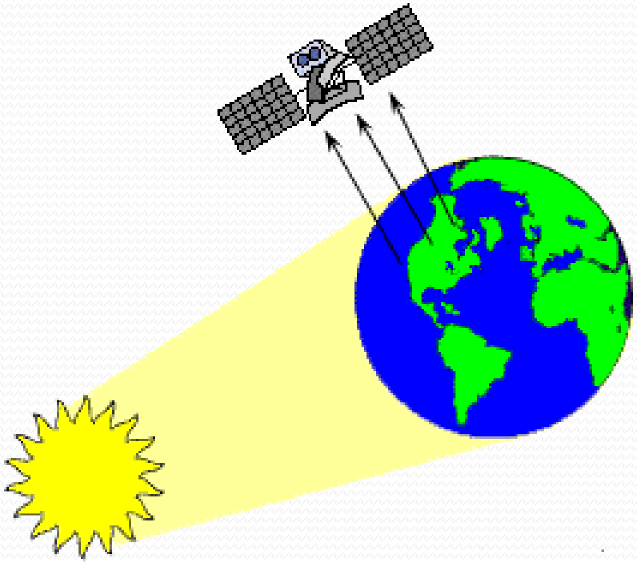
Camera



Scanner

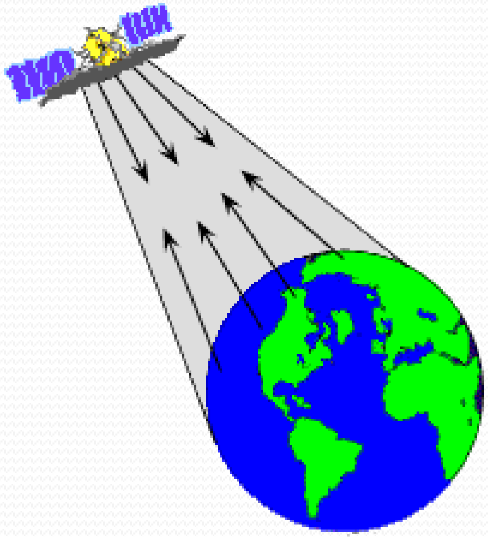
# PASSIVE SENSORS

- 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.



# 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



- **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.

# COMMON SENSORS USED IN REMOTE SENSING

- Cameras
- Scanners
- Radar

# CHARACTERISTICS OF CAMERA

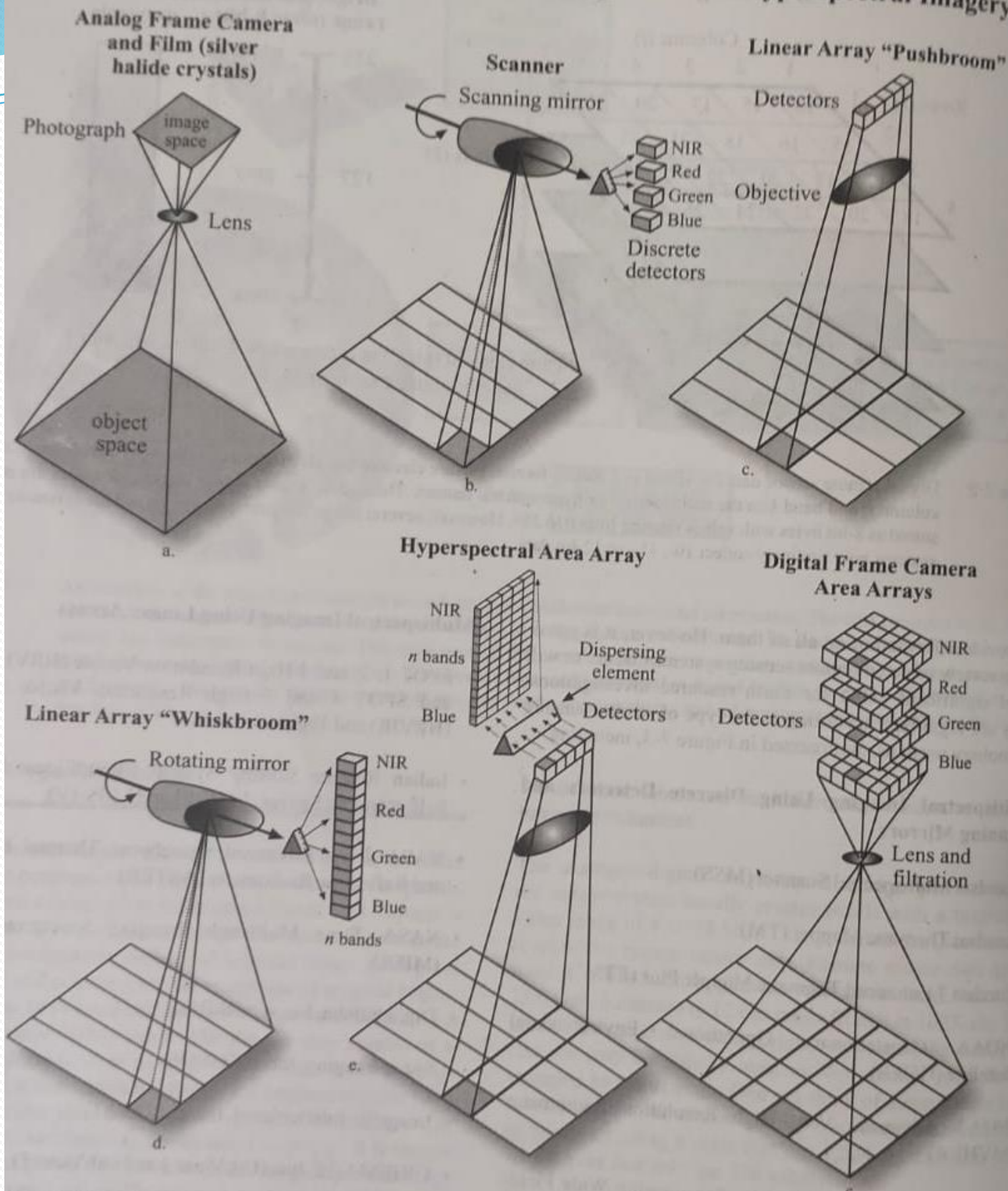
- Passive Remote Sensing
- Very high resolution imagery
- Stereo-capability
- Films - black & white, Colour, Colour Infrared
- Central perspective
- Well-defined geometry.

# CHARACTERISTICS OF SCANNER

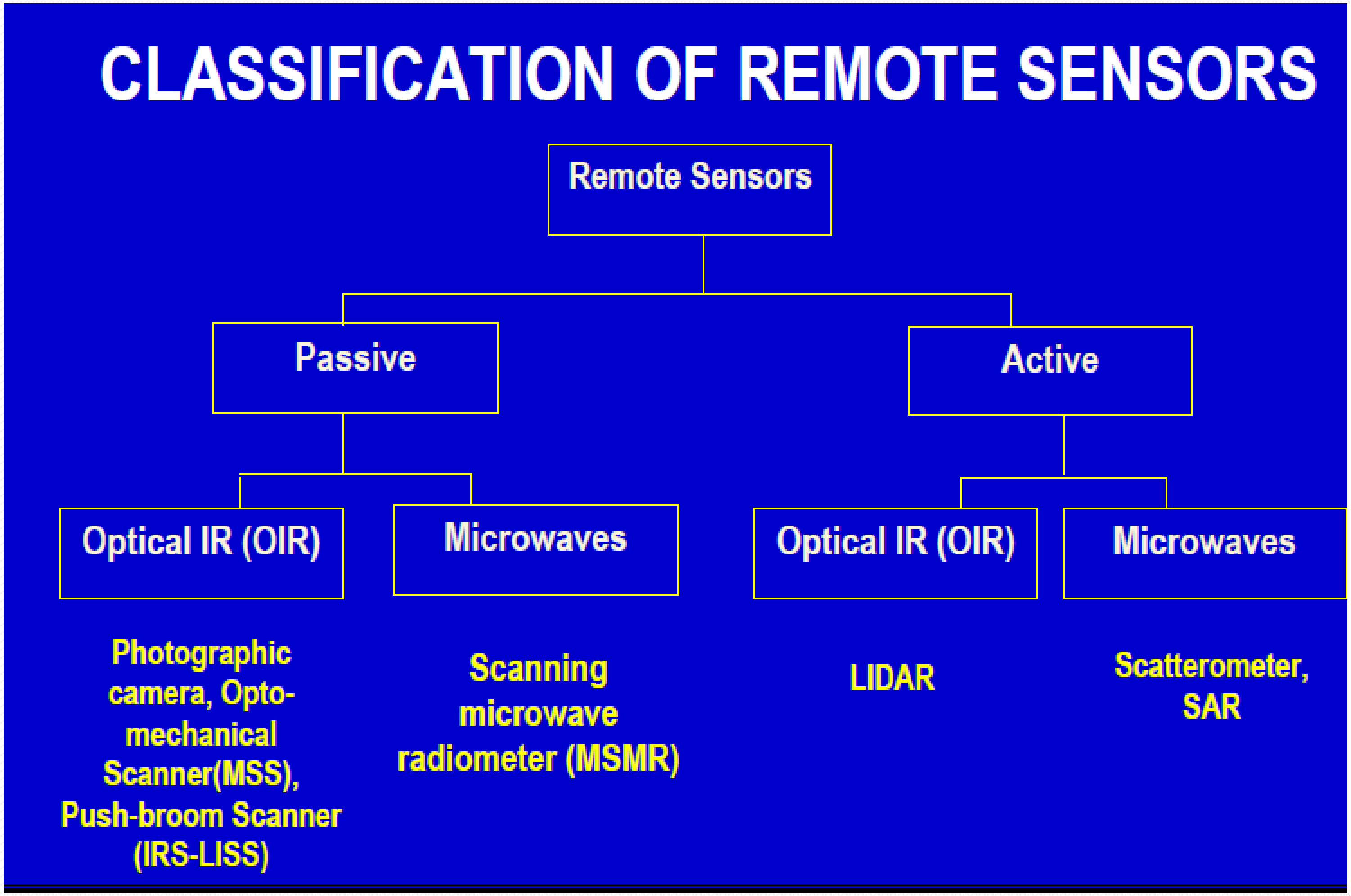
- Output in digital form
- Highly amenable for computer processing
- No consumables
- Flexible w.r.t. radiometric and spectral resolutions

