Application of Remote Sensing and GIS on Environmental Studies (GeES 524)

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Post Graduate programme/2020

Part -1

Principles of Remote Sensing

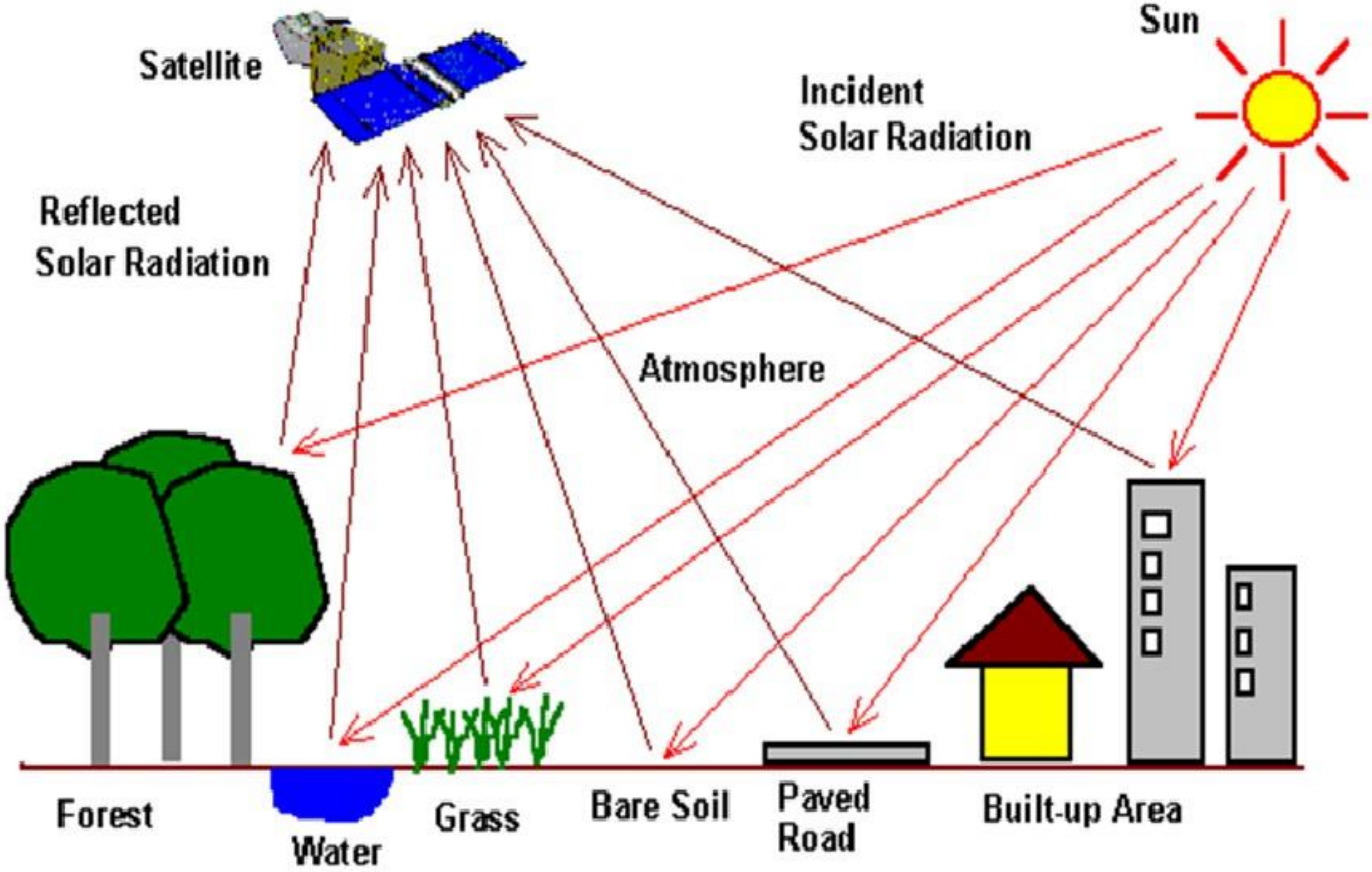
Remote Sensing definition

1. science and art of *obtaining* information about an object, area or phenomenon through the analysis of data acquired by a device that is not in physical contact with the object, area or phenomenon under investigation. (Lillesand & Kiefer, 1999).

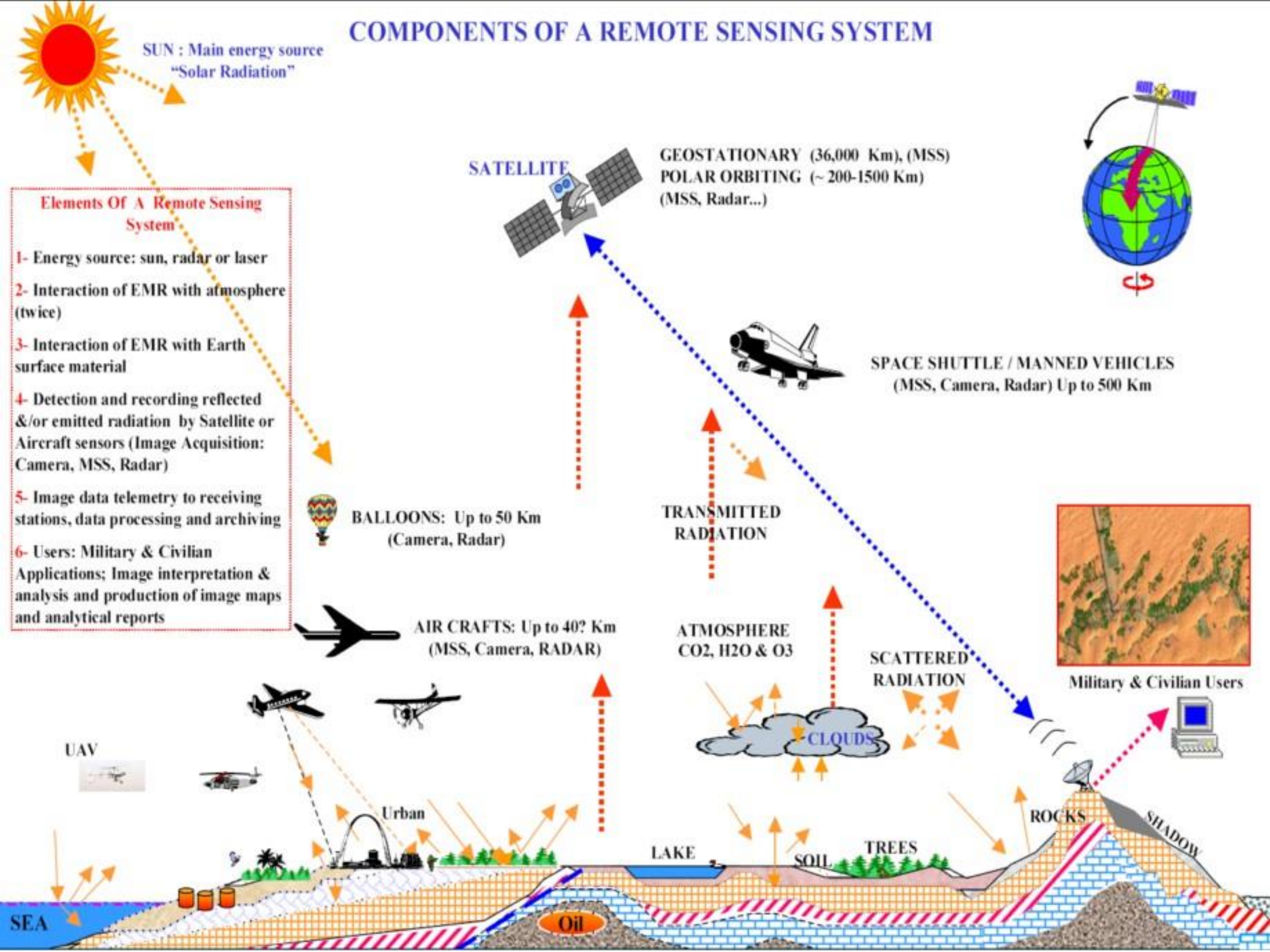
2. "The use of electromagnetic radiation sensors to record images of the environment, which can be interpreted to yield useful information" (Curran, 1985)

If you are reading these texts, you are doing remote sensing

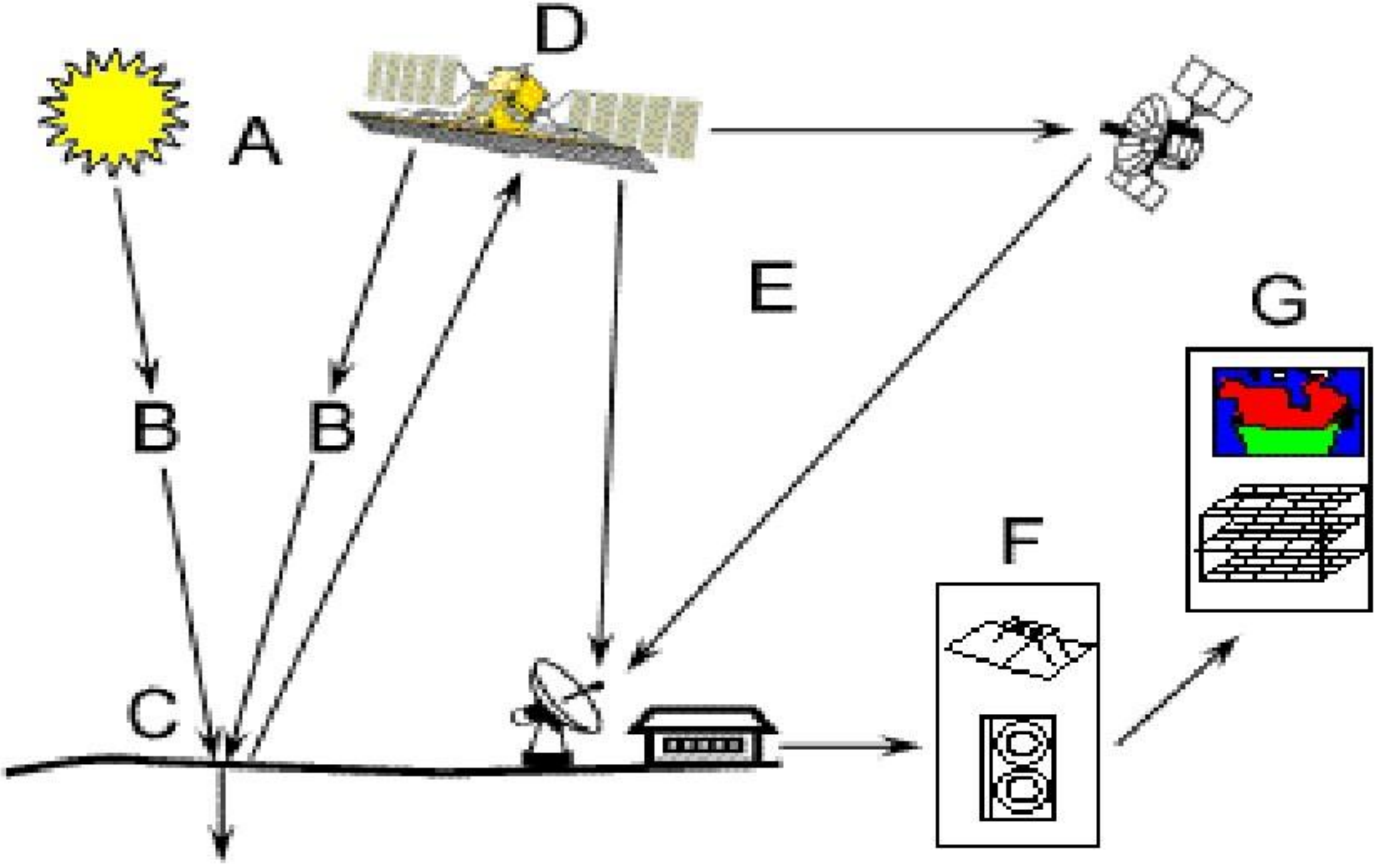
- **the sensor:** your eye responding to the light reflected from the screen
- **the data:** impulses acquired by your eye corresponding to the amount of light reflected from the light and dark areas on the screen
- **the analysis:** your mental computer (brain) interpreting letters, words, and sentences to derive information


Satellite
Sun
Incident
Solar Radiation
Reflected
Solar Radiation
Atmosphere
Forest
Water
Grass
Bare Soil
Paved
Road
Built-up Area

COMPONENTS OF A REMOTE SENSING SYSTEM



Basic processes of remote sensing



- **Energy Source or Illumination (A)** - the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

- **Radiation and the Atmosphere (B)** - as the energy travels from its source to the target interacts with the atmosphere it passes through.