## CHARACTERISTICS OF RADAR

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

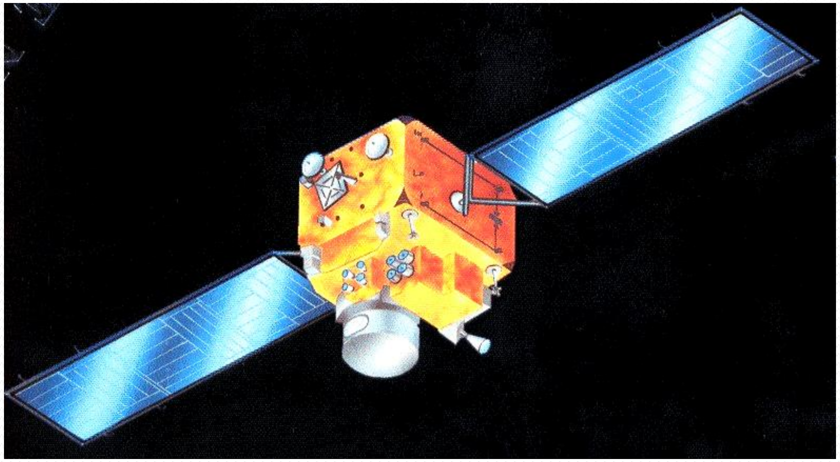



3 Six types of remote sensing systems used for multispectral and hyperspectral data collection: a) traditional aerial photography, b) multispectral imaging using a scanning mirror and discrete detectors, c) multispectral imaging with linear arrays (often referred to as "pushbroom" technology), d) imaging with a scanning mirror and linear arrays (often referred to as "whiskbroom" technology), e) imaging spectrometry using linear and area arrays, and f) digital frame camera aerial photography based on area arrays.


CLASSIFICATION OF REMOTE SENSORS
Remote Sensors
Passive
Active
Optical IR (OIR)
Microwaves
Optical IR (OIR)
Microwaves
Photographic camera, Opto-mechanical Scanner(MSS), Push-broom Scanner (IRS-LISS)
Scanning microwave radiometer (MSMR)
LIDAR
Scatterometer, SAR

- **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)

# PLATFORM CHARACTERISTICS



# 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
- No fuel needed(for 3 years operation)
- Defence permission not needed
- Wide, synoptic view
- Very stable platform
- Limited repeat coverage
- Highly cost effective

## ORBIT

The path followed by a satellite

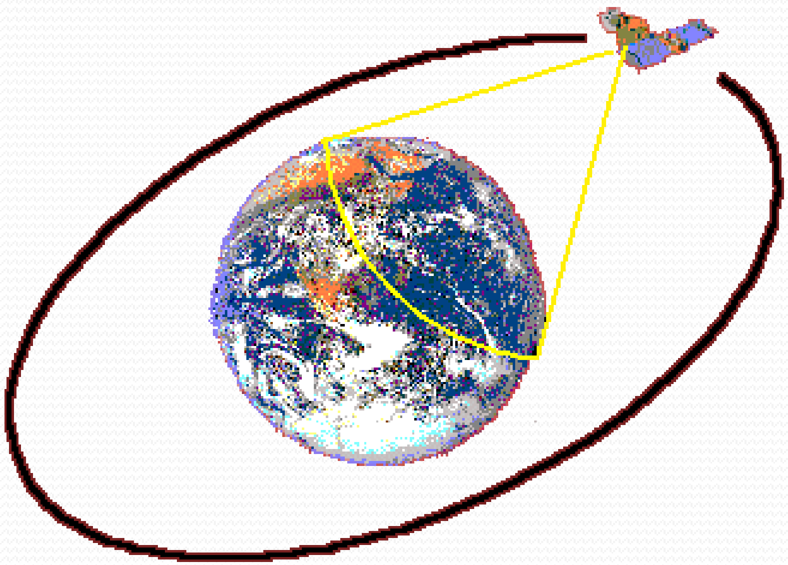
**Two types of Orbits are**

1) Geostationary Orbits

2) Near Polar Orbits

# GEOSTATIONARY ORBITS

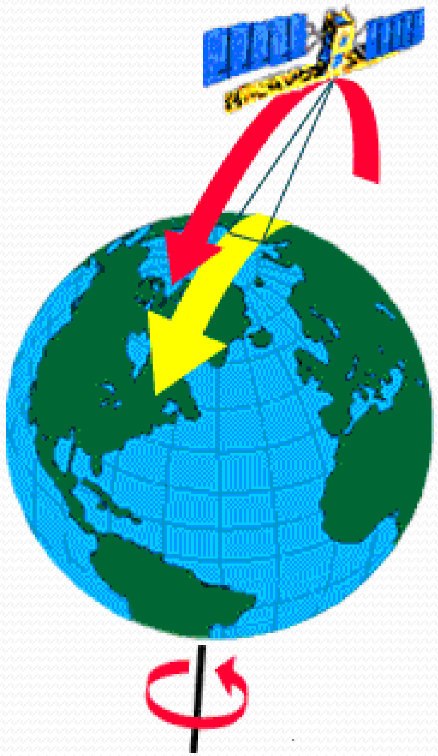
- At altitudes of approximately 36,000 kilometres
- Revolve at speeds which match the rotation of the Earth so that they seem stationary, relative to the Earth's surface
- This allows the satellites to observe and collect information continuously over specific areas



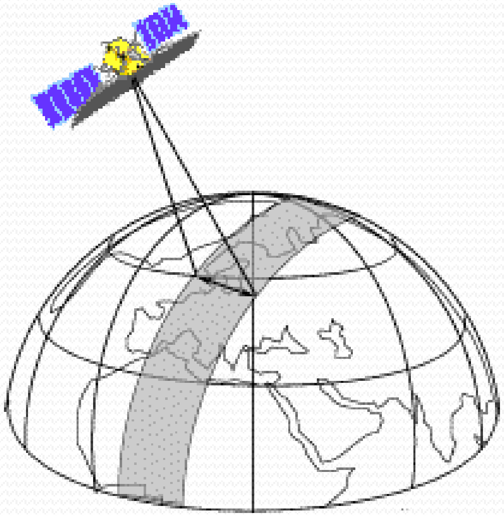
# NEAR-POLAR ORBITS

- 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**.



# 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.**

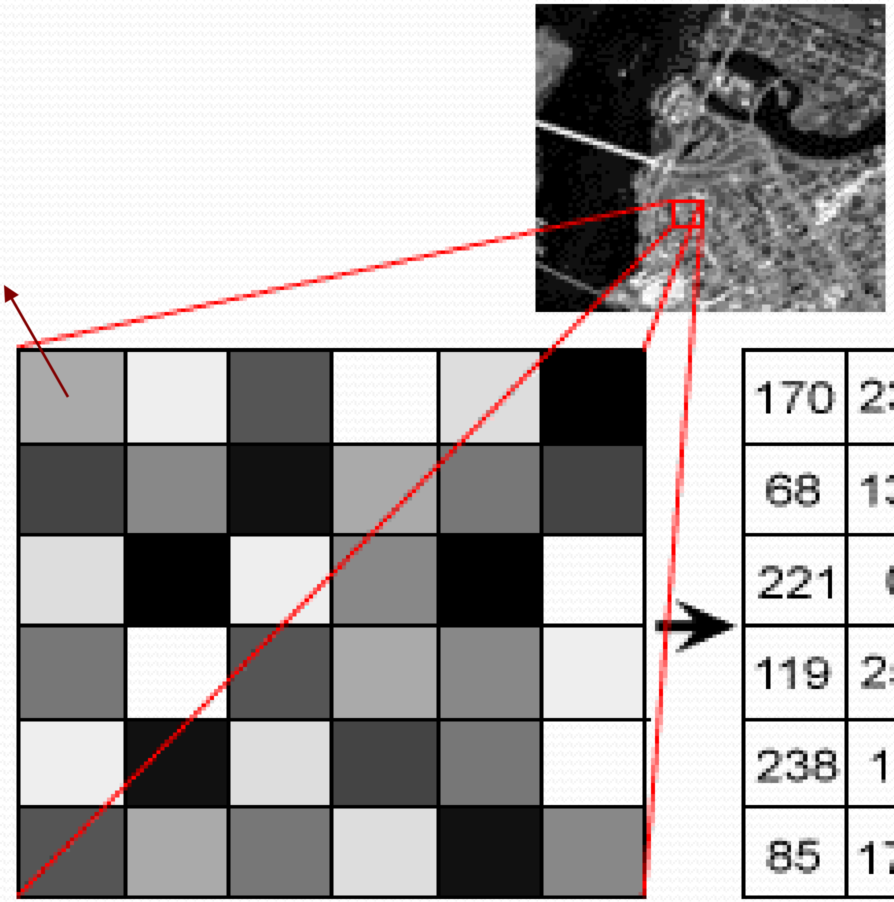
# PIXELS (Picture + elements)

Black - 0

White - 255

Grey values

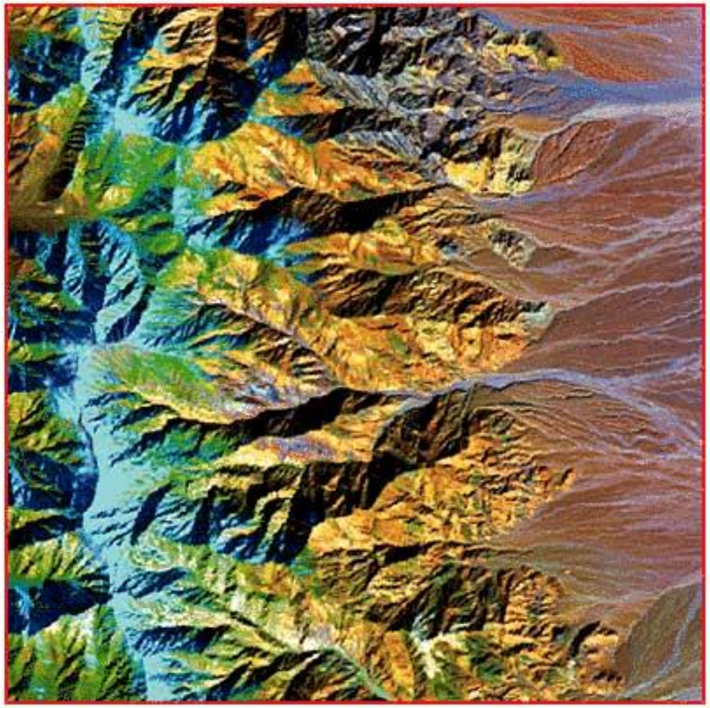
Pixel



| | | | | | |
|---|---|---|---|---|---|
| 170 | 238 | 85 | 255 | 221 | 0 |
| 68 | 136 | 17 | 170 | 119 | 68 |
| 221 | 0 | 238 | 136 | 0 | 255 |
| 119 | 255 | 85 | 170 | 136 | 238 |
| 238 | 17 | 221 | 68 | 119 | 255 |
| 85 | 170 | 119 | 221 | 17 | 136 |