  This interaction may take place a second time as the energy travels from the target to the sensor.

- **Interaction with the Target (C)** - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
- **Recording of Energy by the Sensor (D)** - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

- **Transmission, Reception, and Processing (E)** - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

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

- **Application (G)** - 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.

Process of remote sensing data analysis

1. Visual interpretation of digital data using computer software (e.g. Erdas) and stereoscopes.
2. Using image enhancement techniques.
3. Generation of maps, tables, computer files for further decision making using GIS
4. Presentation to the users

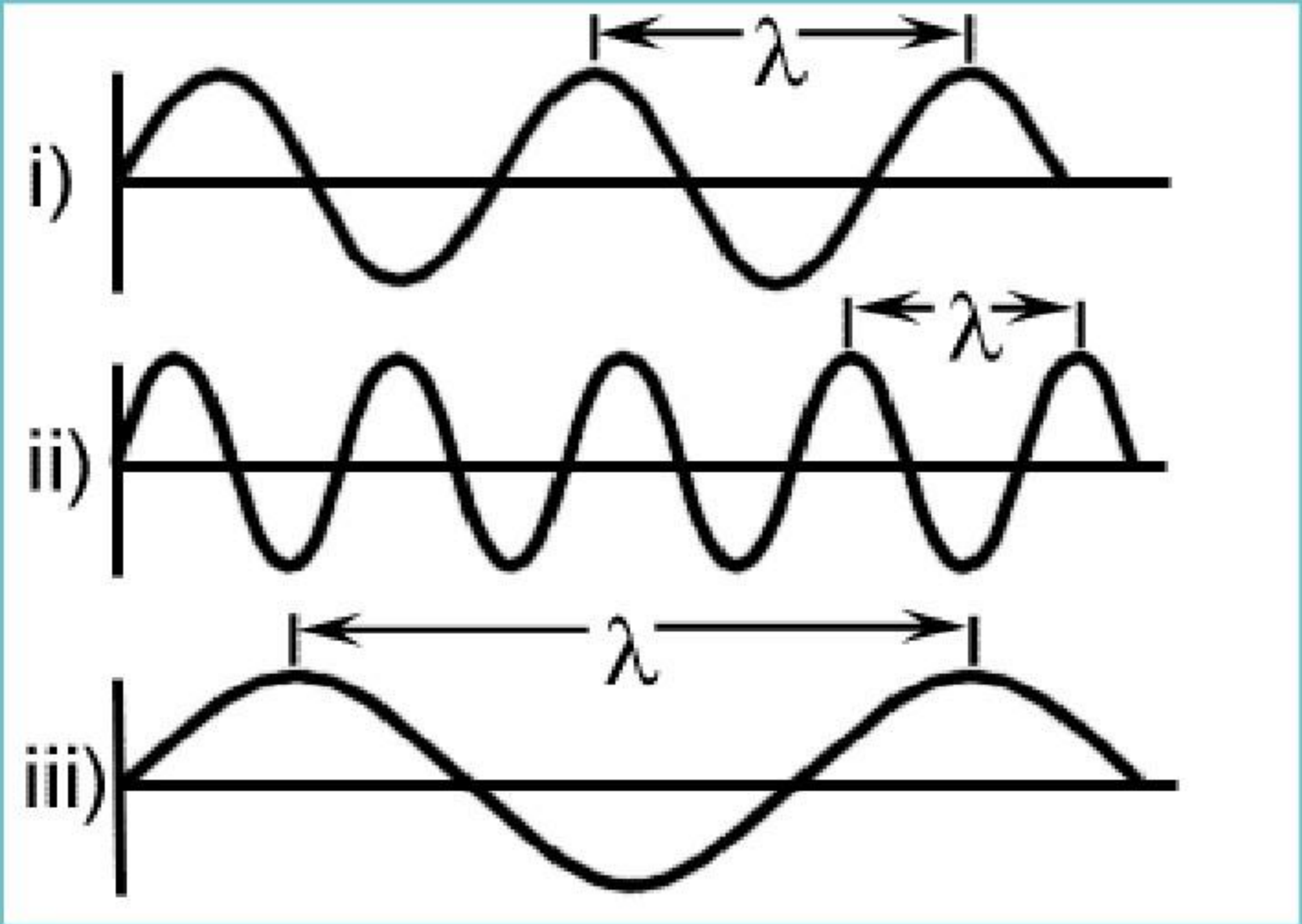
ENERGY SOURCES :

Electromagnetic radiation

EMR: Wavelength and Frequency

- Wavelength is measured in metres (m) or some factor of metres such as:
  - nanometres (nm, 10^{-9} metres),
  - micrometers (mm, 10^{-6} metres) or
  - centimetres (cm, 10^{-2} metres).
- Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in hertz (Hz), equivalent to one cycle per second, and various multiples of hertz.

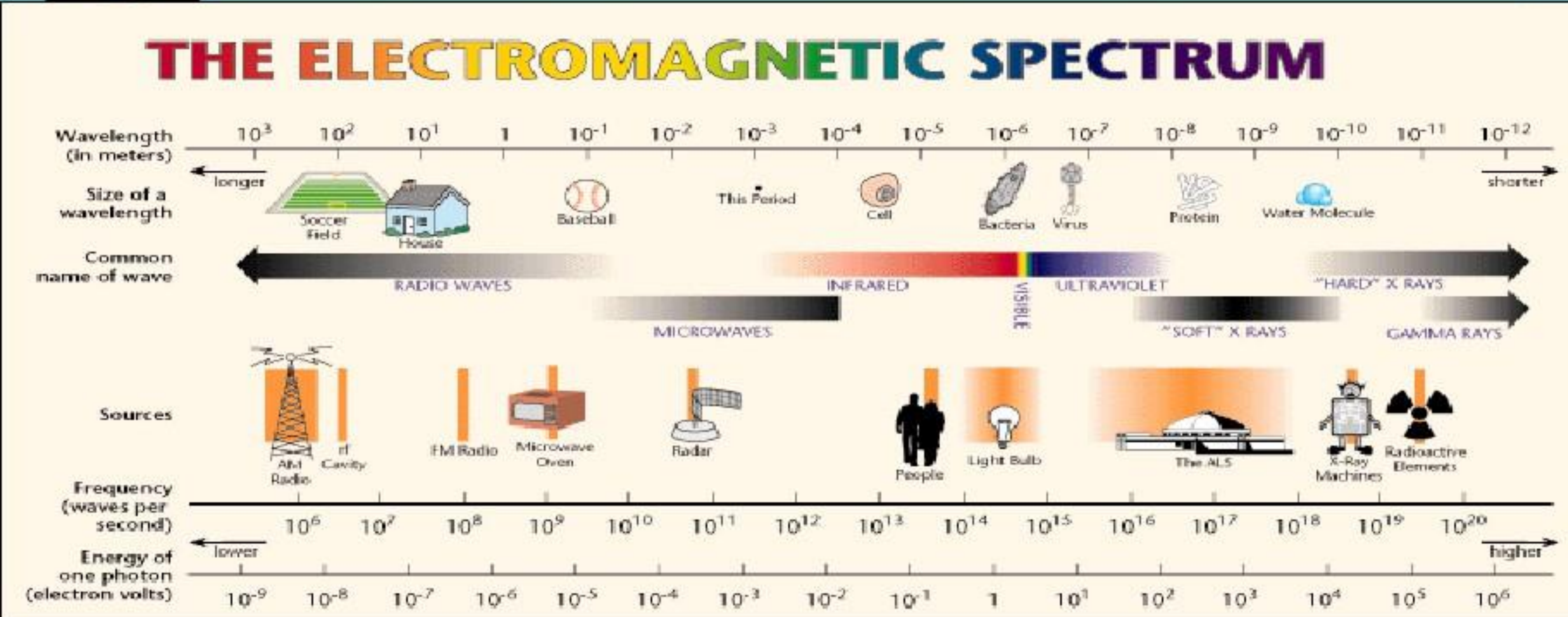
Wavelength and Frequency cont'd

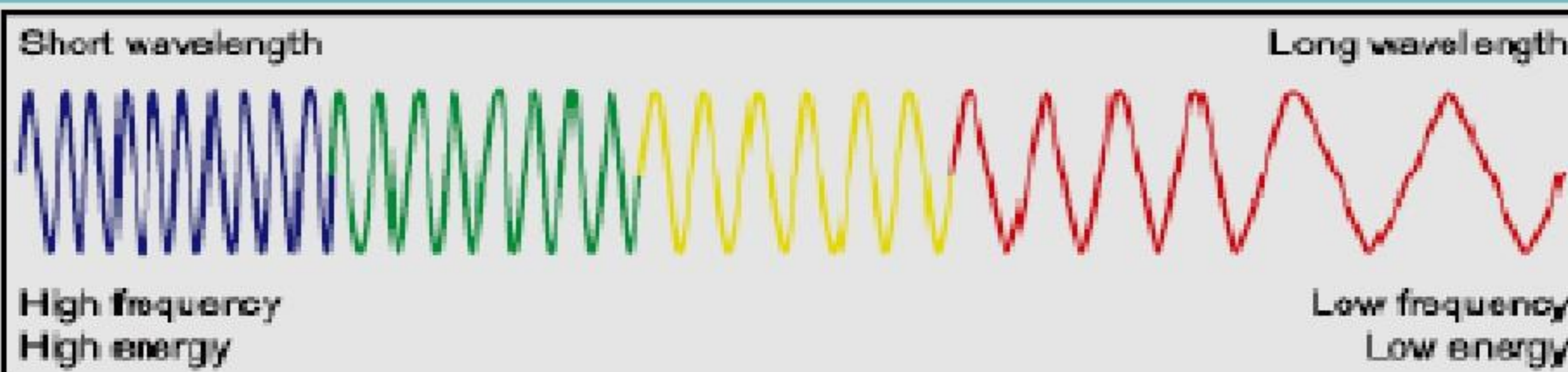


Electromagnetic Spectrum

Electromagnetic Spectrum

- The electromagnetic spectrum ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio/TV waves).
- There are several regions of the EM spectrum which are useful for remote sensing.

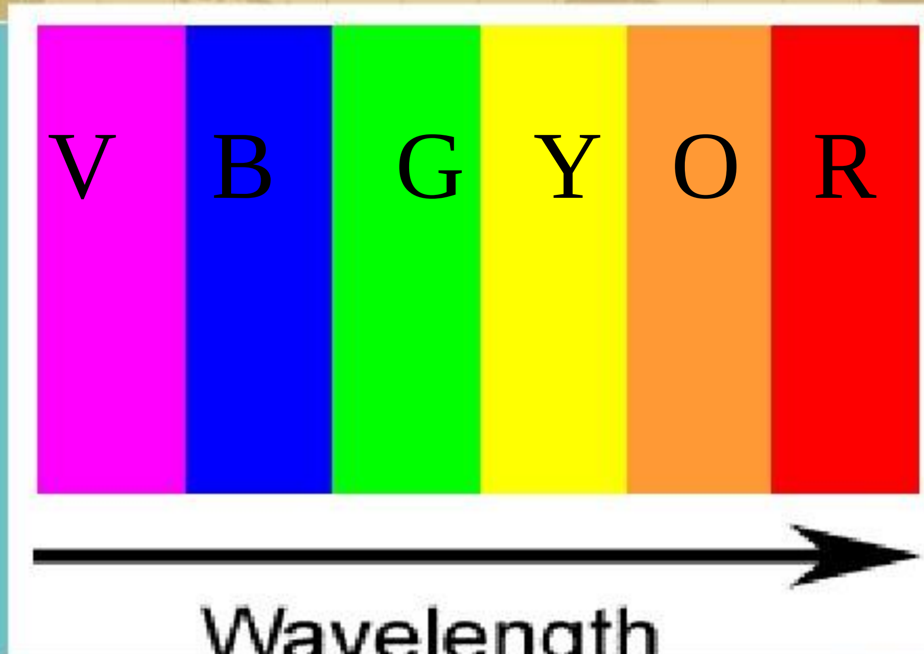

THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^{3} 10^{2} 10^{1} 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12}
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}
lower
higher
Energy of one photon (electron volts)
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6}


Short wavelength
Long wavelength
High frequency
High energy
Low frequency
Low energy

Visible Spectrum

- The light which our eyes (our remote sensors) can detect is part of the visible spectrum.
- It is important to recognise that the range of visible portion is very small (narrow) as compared 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.
- It is important to note that this is the only portion of the EM spectrum we human beings can associate with the concept of colours.