# FOUR TYPES OF RESOLUTION

- Spatial Resolution
- Spectral Resolution
- Radiometric Resolution
- Temporal Resolution



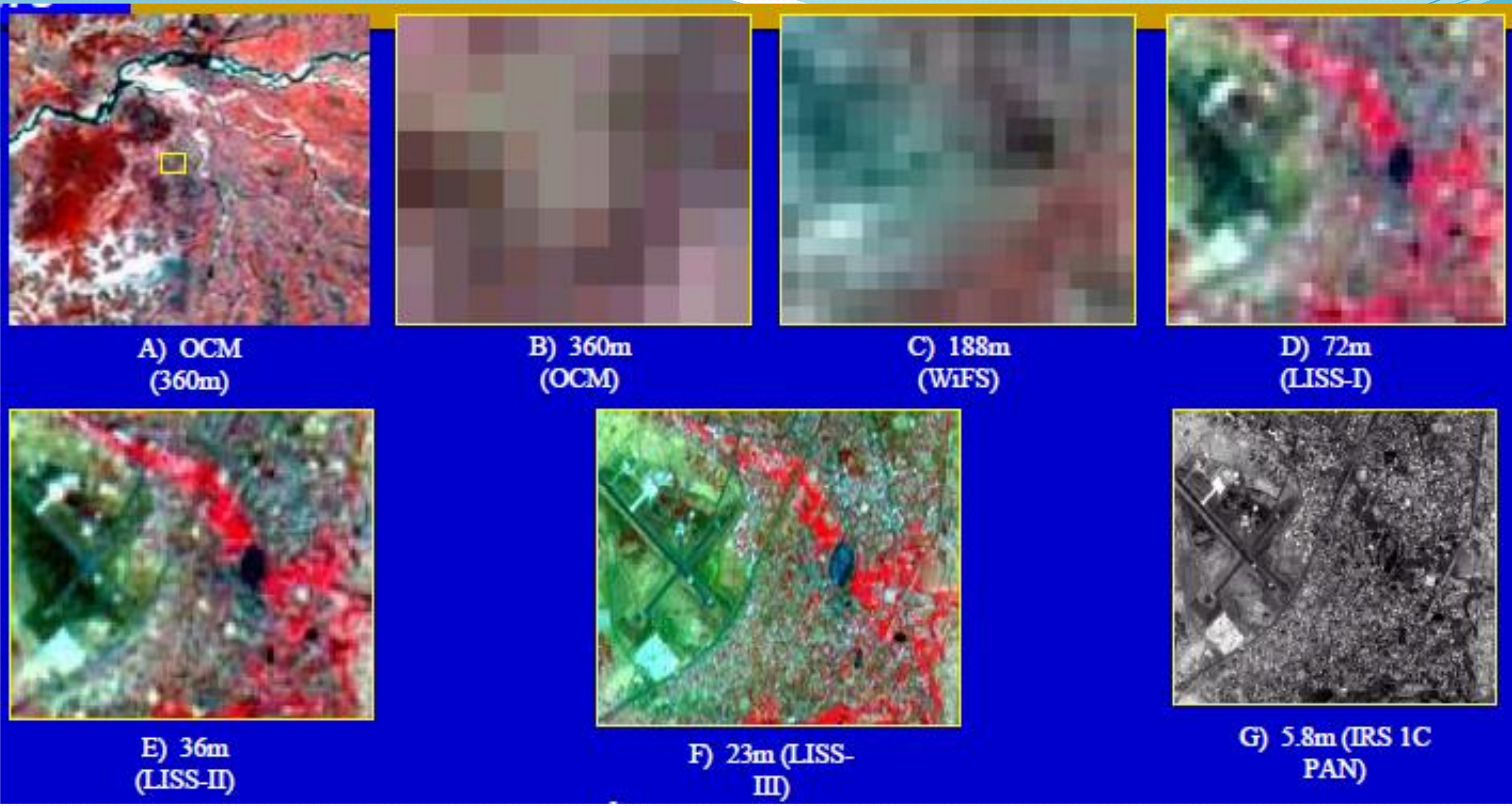
# Spatial Resolution

- 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 (≈ 4km x 4km) 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

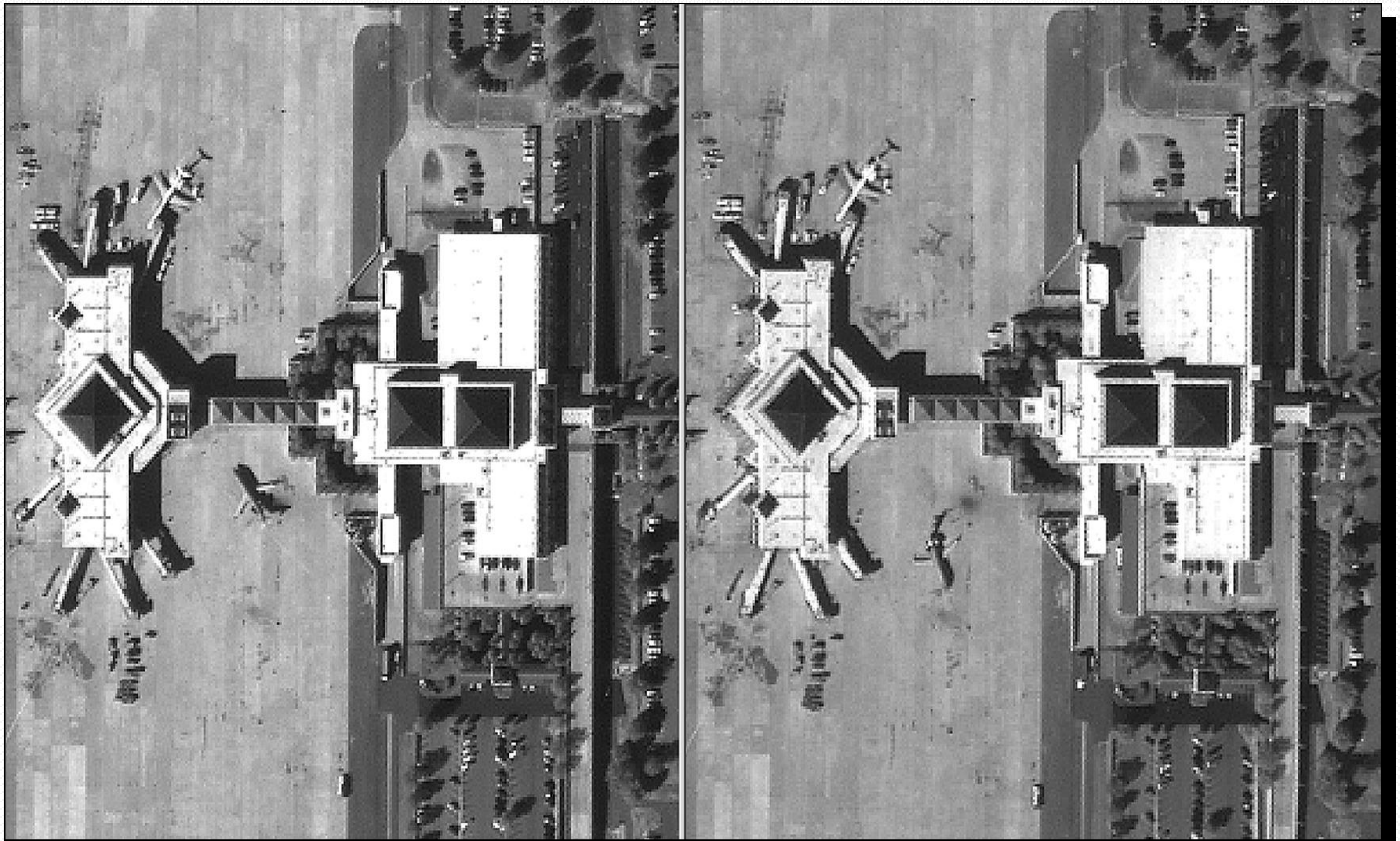

Shanghai, China
SPOT 2.5m

# IKONOS Panchromatic Images of Washington, DC

1 x 1 m spatial resolution

Jensen, 2000

# IKONOS Panchromatic Stereopair of Columbia, SC Airport



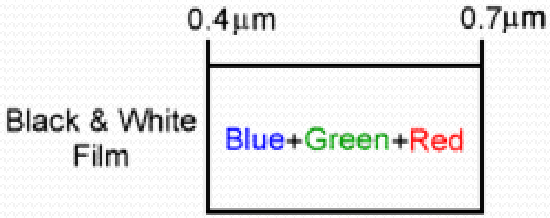
Jensen, 2000

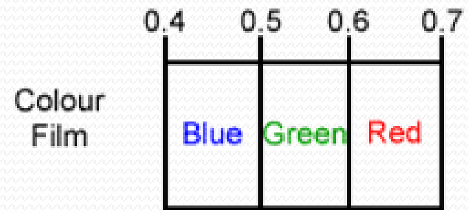
November 15, 2000

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

Panchromatic 1 x 1 m

# Spectral Resolution

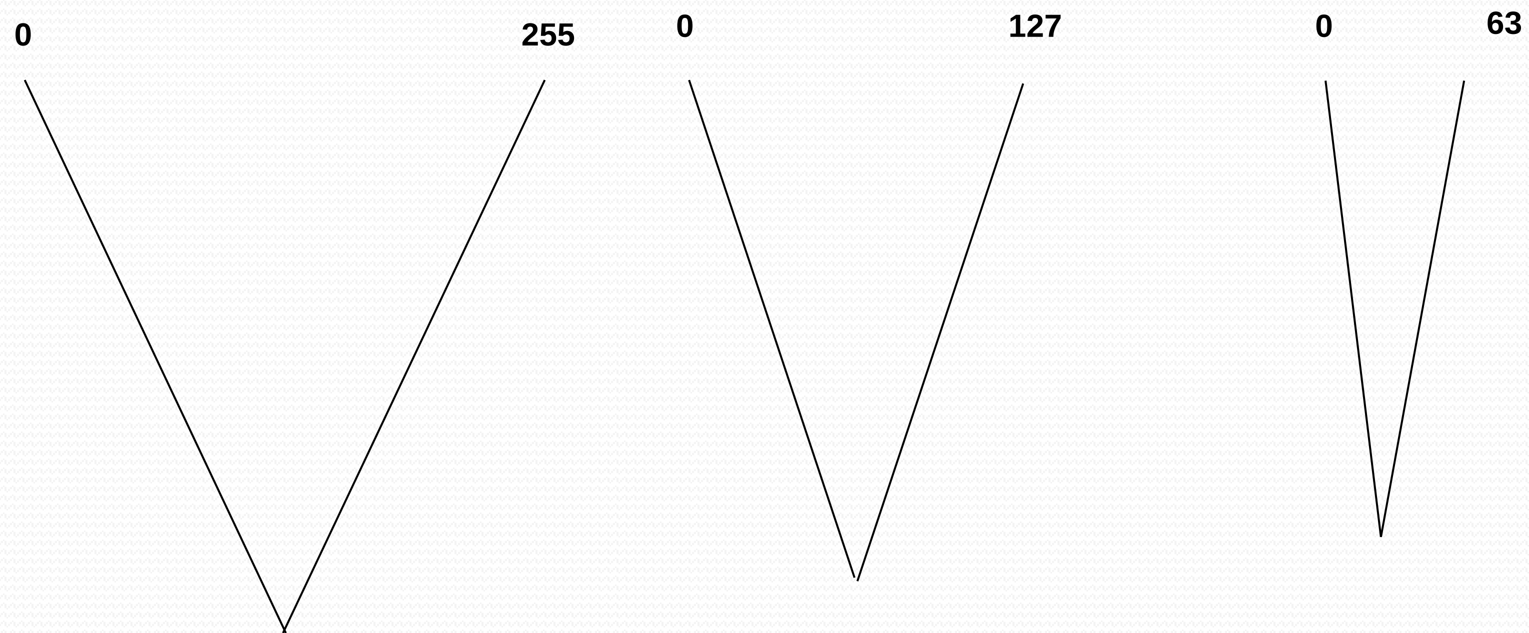



- Ability of a sensor to define fine wavelength intervals.
- The finer the spectral resolution, the narrower is the wavelength range for a particular channel or band.

# 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

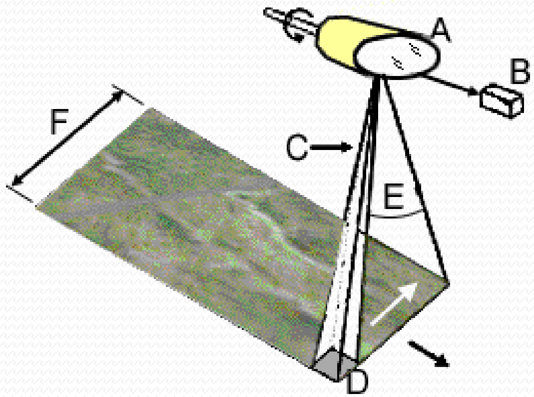
- Time interval between two successive visits of the satellite for the same place.

- Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing **multi-temporal** imagery.

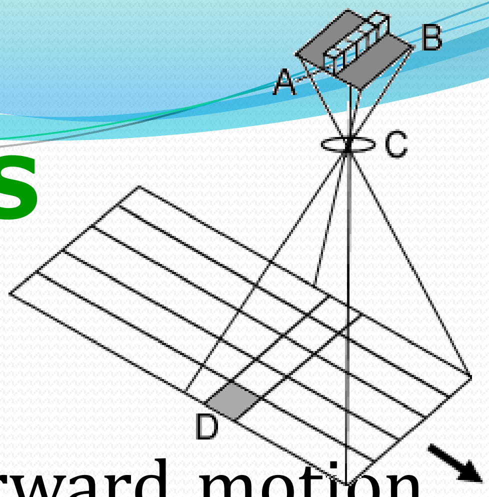
# SCANNERS

# 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**.

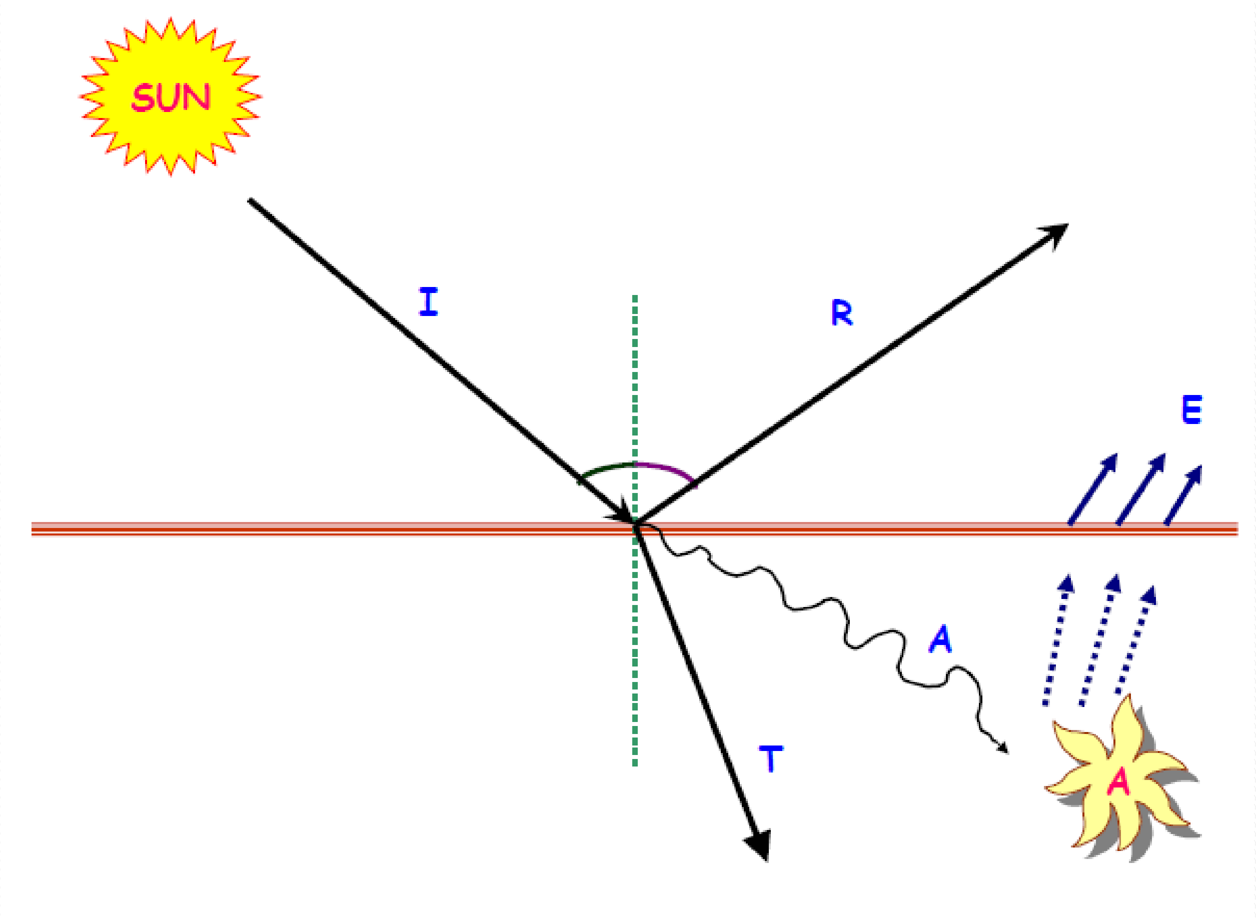


# ALONG-TRACK SCANNERS



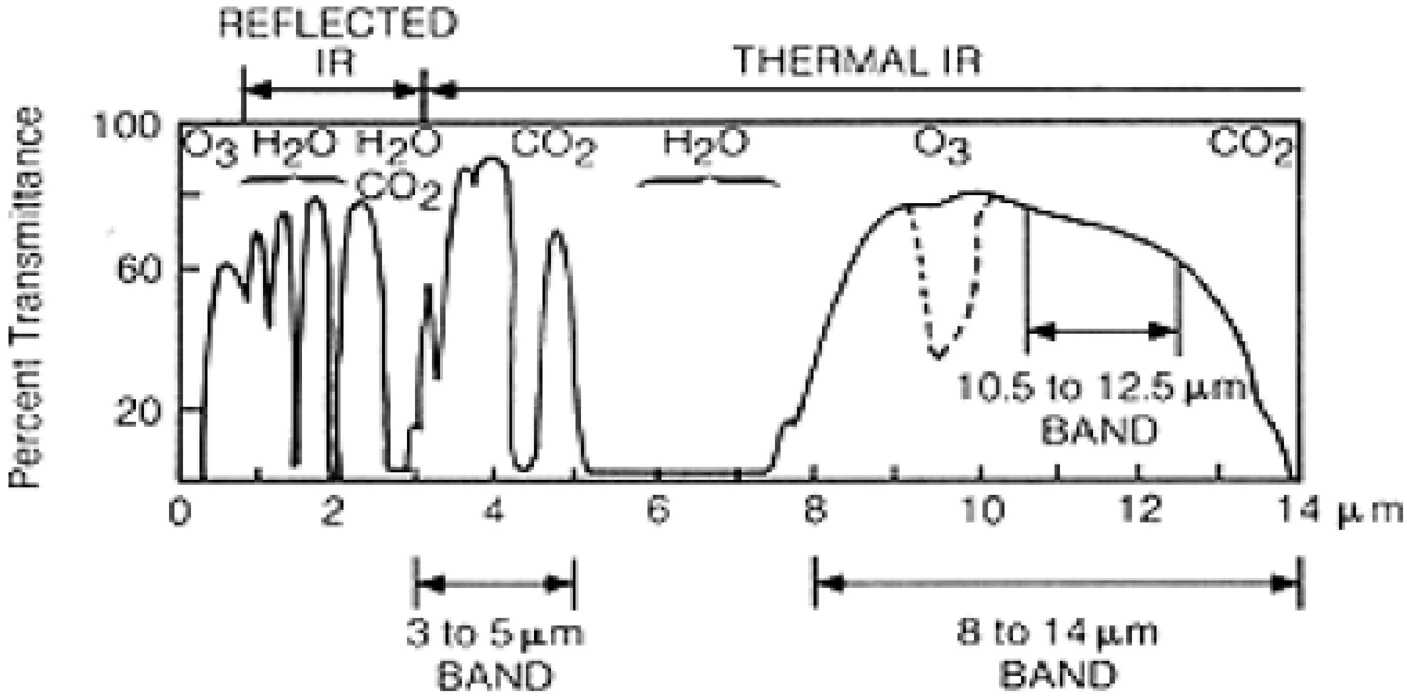

- **Along-track scanners** also use the forward motion of the platform to record successive scan lines and build up a two-dimensional image, perpendicular to the flight direction.
- Instead of a scanning mirror, they use a linear array of detectors (A) located at the focal plane of the image (B) formed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