V B G Y O R
Wavelength

VIOLET: 0.400 - 0.446 Pm

BLUE: 0.446 - 0.500 Pm

GREEN: 0.500 - 0.578 Pm

YELLOW: 0.578 - 0.592 Pm

ORANGE: 0.592 - 0.620 Pm

RED: 0.620 - 0.700 Pm

- Blue, green, and red are the primary colours or wavelengths of the visible spectrum.
- They are basic colours because all other colours can be formed by combining blue, green, and red in various proportions (reflection).
- Although we see sunlight as a uniform or homogeneous colour, it is actually composed of various wavelengths and frequencies.
- The visible portion of this radiation can be shown when sunlight is passed through a glass prism

Infrared(IR)Region

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

Reflected and Thermal IR

- Radiation in the reflected IR region is used for remote sensing purposes in similar manner with 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 Region

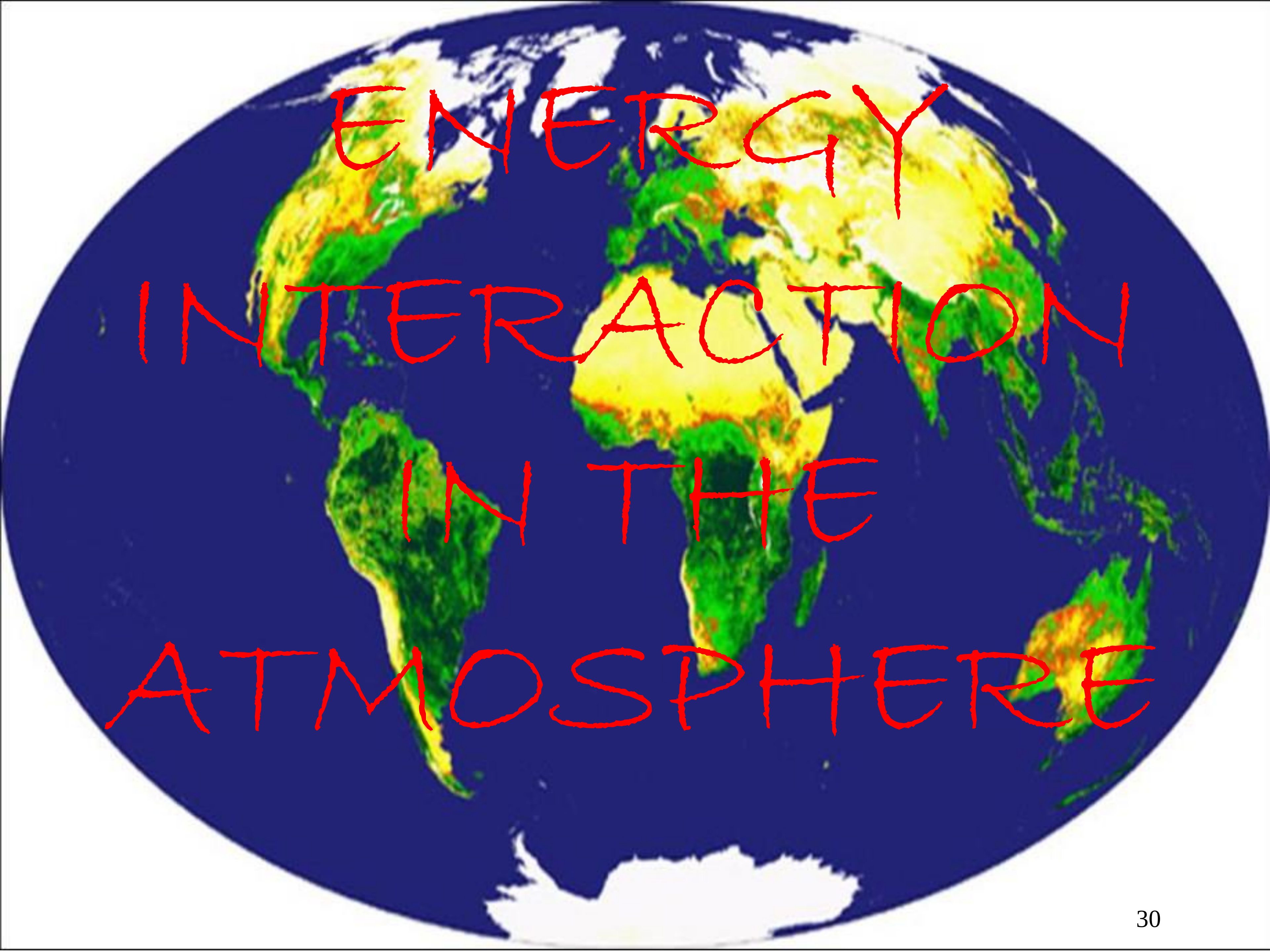
- This portion of the spectrum is becoming more important in recent years, which ranges between 1 mm to 1 m.
- This covers the longest wavelengths (in range) used for remote sensing.
- The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts.

Radiation Emission

Emission of Radiation from Energy Sources

- Each emitted energy has similar characteristic with array of incoming radiation waves.
- A useful concept (reference), which is widely used in optics-study is a **blackbody**.
- A blackbody is defined as an object that absorbs all of the incident energy upon it, and emits the maximum amount of radiation at all wavelengths.
- Thus, emission (emitted energy) of natural surfaces is always compared with those of a black-body: often serve as reference to measure efficiency of others.

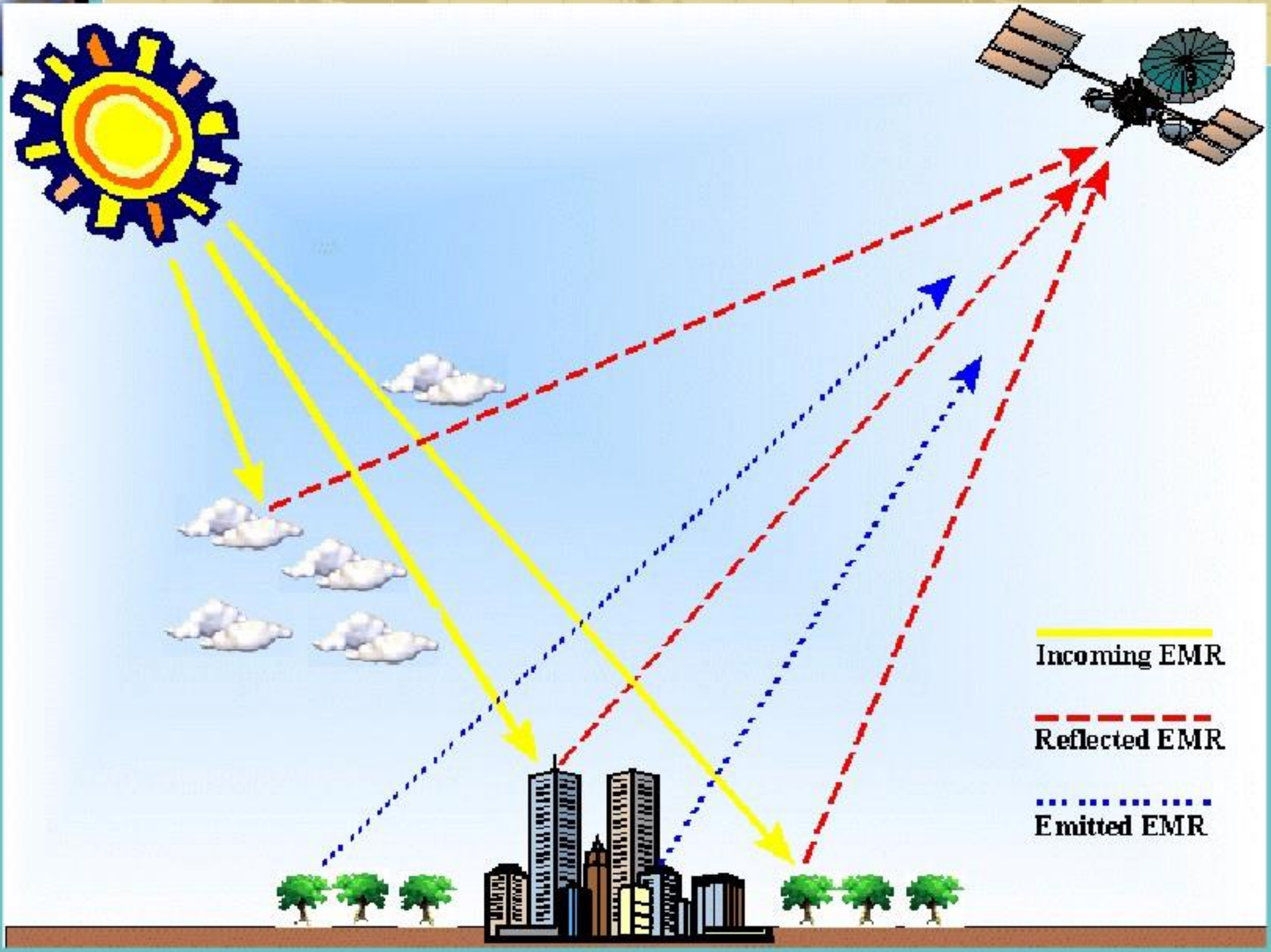
ENERGY INTERACTION IN THE ATMOSPHERE



Energy Interaction in the Atmosphere

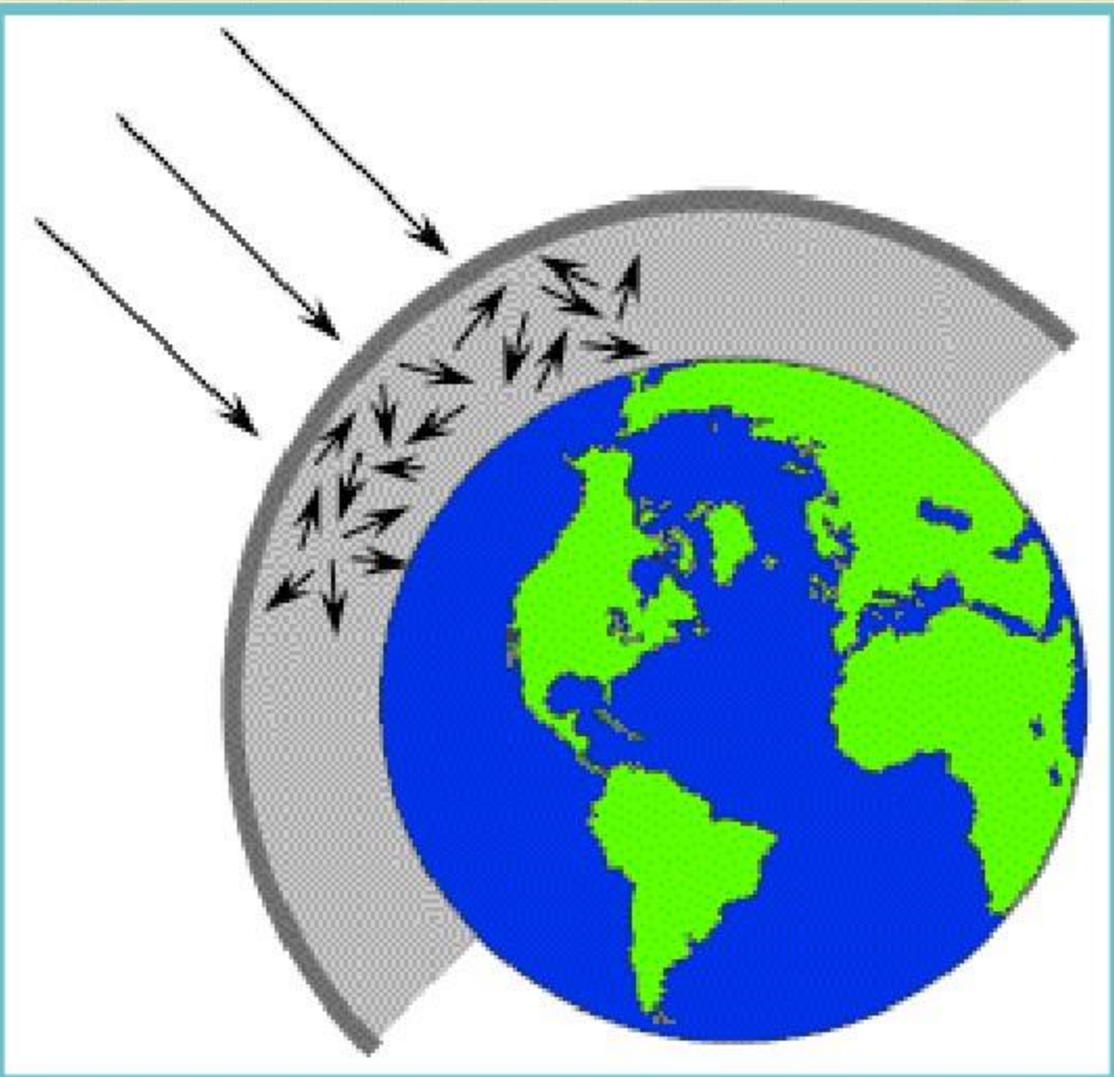
- All radiation detected by remote sensors passes through atmosphere.
- The net effect of the atmosphere varies with:
  - Differences in path length (e.g. scatter and diffraction)
  - Magnitude of the energy signal that is being sensed (e.g. blurred effects)
  - Atmospheric conditions present
  - The wavelengths involved.

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


Incoming EMR
Reflected EMR
Emitted EMR

Atmospheric Scattering

- Atmospheric scattering is the unpredictable diffusion of radiation by particles in the atmosphere.
- Three types of scattering can be distinguished, depending on the relationship between the diameter of the scattering particle (**a**) and the wavelength of the radiation (□).



Scattering of EM energy by the atmosphere

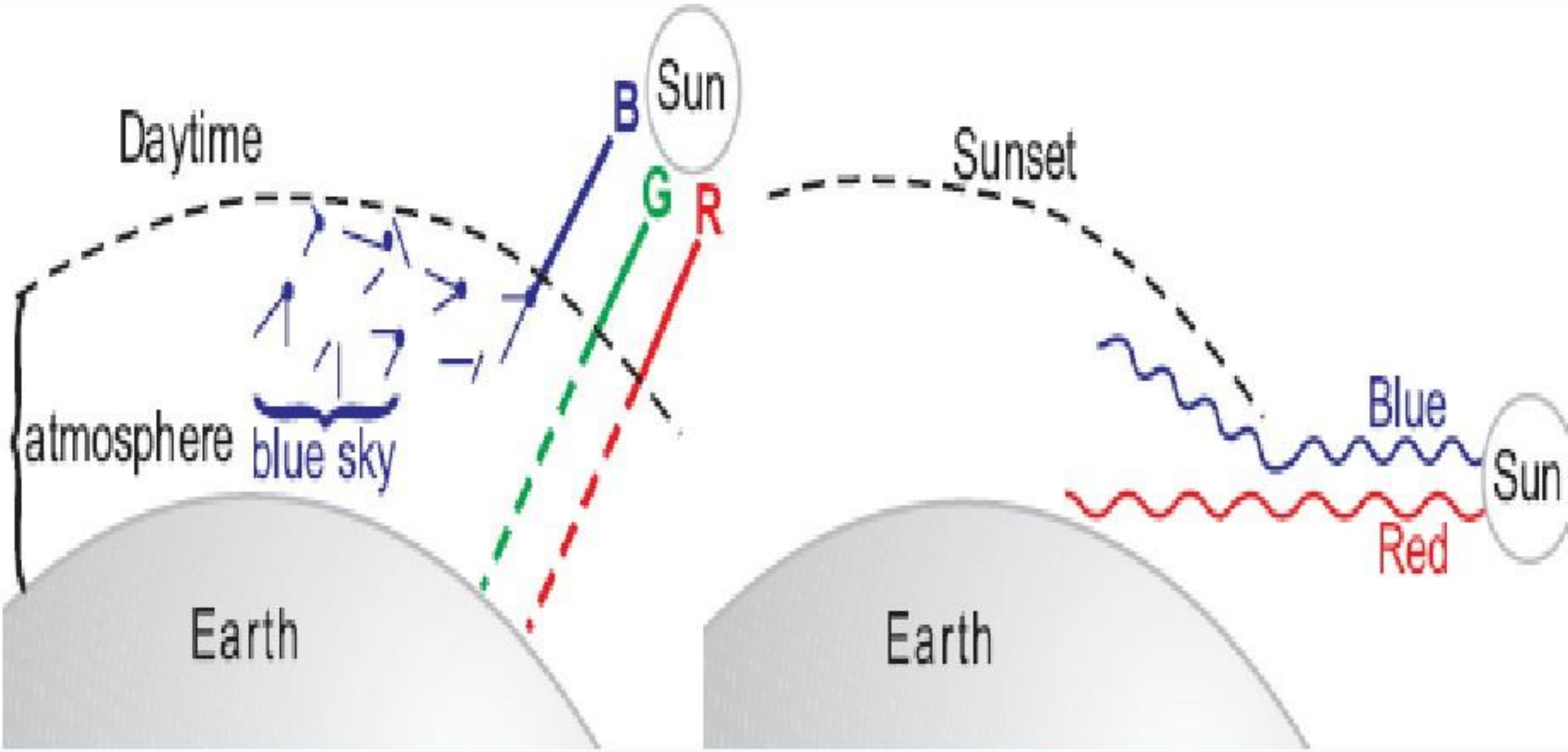
1. Selective scattering

a. Rayleigh Scattering

a < □

- Rayleigh scatter is common when radiation interacts with atmospheric molecules (gas molecules) and other tiny particles (aerosols) that are much smaller in diameter than the wavelength of the interacting radiation.
- The effect of Rayleigh scatter is inversely proportional to the fourth power of the wavelength.
- short wavelengths are more likely to be scattered than long wavelengths.
- Rayleigh scatter is one of the principal causes of haze in imagery.

Rayleigh scattering causes us to perceive a blue sky during daytime and a red sky at sunset.



b. Mie Scattering

a <=> □

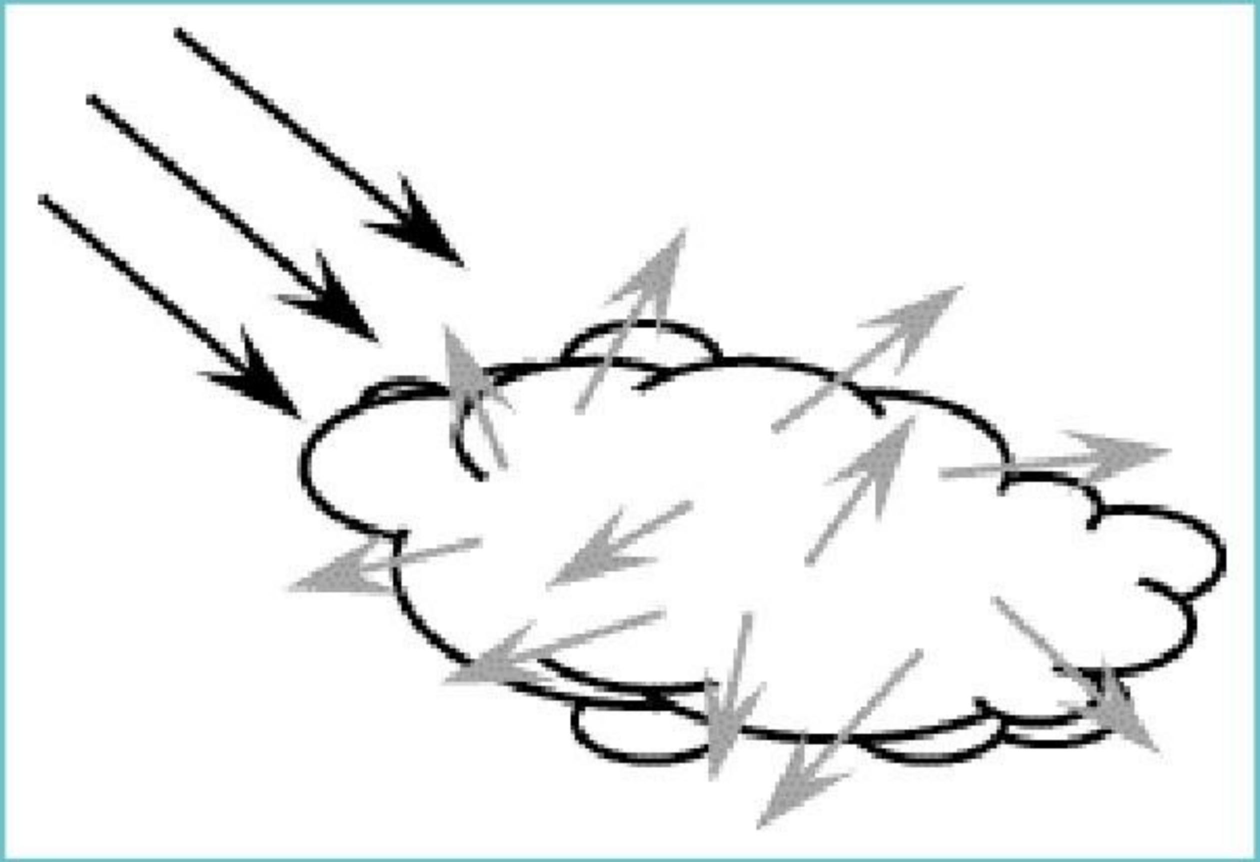
- Mie scatter exists when the atmospheric particle diameter is essentially equal to the energy wavelengths being sensed.
- Water vapour and dust particles are major causes of Mie scatter. This type of scatter tends to influence longer wavelengths than Rayleigh scatter.
- Although Rayleigh scatter tends to dominate in most atmospheric conditions, Mie scatter is also very significant.

2. Non-selective scatter

a > □

- Non-selective scatter is more of a problem, and occurs when the diameter of the particles causing scatter are much larger than the wavelengths being sensed.
- Water droplets, that commonly have diameters of between 5 and 100mm, can cause such scatter, and can affect all visible and near - to - mid-IR wavelengths equally.
- Consequently, this scattering is “non-selective” with respect to wavelength. In the visible wavelengths, equal quantities of blue green and red light are scattered.

Non-selective scatter cont’d

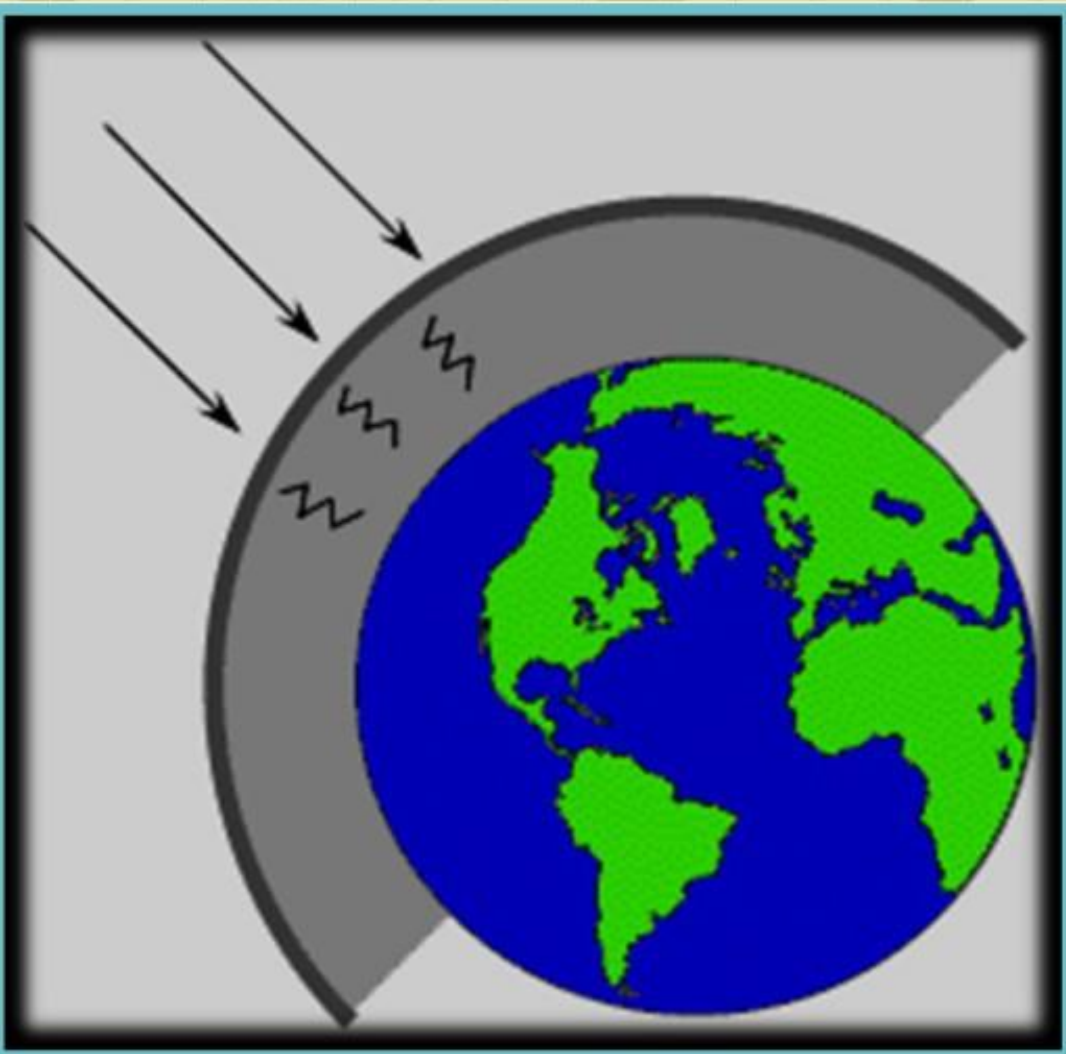


Non-Selective scatter of EM radiation by a cloud

Atmospheric Absorption

- In contrast to scatter, atmospheric absorption results effective loss of energy to atmospheric constituents (elements).
- This normally involves absorption of energy at a given wavelength.
- The most efficient absorbers of solar radiation are:
  - Water Vapour
  - Carbon Dioxide
  - Ozone