# 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°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 ($\varepsilon$)**

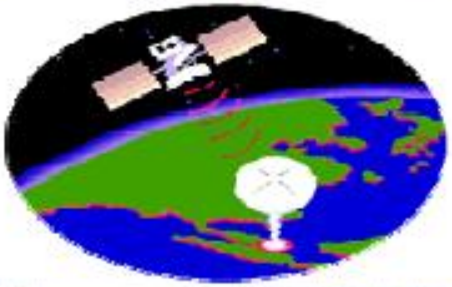
**Thermal Inertia (P)**

**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 μm; resolution 600 m

**Thermal Infrared Multispectral Scanner (TIMS)**
6 bands between 8-12 μm

**NOAA AVHRR**
5 bands; resolution 1.1 km

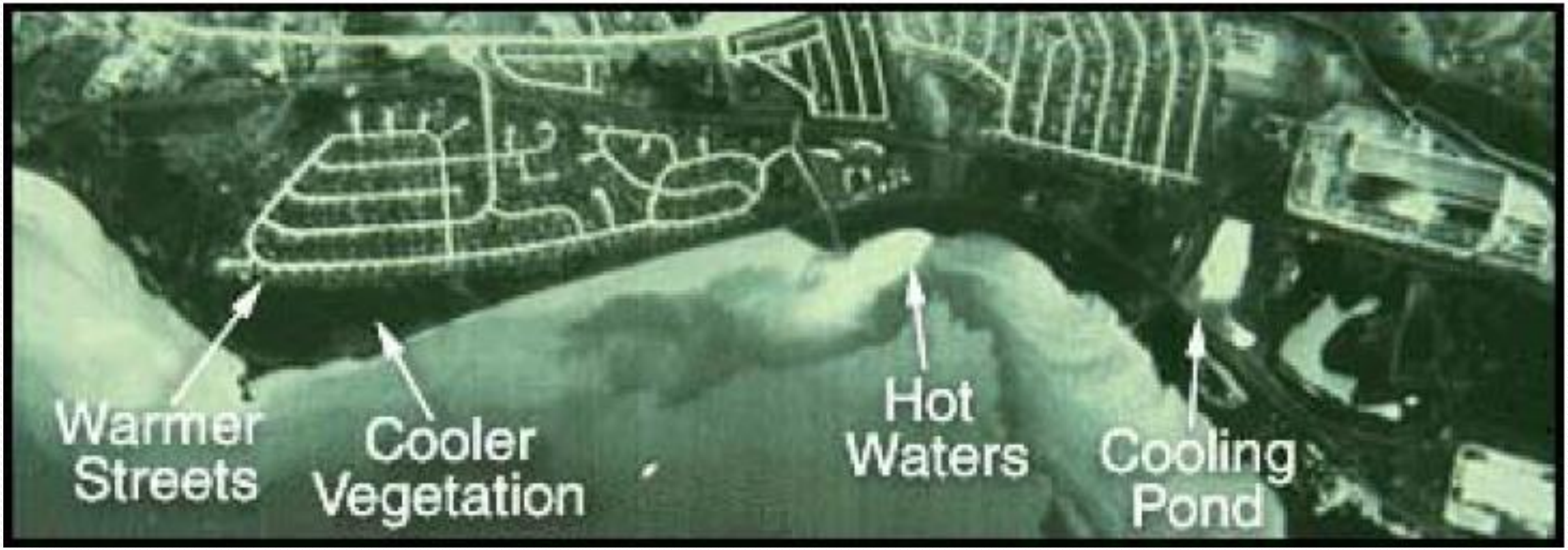
## Landsat Thematic Mapper (TM) band 6

**10.4 - 12.5 μm; 60 m resolution**

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

**High resolution multispectral imager**
**3 bands in VNIR (0.5 - 1.0 μm); 15 m resolution**
**6 bands in SWIR (1.0-2.5 μm); 30 m resolution**
**5 bands in TIR (8-12 μm); 90 m resolution**

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


Warmer
Streets
Cooler
Vegetation
Hot
Waters
Cooling
Pond

# 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

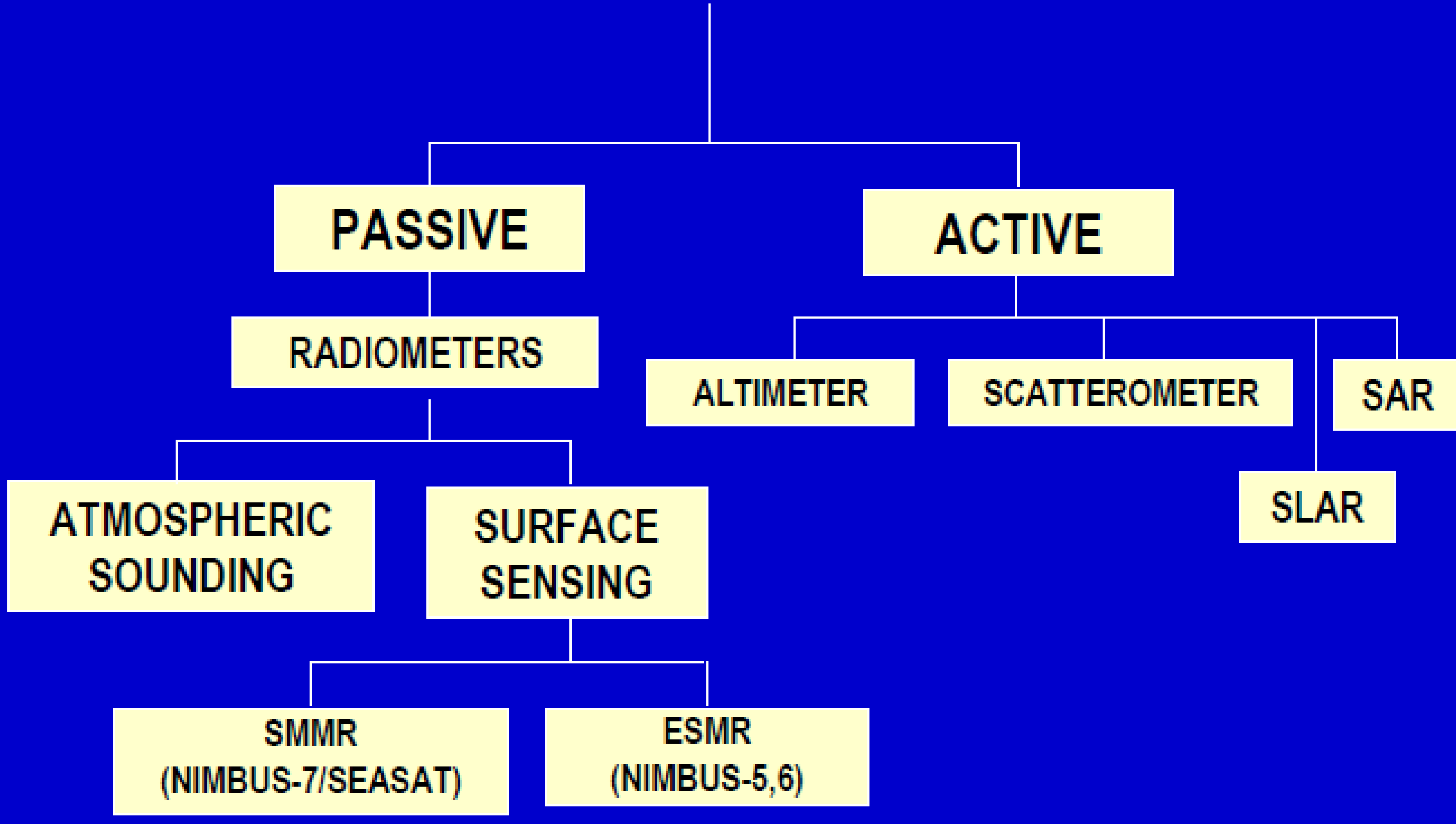
emission - in passive mode,

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.

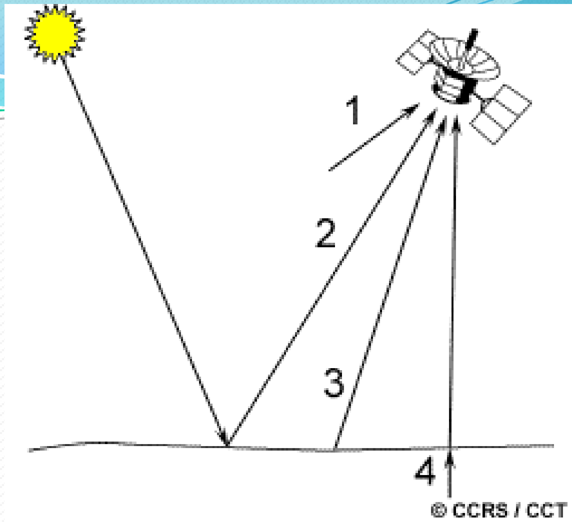
**Advantages over remote sensing in the other regions of EMR.**

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.

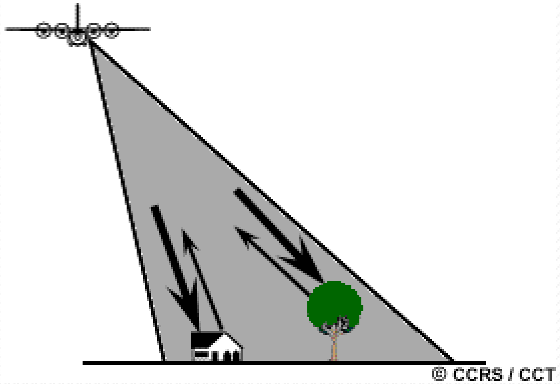
# MICROWAVE SENSORS



**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 **RA**dio **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**.

**RADAR** acronym **Radar Detection and Ranging Active** is an active microwave remote sensing system.

Various systems used to describe imaging radar are Side Looking Radar (SLAR) or Real Aperture Radar (RAR), Synthetic Aperture Radar (SAR), Active Microwave Imager (AMI). Scatterometer, Altimeter and Rain Mapping Radar etc. also fall under active microwave sensors

**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**

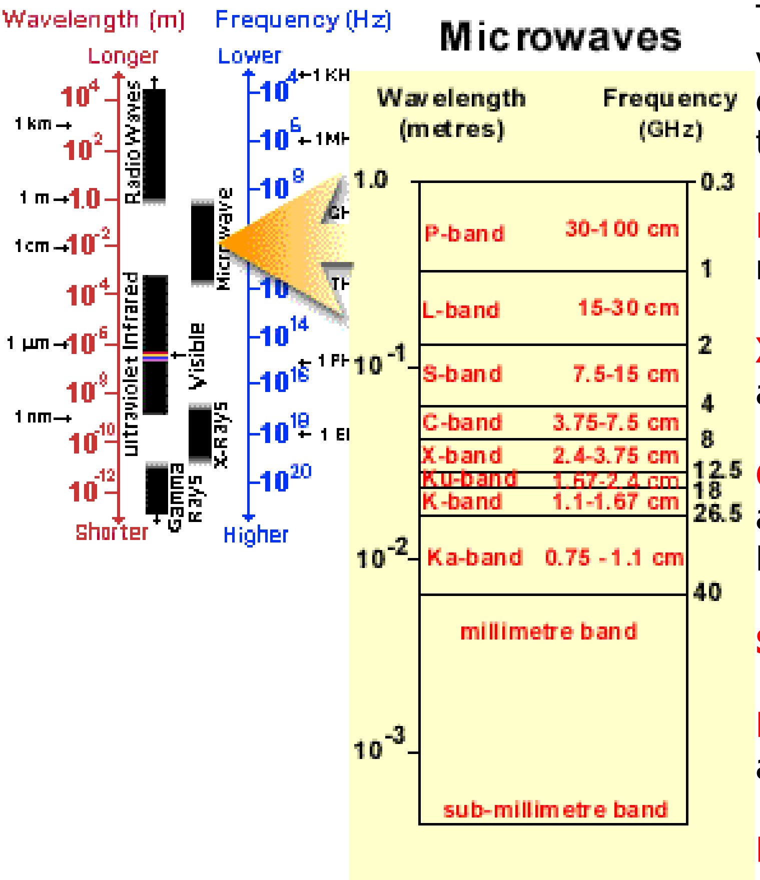
It measures the ocean surface topography, significant wave height and surface wind speed. It can also be configured to measure the terrain evaluation on land. It operates in nadir looking mode.

**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.

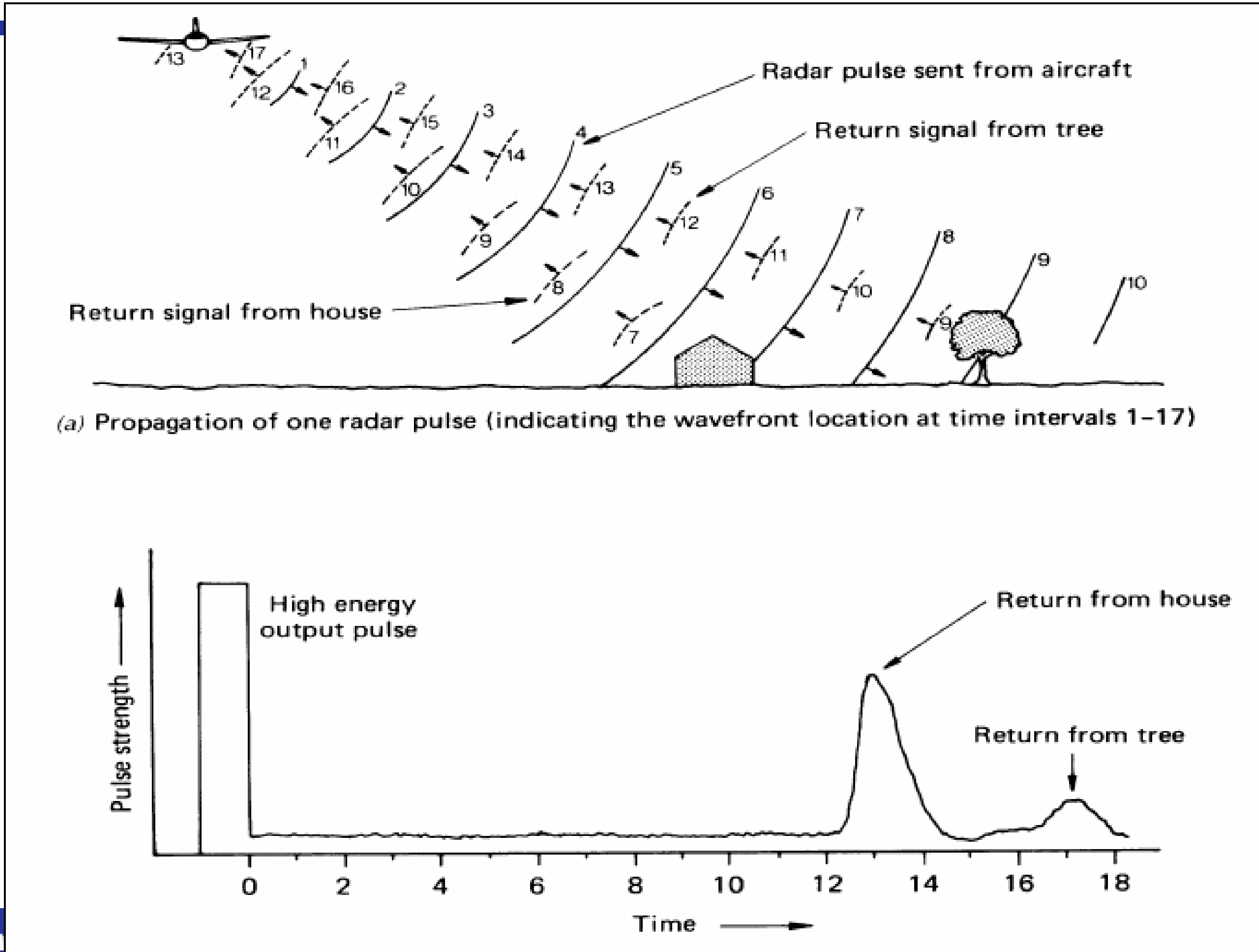
a) System properties

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

b) Terrain properties

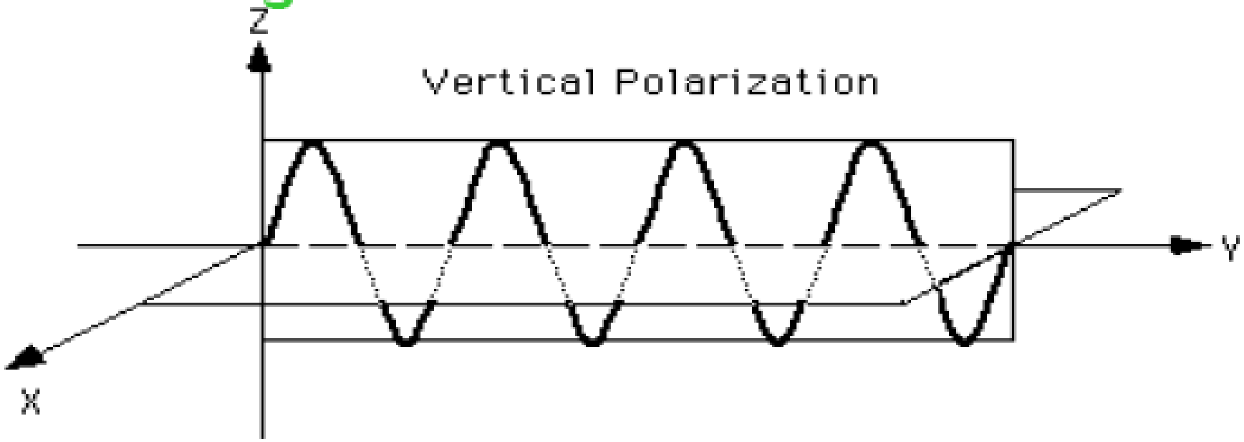
- i) Dielectric constant
- ii) Surface roughness
- ii) Feature orientation

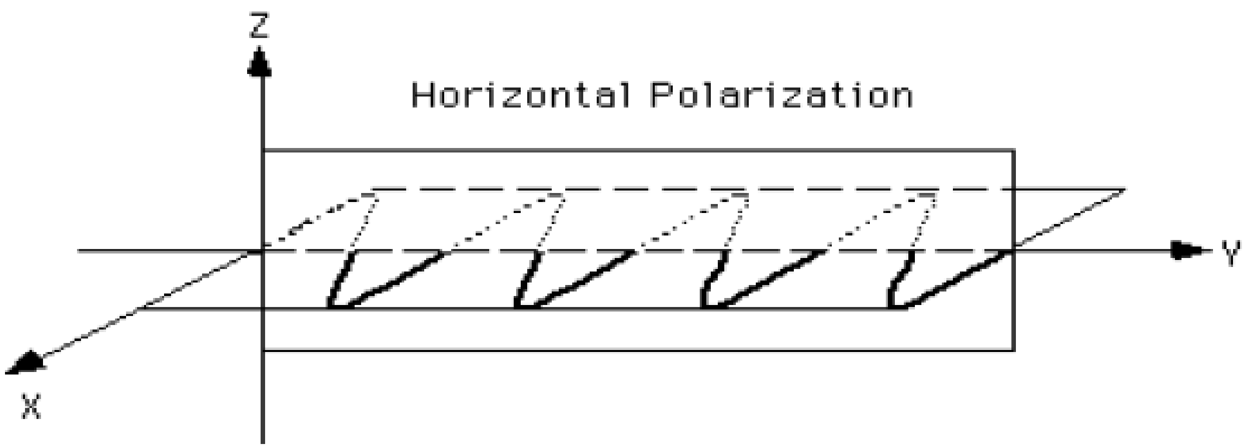
# Radar pulse propagation and reflection