Atmospheric Absorption cont'd



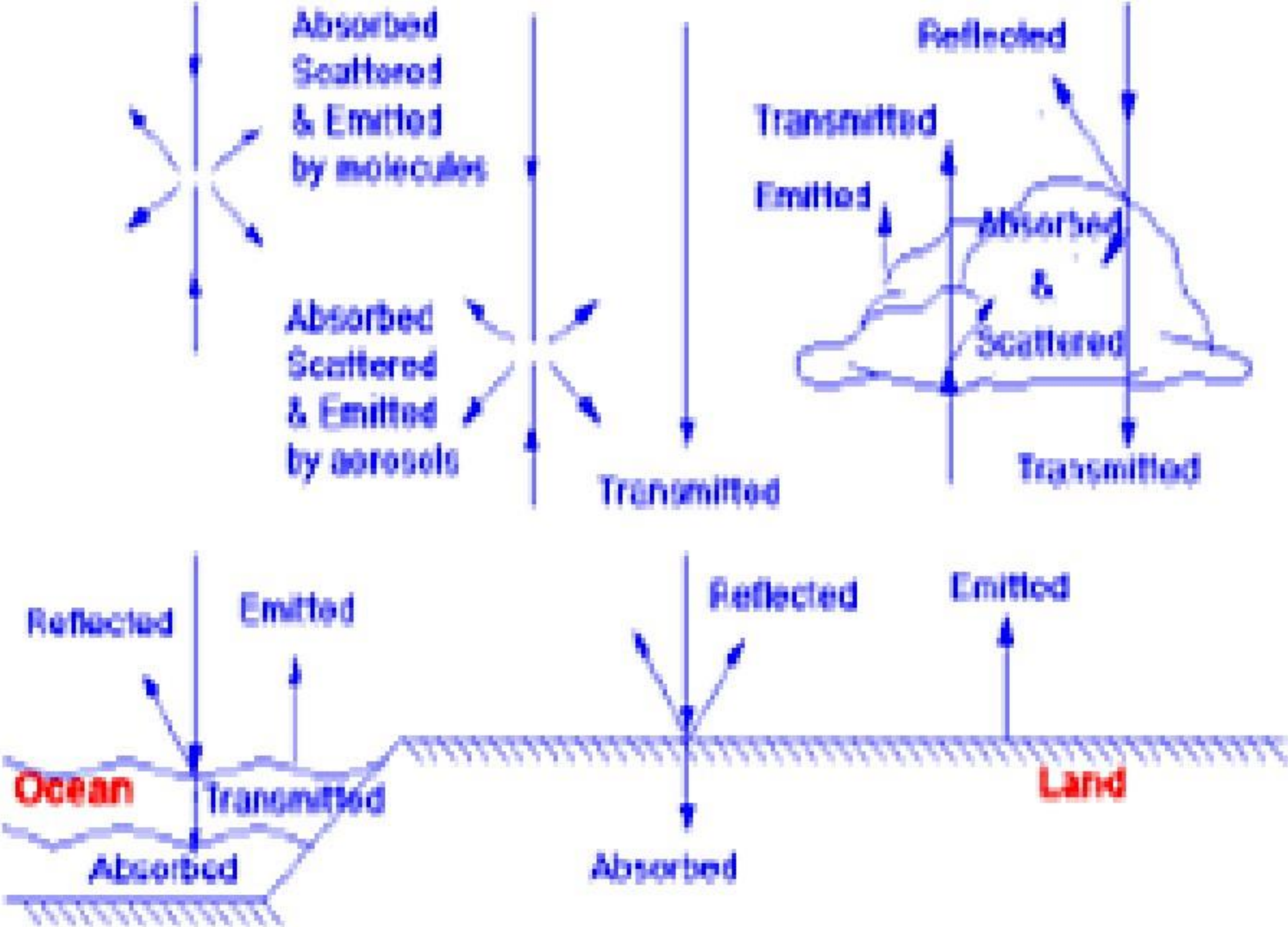
Absorption of EM energy by the atmosphere

Part 2:

Energy Interactions with Earth Surface Features

When Electromagnetic energy is incident on any given earth surface feature, three fundamental energy interactions with the feature are possible:

- **Reflection**
- **Absorption**
- **Transmission**


Absorbed
Scattered
& Emitted
by molecules
Absorbed
Scattered
& Emitted
by aerosols
Transmitted
Reflected
Transmitted
Emitted
Absorbed
&
Scattered
Transmitted
Reflected
Emitted
Ocean
Transmitted
Absorbed
Reflected
Emitted
Absorbed
Land

Energy Interactions cont'd

The relationship between these three energy interactions :

$$E_i(\square) = E_r(\square) + E_a(\square) + E_t(\square)$$

E_i	=	**Incident energy**
E_r	=	**Reflected energy**
E_a	=	**Absorbed energy**
E_t	=	**Transmitted energy**

Energy reflection

- The proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending on their material type and condition.
- These differences help us to distinguish different features on an image.
- The geometric manner and surface roughness are important factor that affect surface reflectio[redacted]

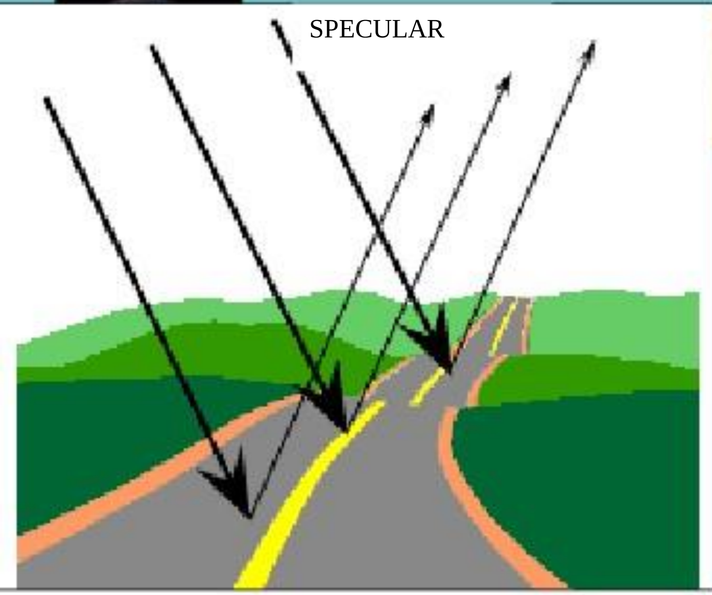
Types of reflection:

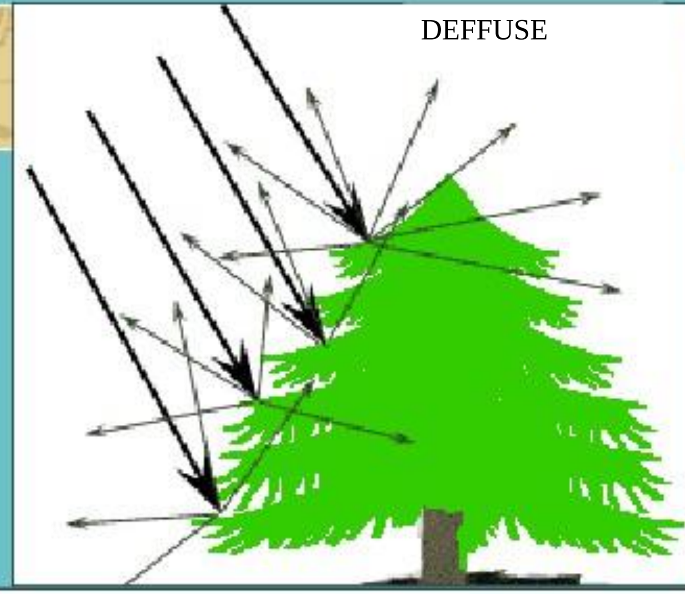
1. Specular reflection

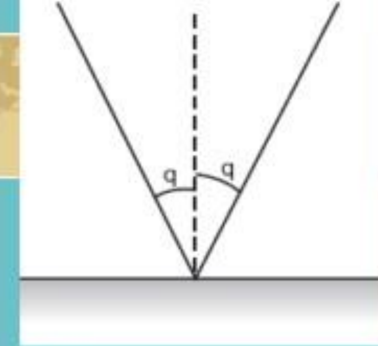
- it is a mirror-like reflection, typically occurs when a surface is smooth and all (or almost all) of the energy is directed away from the surface in a single direction.
- a water surface or a glasshouse roof reflects in a Specular manner.
- results in a very bright spot (also called „hot spot“) in the image.

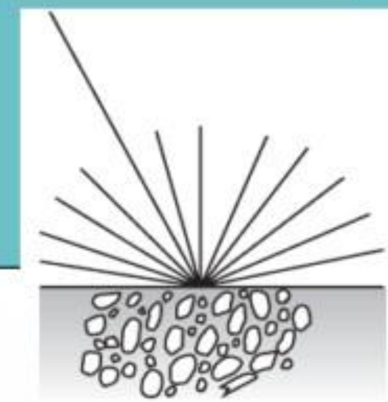
2. Diffuse reflection

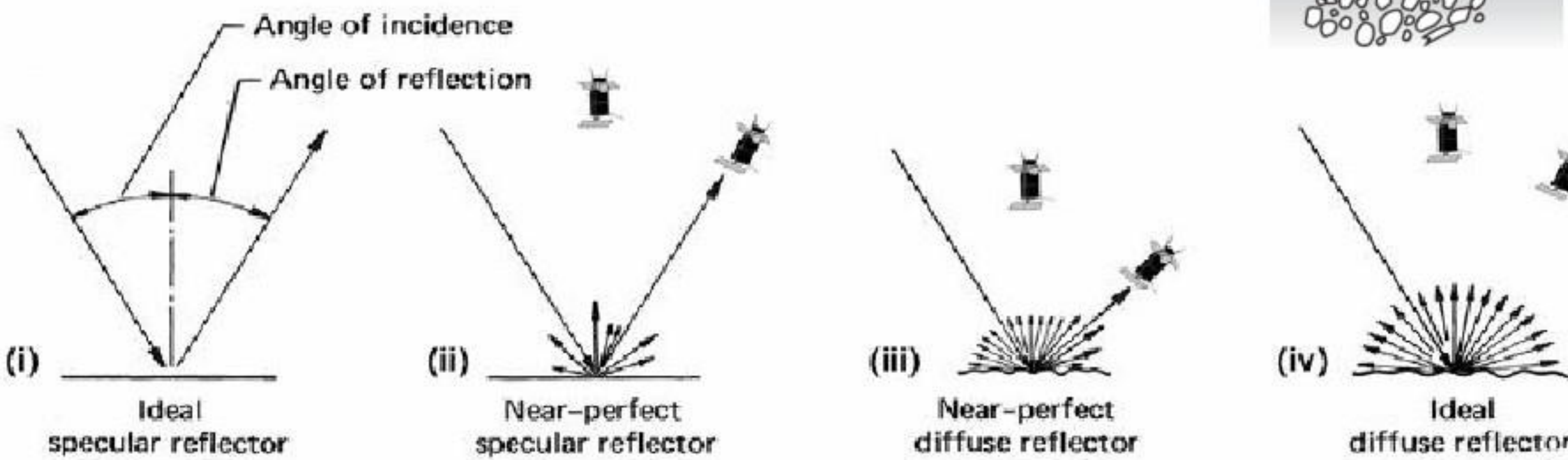
- Occurs when the surface is rough and the energy is reflected almost uniformly in all directions.
- Most earth surfaces are neither perfectly Specular nor diffuse reflectors.
- In short, when the wavelength of incident energy is much smaller than the particle sizes that make up a surface, then it will be diffused.
- Hence, in remote sensing, we are often interested in measuring the diffuse reflectance properties of terrain features.