# 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.**

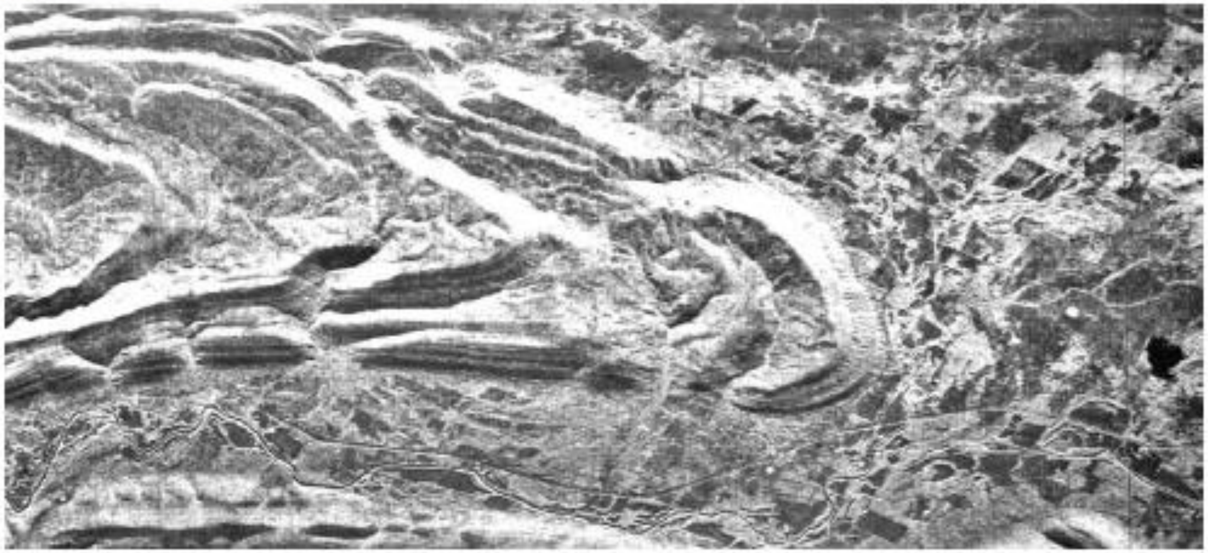
# Polarised images

SLAR system

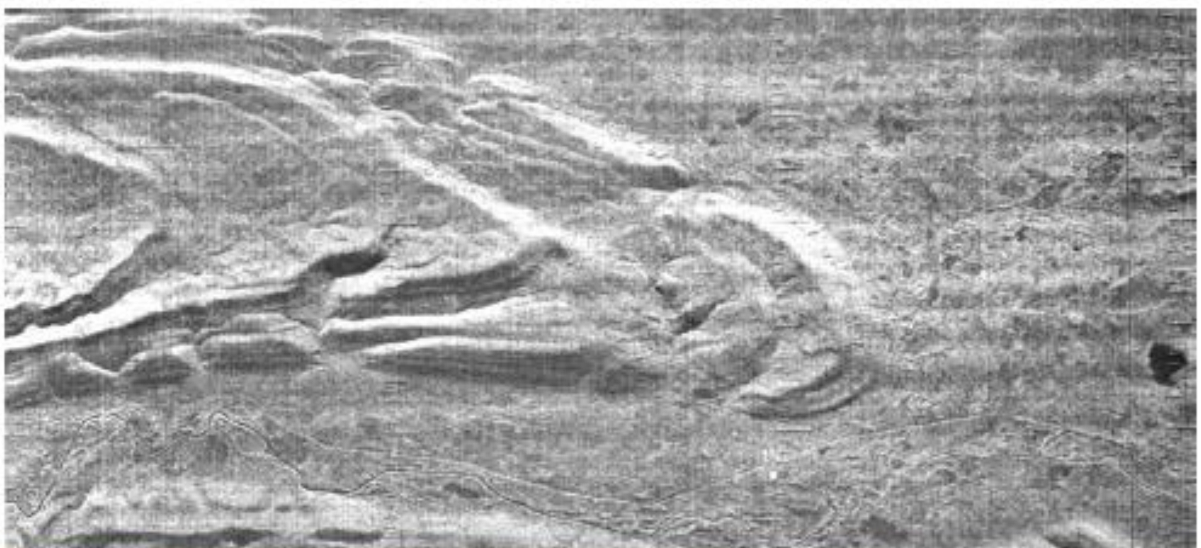
Oklahoma

Scale 1:160,000

K band (3.2cm)



HH polarization



HV polarization

# 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.

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# 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** | 99.2º | 99.2º | 99.2º | 98.2º | 98.2º | 98.2º |
| **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 (µm) | | | Landsat-8 OLI and *TIRS* Bands (µm) | | |
|---|---|---|---|---|---|
| | | | 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 | *100 m TIR-1* | *10.60 – 11.19* | Band 10 |
| | | | *100 m TIR-2* | *11.50 – 12.51* | 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 |

# Spot series of satellite

| | SPOT 1 | SPOT 2 | SPOT 3 | SPOT 4 | SPOT 5 | SPOT 6 | SPOT 7 |
|---|---|---|---|---|---|---|---|
| **Operators** | CNES (owner), Spot Image (operator) | | | | | Airbus DS | |
| **Launch dates** | 22 February 1986 | 22 January 1990 | 26 September 1993 | 24 March 1998 | 4 May 2002 | 9 September 2012 | 30 June 2014 |
| **EOL** | November 2003 | July 2009 | November 1996 | 29 June 2013 | March 2015 | operating nominally | operating nominally |
| **Orbit Height** | 832 km | | | | | 694 km | |
| **Orbit Type** | 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 | | | | | | |
| **Orbit Period** | 101 minutes | | | | | 98.79 minutes | |
| **Inclination** | 98.7º | | | | | 98.2º | |
| **Repeat Cycle** | 26 days | | | | | | |
| **Onboard sensors provided under TPM** | HRV | HRV | HRV | HRVIR, VEGETATION | HRG, HRS, VEGETATION | NAOMI | NAOMI |
| **Resolution** | 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) | |
| **Swath Width** | 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<br>Multispectral: 6 m at nadir | |
| Swath Width | 60 km | |
| Field of Regard | ±30º (spacecraft tilting capability about nadir for event monitoring) | |
| Bands | PAN | 0.45-0.75 µm |
| | Blue | 0.45-0.52 µm |
| | Green | 0.53-060 µm |
| | Red | 0.62-0.69 µm |
| | NIR (Near Infrared) | 0.76-0.89 µm |

# 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<br>0.52-0.59<br>0.62-0.68<br>0.77-0.86 | 72.5 m LISS-I<br>36 m LISS-II | 148<br>74 x 2<br>(swath of 148 km) | 22 |
| IRS-1B | 29.08.1991 | LISS-I and LISS-II A/B | same as for IRS-1A | | 148<br>74 x 2 | 22 |
| IRS-P2 | 15.10.1994 | LISS-II M | 0.45-0.52<br>0.52-0.59<br>0.62-0.68<br>0.77-0.86 | 32 m x 37 m | 66 x 2<br>(131 km for combined swaths) | 24 |
| IRS-1C | 28.12.1995 | LISS-III | 0.52-0.59<br>0.62-0.68<br>0.77-0.86<br>1.55-1.70 | 23.5<br>23.5<br>23.5<br>70 | 142<br>142<br>142<br>148 | 24 |
| | | PAN | 0.50-0.75 | 5.8 | 70 | 24 (5) |
| | | WiFS | 0.62-0.68<br>0.77-0.86 | 188 | 804 | 5 |
| IRS-P3 | 21.03.1996 | WiFS | 0.62-0.68<br>0.77-0.86<br>1.55-1.70 | 188 | 804 | 5 |
| | | MOS-A<br>MOS-B<br>MOS-C | 0.75-0.77<br>0.41-1.01<br>1.595-1.605 | 1500<br>520<br>550 | 195<br>200<br>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<br>MSMR | 0.4-0.9<br>6.6, 10.65, 18, 21 GHz (frequencies) | 360 x 236<br>105x68, 66x43, 40x26, 34x22 (km for frequency sequence) | 1420<br>1360 | 2<br>2 |
| IRS-P6 ResourceSat-1 | 17.10.2003 | LISS-IV | 0.52-0.59<br>0.62-0.68<br>0.77-0.86 | 5.8<br>5.8<br>5.8 | 70 | 24 (5) |
| | | LISS-III* | 0.52-0.59<br>0.62-0.68<br>0.77-0.86<br>1.55-1.70 | 23.5<br>23.5<br>23.5<br>23.5 | 140 | 24 |
| | | AWiFS | 0.62-0.68<br>0.77-0.86<br>1.55-1.70 | 70<br>70<br>70 | 740 | 5 |
| IRS-P5 CartoSat-1 | 05.05.2005 | PAN-F<br>PAN-A | 0.50-0.75<br>0.50-0.75 | 2.5<br>2.5 | 30<br>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<br>SCAT<br>ROSA | 0.40-0.90 8 bands<br>13.515 GHz<br>GPS occultation | 360 x 236<br>25 km x 25 km | 1420<br>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<br>B3 0.62-0.68<br>B4 0.77-0.86<br>B5 1.55-1.70 | 0.50 -0.75 | B3 0.62-0.68<br>B4 0.77-0.86 | 0.52-0.59<br>0.62-0.68<br>0.77-0.86 | 0.52-0.59<br>0.62-0.68<br>0.77-0.86<br>1.55-1.70 | 0.52-0.59<br>0.62-0.68<br>0.77-0.86<br>1.55-1.70 | 0.402-0.422<br>0.433-0.453<br>0.480-0.500<br>0.500-0.520<br>0.545-0.565<br>0.660-0.680<br>0.745-0.785<br>0.845-0.885 |
| Spatial Resolution (m) | 23.5 for B2,B3,B4 and<br>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 ± 26° | 774 km | 141km | 23.9<br>(MX mode)<br>70.3<br>(PAN mode) | 740 km | 1420 km |
| Radiometric levels | 128 | 64 | 128 | 7 bits | 7 bits | 10 bits | |