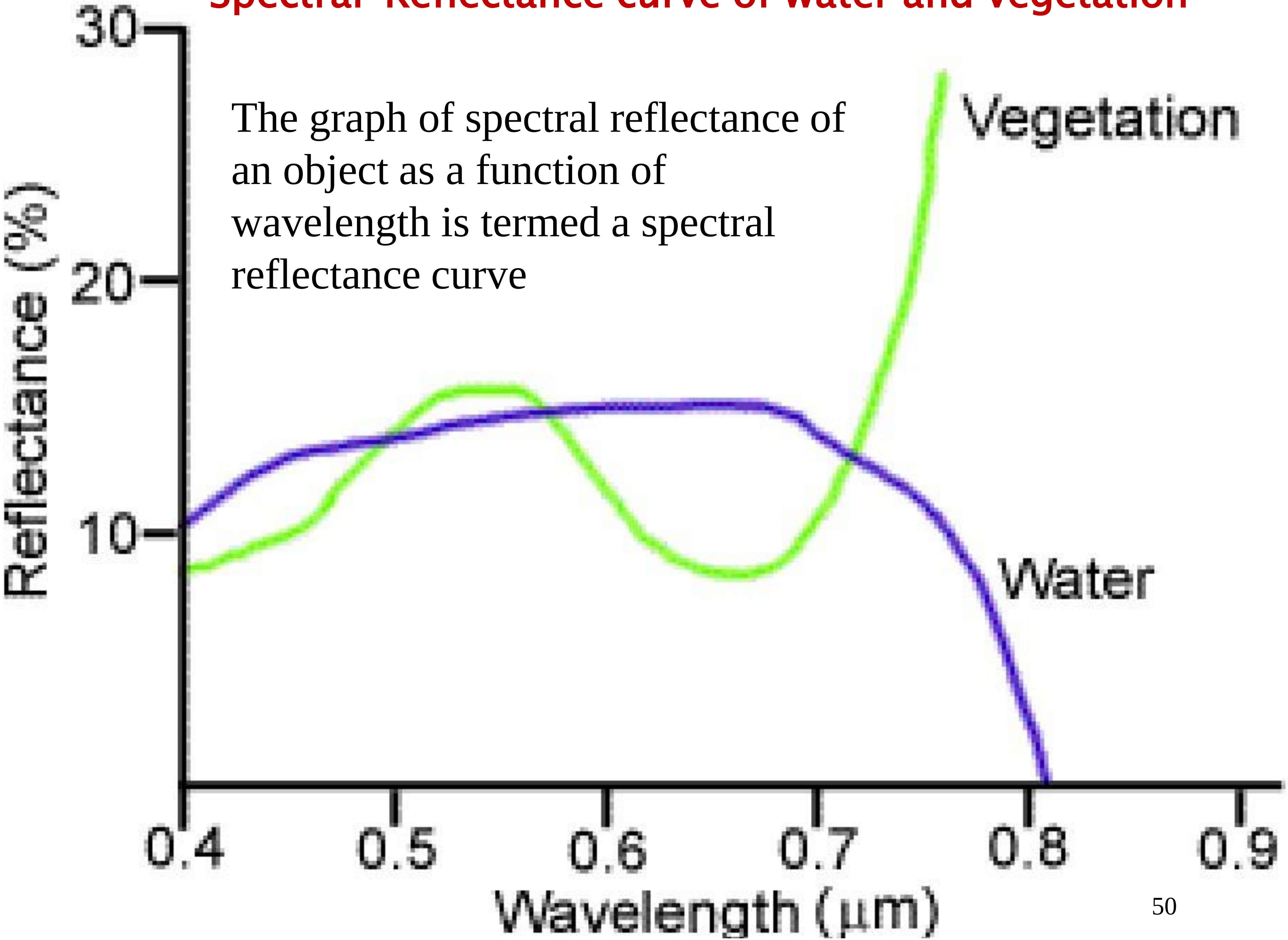
Specular versus diffuse reflectance.

Reflectance of Surfaces

- Most earth surface features lie somewhere between perfectly Specular or perfectly diffuse reflectors.
- It depends on the surface roughness of the feature in comparison to the wavelength of the incoming radiation.
- If the wavelengths are much smaller than the surface variations or the particle sizes, diffuse reflection will dominate.

Spectral Reflectance curve of water and vegetation

The graph of spectral reflectance of an object as a function of wavelength is termed a spectral reflectance curve

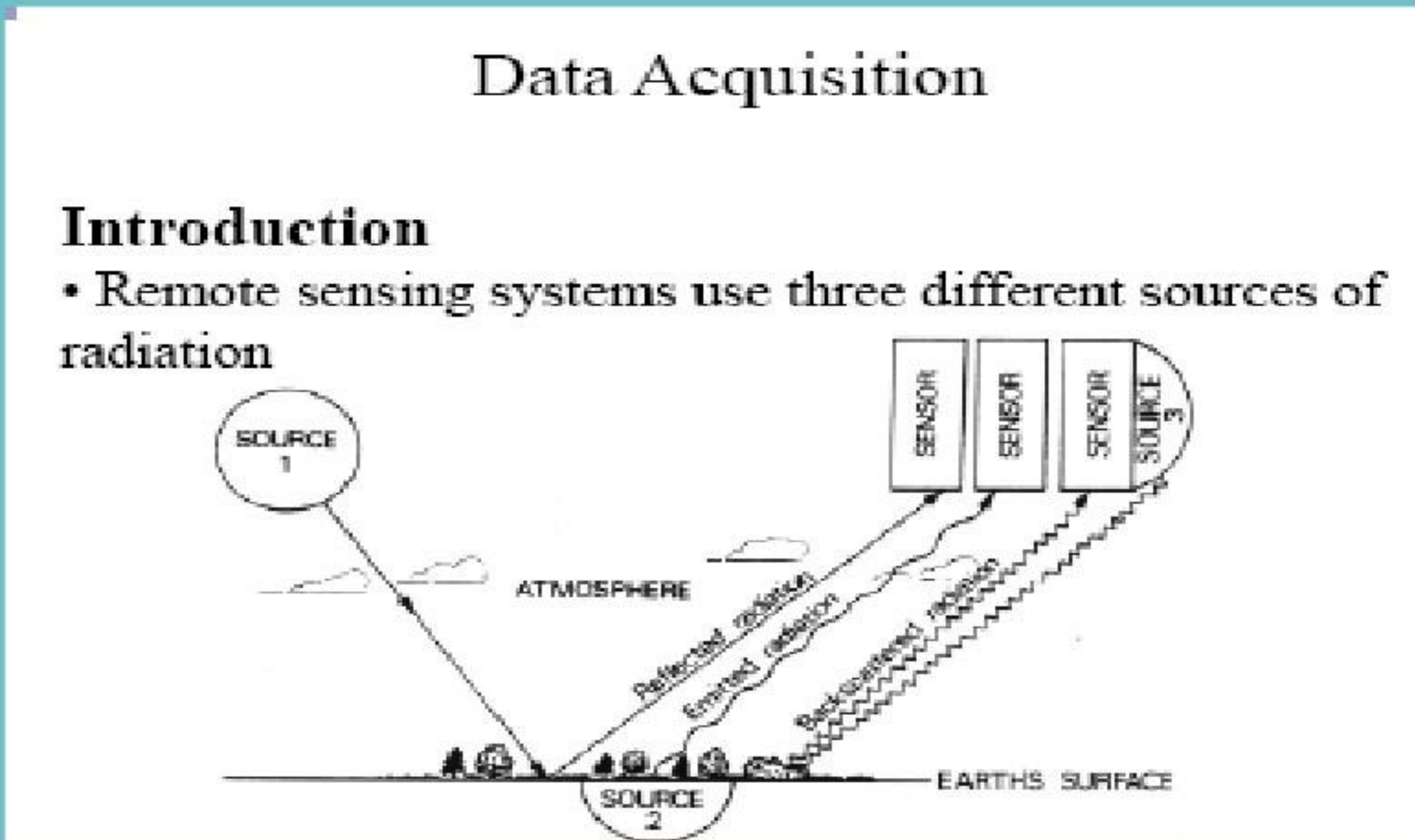


Part 3

DATA ACQUISITION

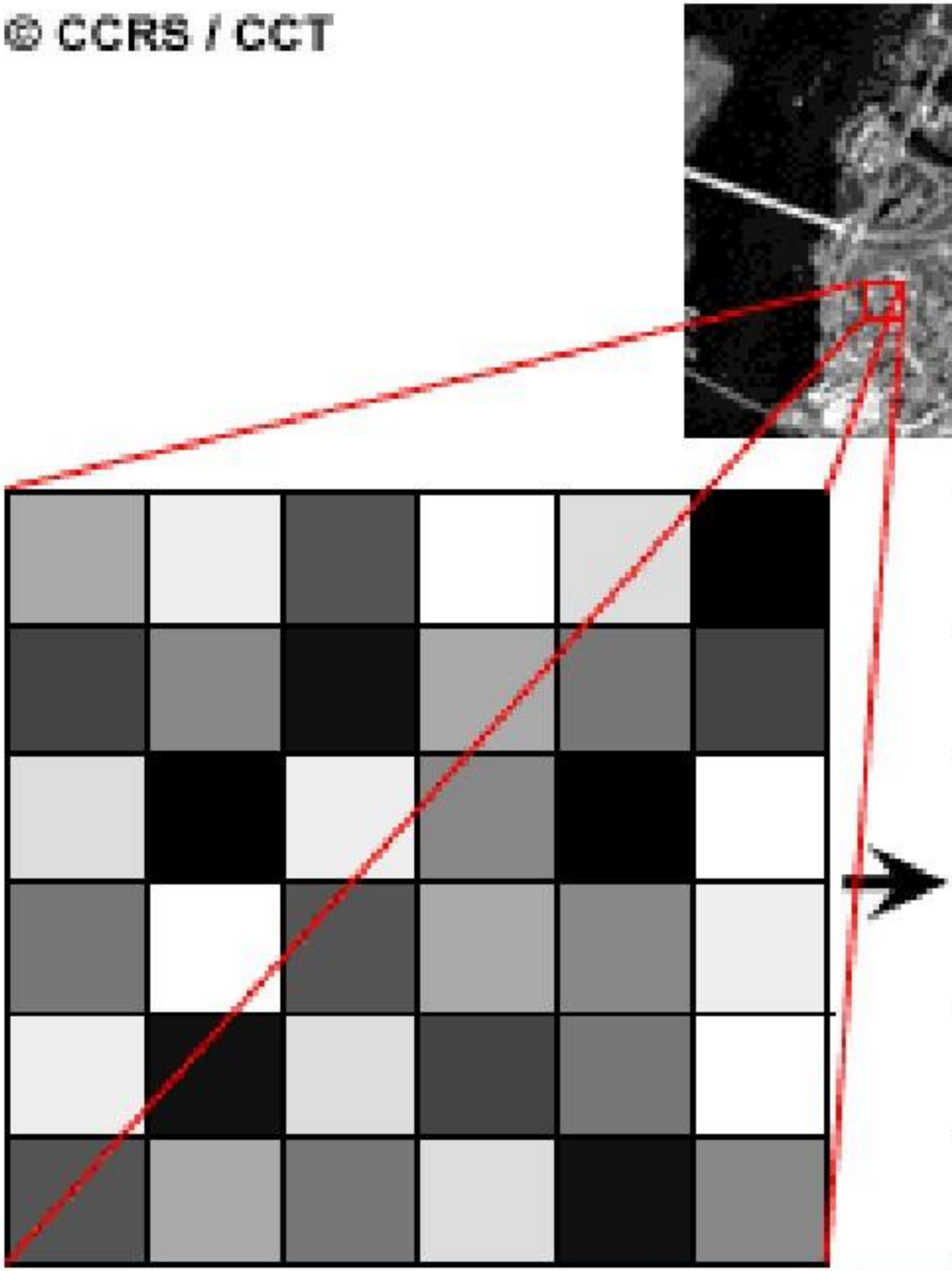
Data acquisition

Remote sensing system uses three different sources of radiations: reflected; emitted; backscattered



Data acquisition cont'd

- The detection of EME can be performed either photographically or digital (electronically).
- Photographic systems have the following advantages over electronic sensors:
- Photographic Advantage:
simple and inexpensive provide high degree of spatial details and geometric integrity
- Electronic sensors advantages:
broader spectral range;
improved calibration potential
ability to users