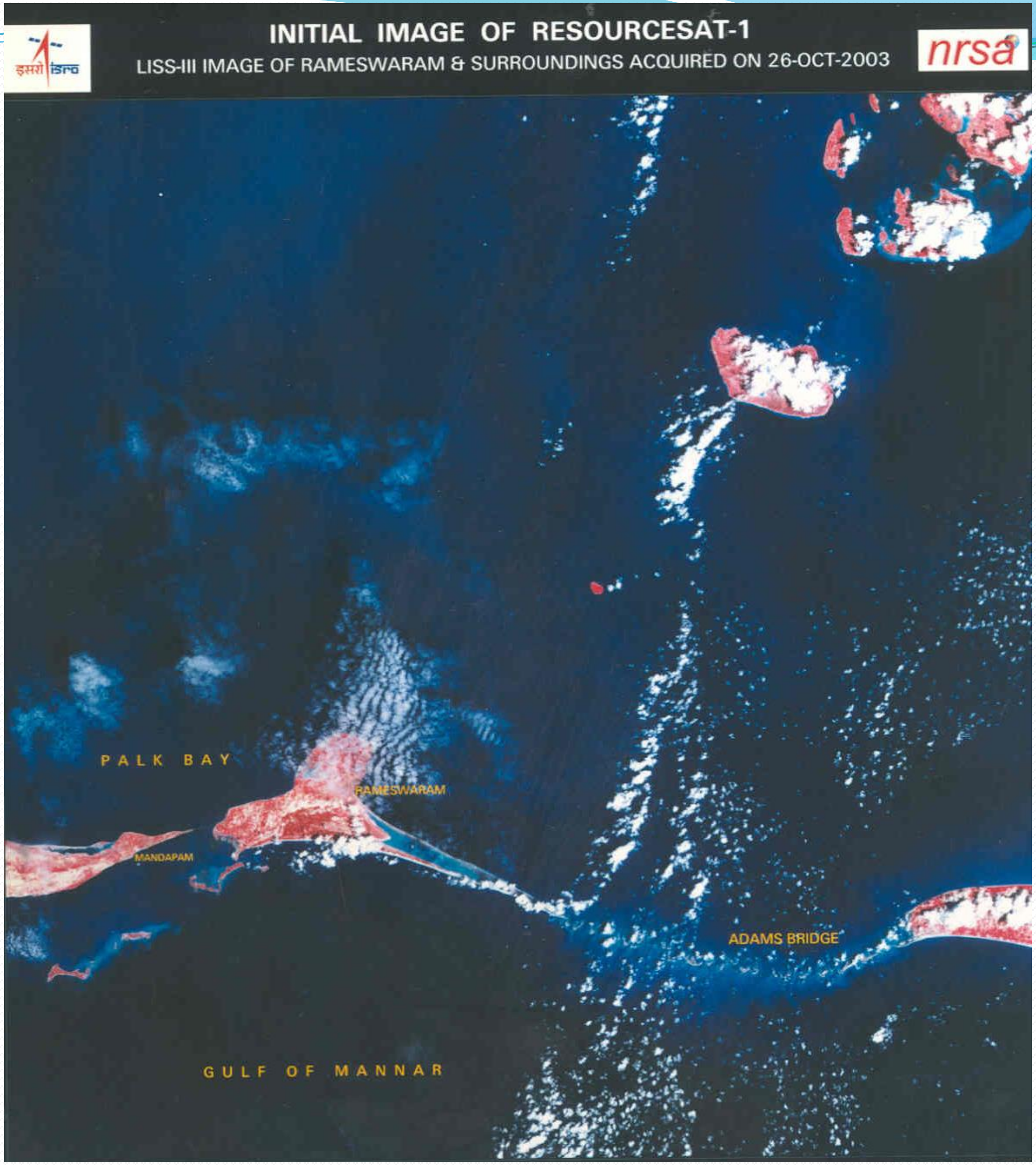
## METEOROLOGICAL SATELLITE

GSAT: Geo Stationary satellites
INSAT: Indian National Satellite system
GOES: Geostationary Operational Environmental Satellites
POES: Polar Operational Environmental Satellites

## HIGH RESOLUTION SATELLITE

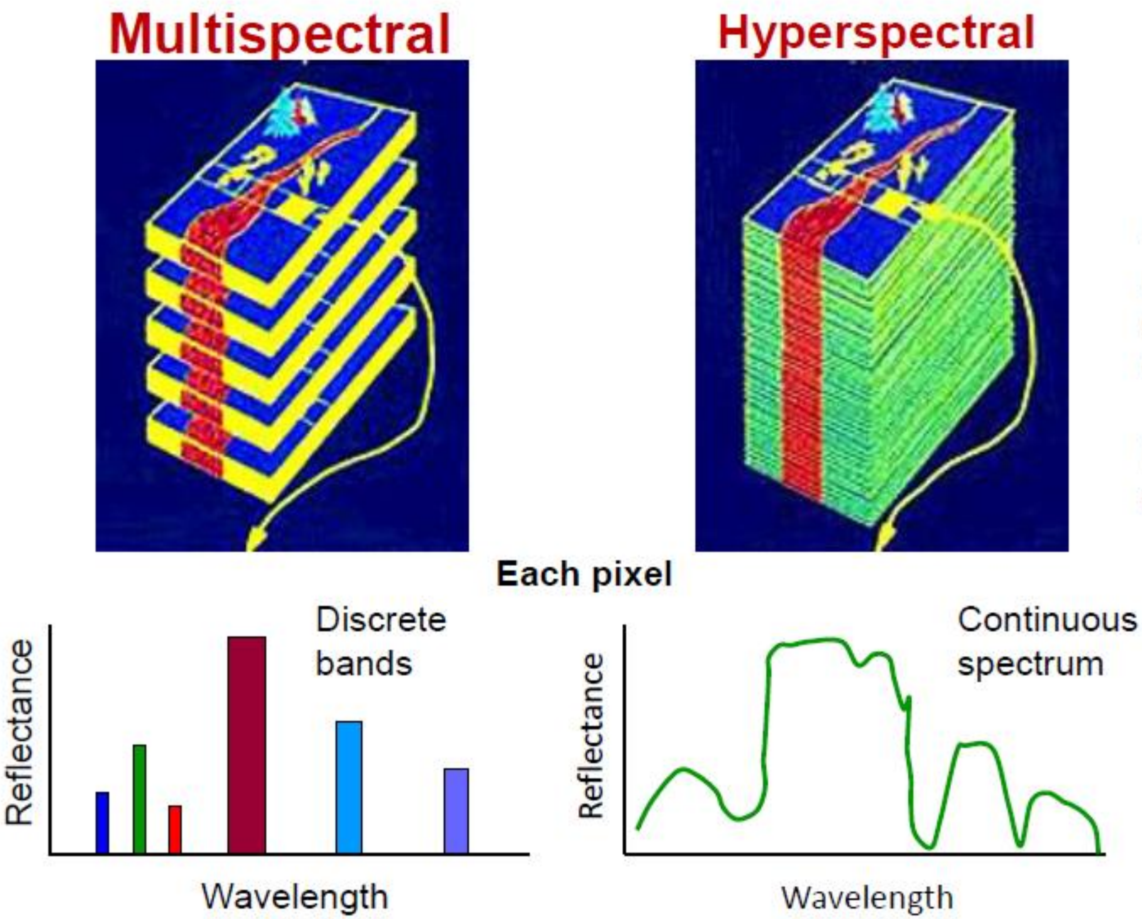
CARTOSAT 2SE and 3
IKONOS
QUICKBIRD
WORLDVIEW
ORBVIEW


FIRST DAY IMAGE OF RESOURCESAT-1
AWiFS IMAGE OF MANASAROVAR & SURROUNDINGS ACQUIRED ON 25 - OCT - 2003
nrsa
MANASAROVAR LAKE
RAKAS LAKE



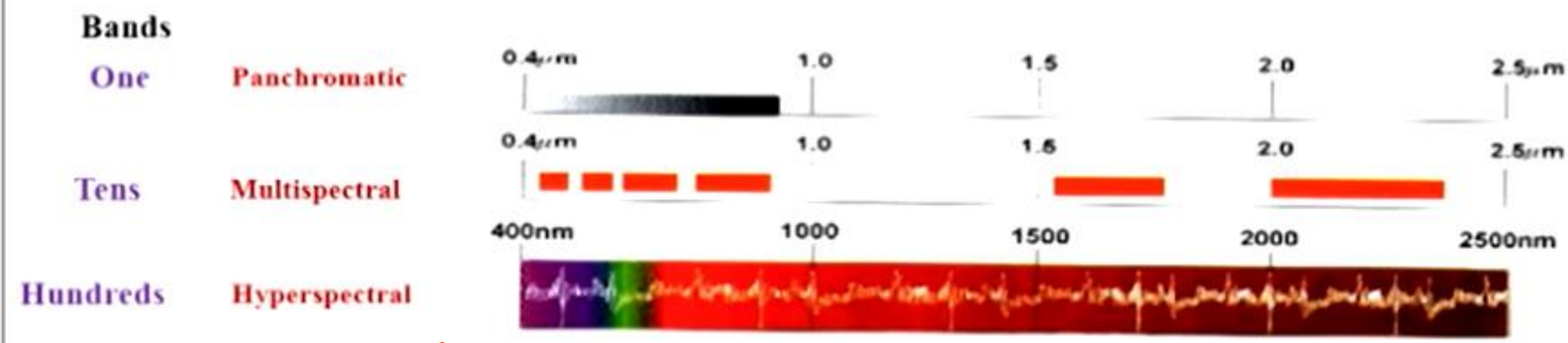
INITIAL IMAGE OF RESOURCESAT-1
LISS-III IMAGE OF RAMESWARAM & SURROUNDINGS ACQUIRED ON 26-OCT-2003
nrsa
PALK BAY
RAMESWARAM
MANDAPAM
ADAMS BRIDGE
GULF OF MANNAR

# Multispectral vs. Hyperspectral




**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**




| Multispectral | Hyperspectral |
|---|---|
| Multispectral instruments can *discriminate* materials. | Hyperspectral imaging is required to actually *identify* 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 mulltispectral sensors | Most current hyperspectral sensors are airborne, hence inaccessible (in the Indian context). |

# Hyperspectral Sensors

| Airborne | Spaceborne |
|---|---|
| ❑ CASI (Canadian technology) | ❑ MODIS |
| ❑ HyMAP (Australian technology) | ❑ MERIS |
| ❑ AVIRIS (American NASA technology) | ❑ Hyperion |
| ❑ HYDICE( US Naval research lab) | ❑ CHRIS |
| ❑ DAIS (European technology) | ❑ HySI |
| ❑ AIMS (Indian technology) | ❑ … |
| ❑ AHySI (Indian technology) | **Ground based** |
| | ❑ Spectro-radiometer |

**ISRO hyperspectral Missions (current & future)**

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

# 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