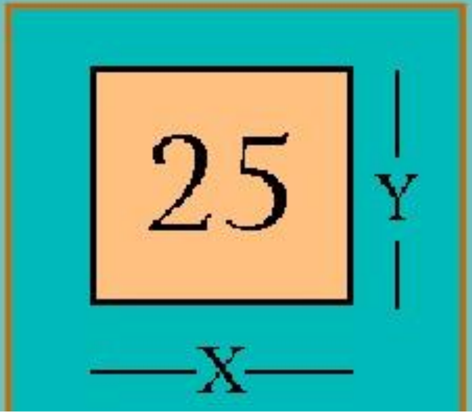
170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Nature of the Image

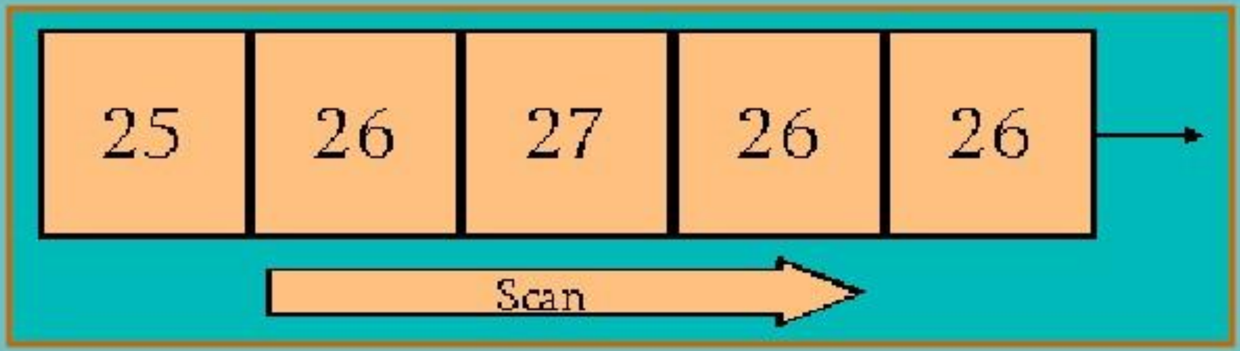
- Spatial Soft-wares are used to analyze and obtain information from images
- Images that we see on a computer screen are made up of picture elements called pixels.

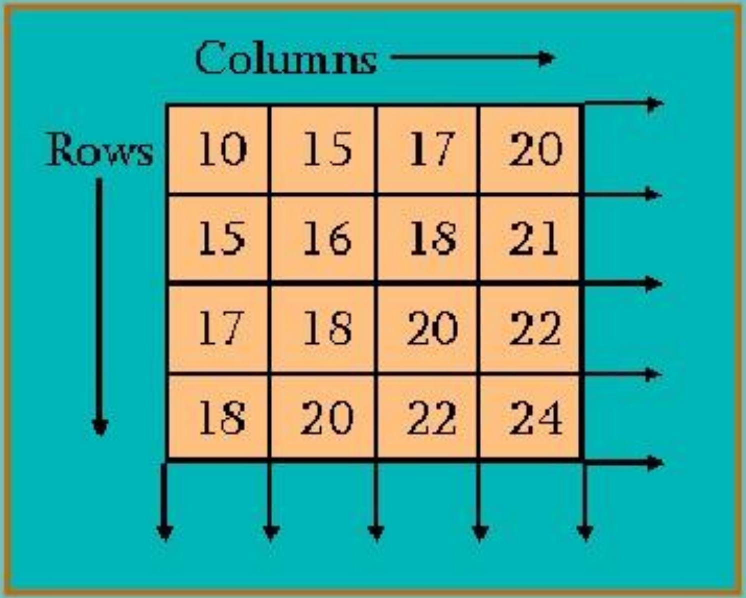
Pixel - picture element having both spatial and spectral properties.

- the spatial property defines their ground height and width.
- the spectral property defines the intensity of spectral response for a cell in a particular band.



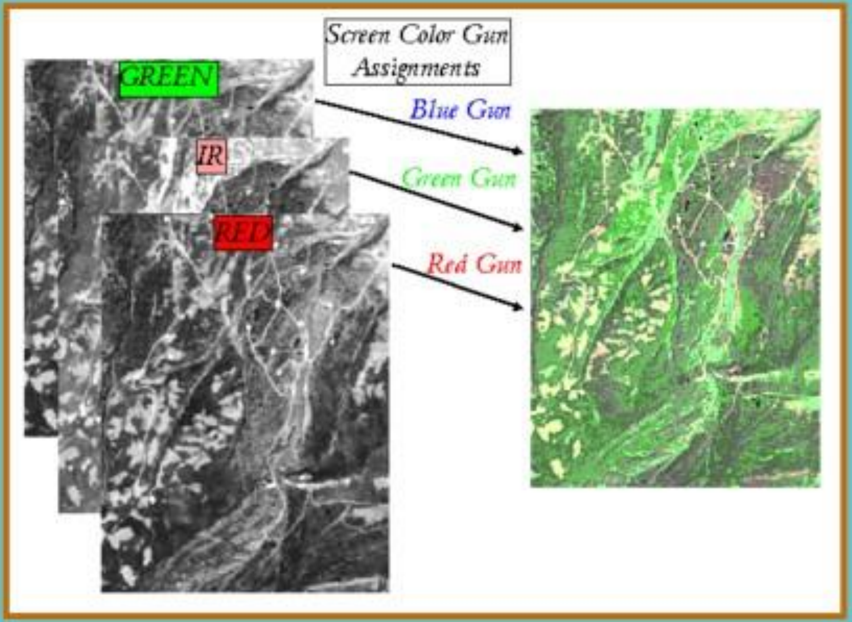
Nature of the Image





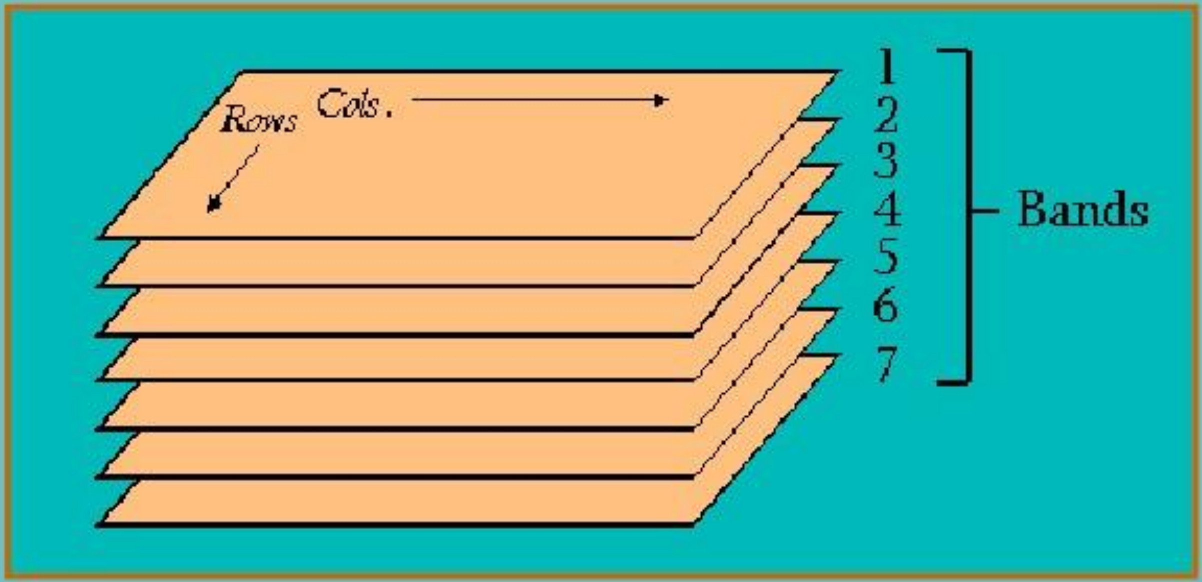
Nature of the Image

- When one band of the EM spectrum is sensed, the output appears grey or black and white.
- Multispectral sensors detect light reflectance in more than one bands of the EM spectrum.
- When these bands are combined they give us color images.



Nature of the Image

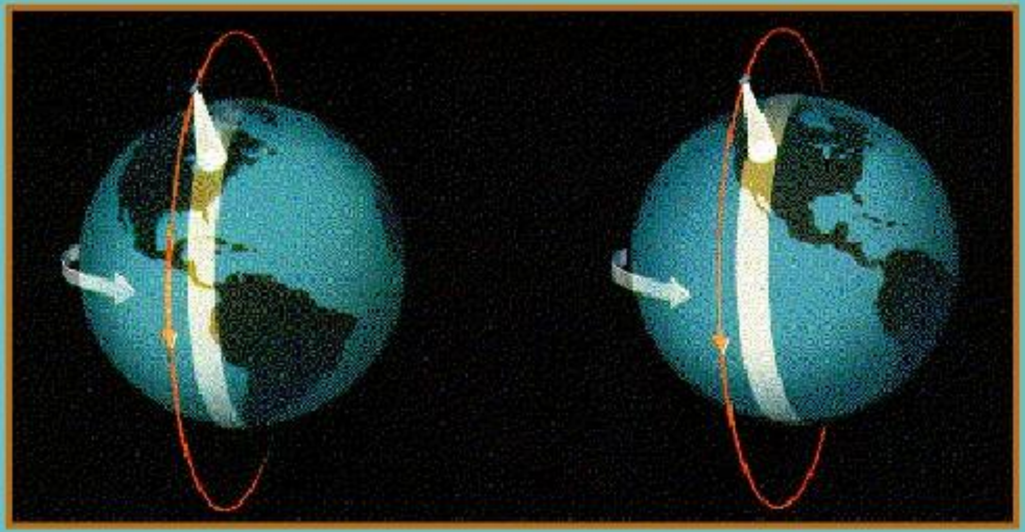
- Band combination: multispectral image is composed of 'n' rows and 'n' columns of pixels in each of three or more spectral bands

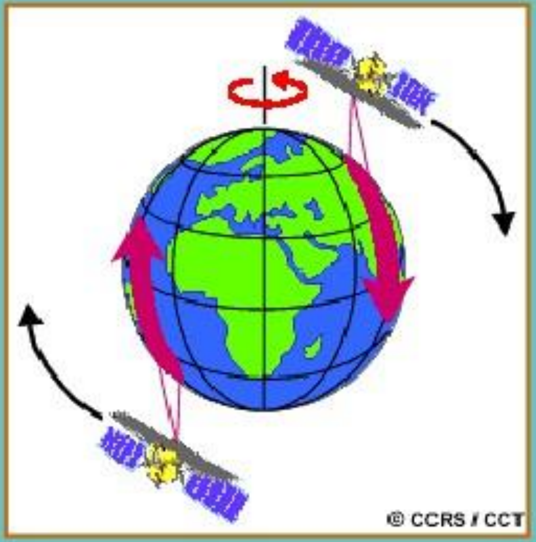


True and False Color Composite

- Combining RGB in order: displays natural color in the image i.e. vegetation in green, water in blue, soil in brown or grey, etc.
- Combining bands randomly: In this case, the target will be displayed in a color different from its actual color; thus, the resulting product is known as a false color composite image.
- These are image enhancement techniques and there are many possibilities of producing false color composite images.

Part 4:
Satellite Remote Sensors





1. Polar-orbiting satellites: moves north to south; position of the satellite"s orbital plane is kept constant relative to the sun.

i.e. Landsat satellite series

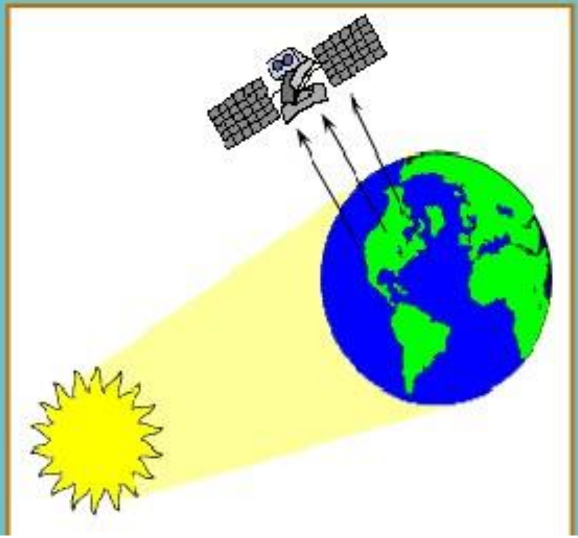
ACTIVE VS PASSIVE REMOTE SENSING

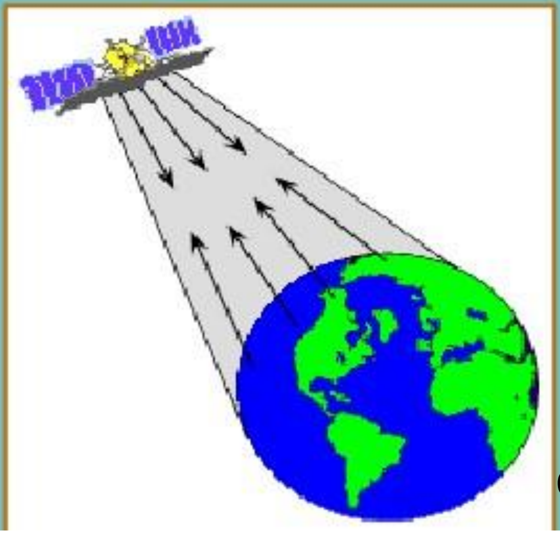
Pas

- Measure natural radiation (sun) which is reflected or emitted by the target (e.g. Microwave sensors, LandSat, SPOT, camera)

Active Remote Sensing

- Transmit their own energy/signal and measure the energy that is reflected or scattered back from the target
- Advantages: ability to “see” regardless of time of day or season; use wavelengths not part of solar spectrum.

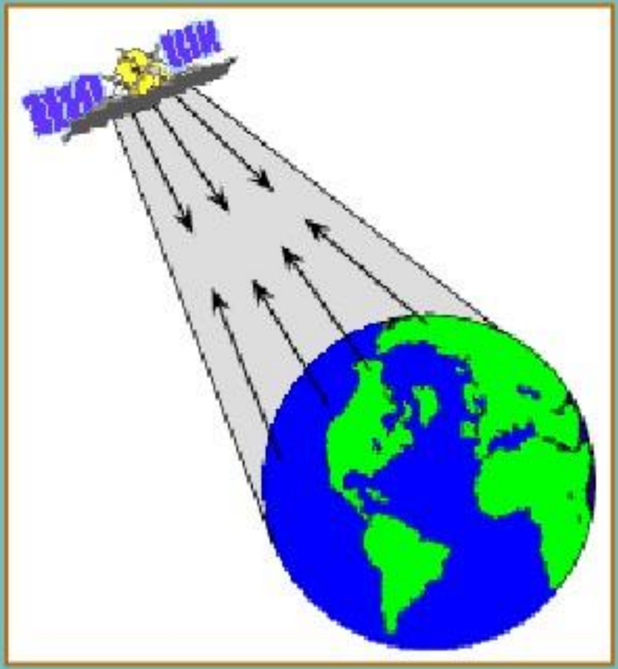




ACTIVE VS PASSIVE REMOTE SENSING

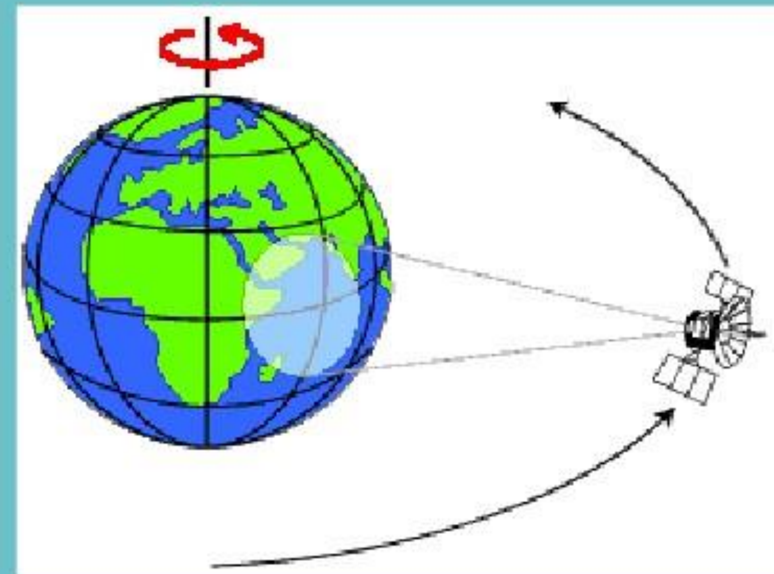
Active Remote Sensing

- transmit their own signal and measure the energy that is reflected or scattered back from the target
- advantages: ability to "see" regardless of time of day or season; use wavelengths not part of solar spectrum; better control of the way target is illuminated



Satellite Characteristics: Orbits and Swaths

Orbits : **geostationary & near-polar orbits**



Geostationary:

- **high altitudes (about 36,000 km),**
- **revolve at speeds which match the rotation of the Earth,**
- **West to East orientation**
- **observe and collect information continuously over specific areas.**
- **Weather and communications satellites commonly have these types of orbits.**

Near-polar orbits:

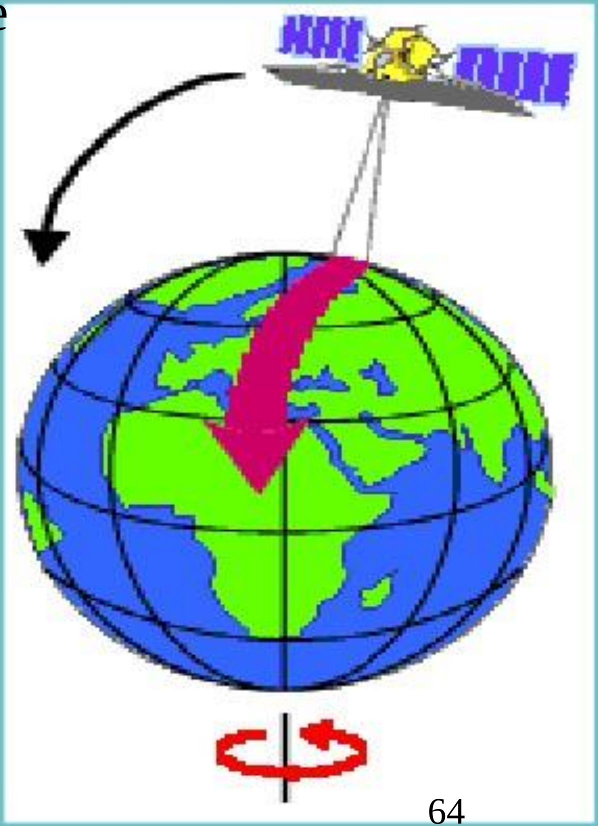
Basically north-south orbit which, in conjunction with the Earth's rotation (west-east), allows them to cover most of the Earth's surface over a certain period of time.

Inclination of the orbit relative to a line running between the North and South poles.

These satellite orbits are sun-synchronous such that they cover each area of the world at a constant local time of day called local sun time

This ensures consistent illumination conditions when acquiring images in a specific season over successive years, or over a particular area over a series of days.

This is an important factor for monitoring changes between images or for mosaicking adjacent images together

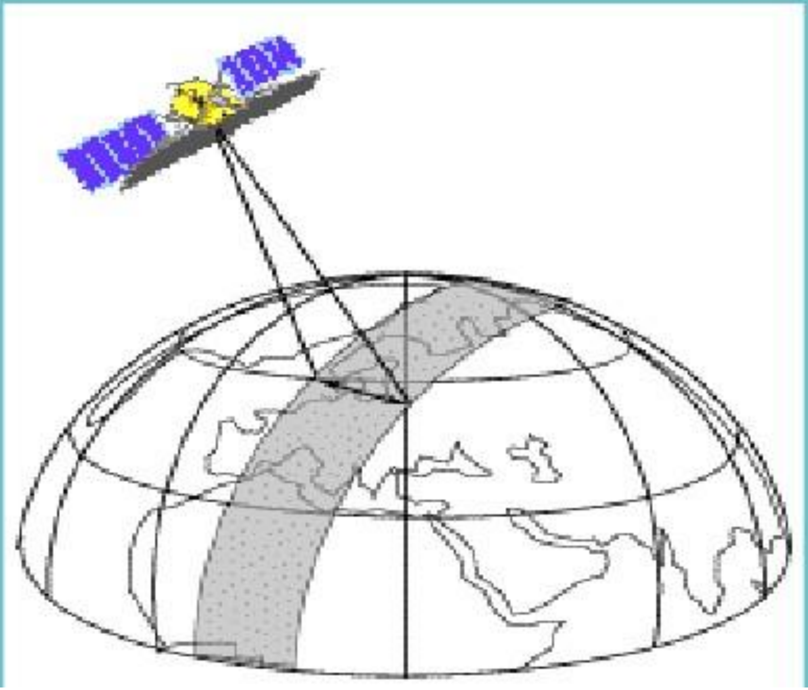


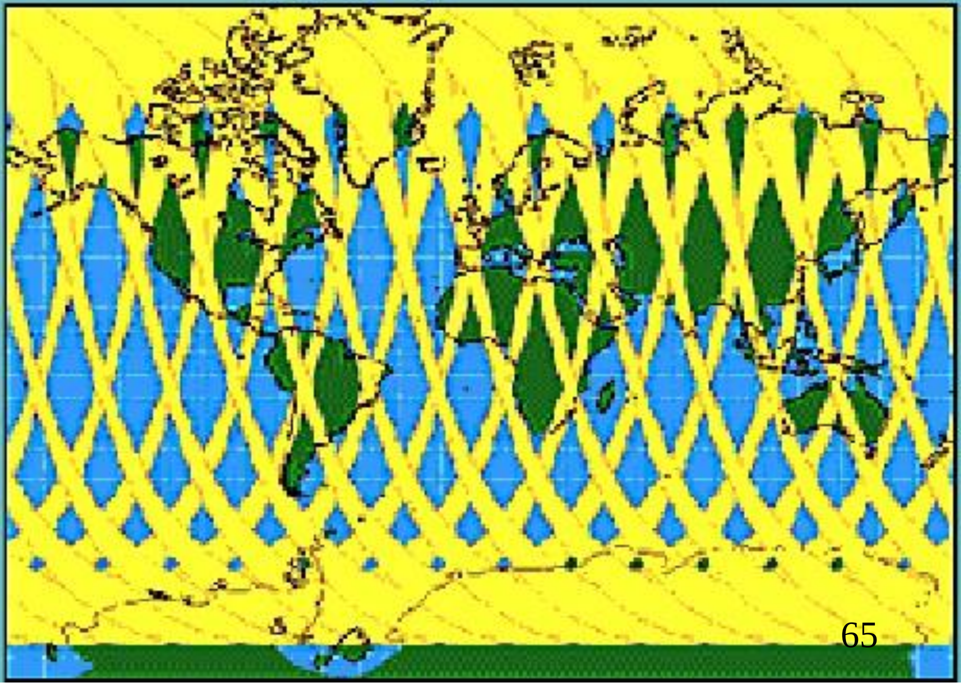
Swath width

The sensor "sees" a certain portion of the Earth's surface at a time. The area or surface covered in the imaged (in one shot) is called **swath.**

The satellite's orbit and the rotation of the Earth work together to allow complete coverage of the Earth's surface(cycle of orbits).

In near-polar orbits, areas at high latitudes will be imaged more frequently than the equatorial zone due to the increasing **overlap in adjacent swaths** as the orbit paths come closer together near the poles.





Platforms and Sensors Technology

Senso [redacted] a target or surface. Sensor must reside (on board) to stable platform.

Platform types*:* Platforms for remote sensors may be located on the ground, on an aircraft or balloon (or some other platform within the Earth's atmosphere), or on a spacecraft or satellite outside of the Earth's atmosphere .

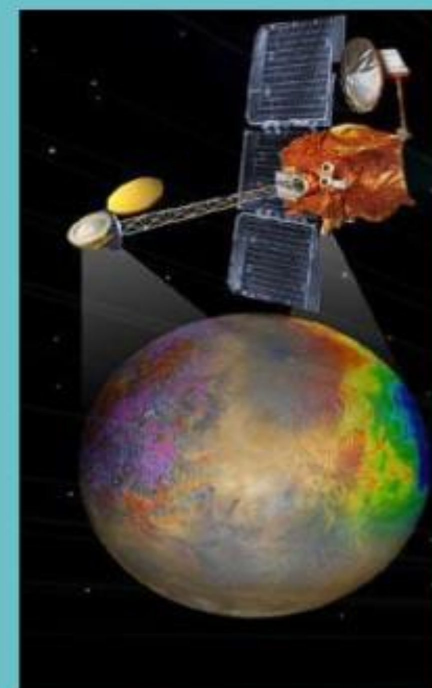
Based on their altitude

- ground borne
- air borne
- space borne

Remote sensing platforms

Ground-based

Airplane-based



Satellite-based

Ground borne platform

The ground based remote sensing system are mainly used for:

- *collecting ground truth and*
- *laboratory simulation studies*

Air borne platform

They are used to:

** acquire aerial photographs for photo interpretation and photogrammetric purposes*

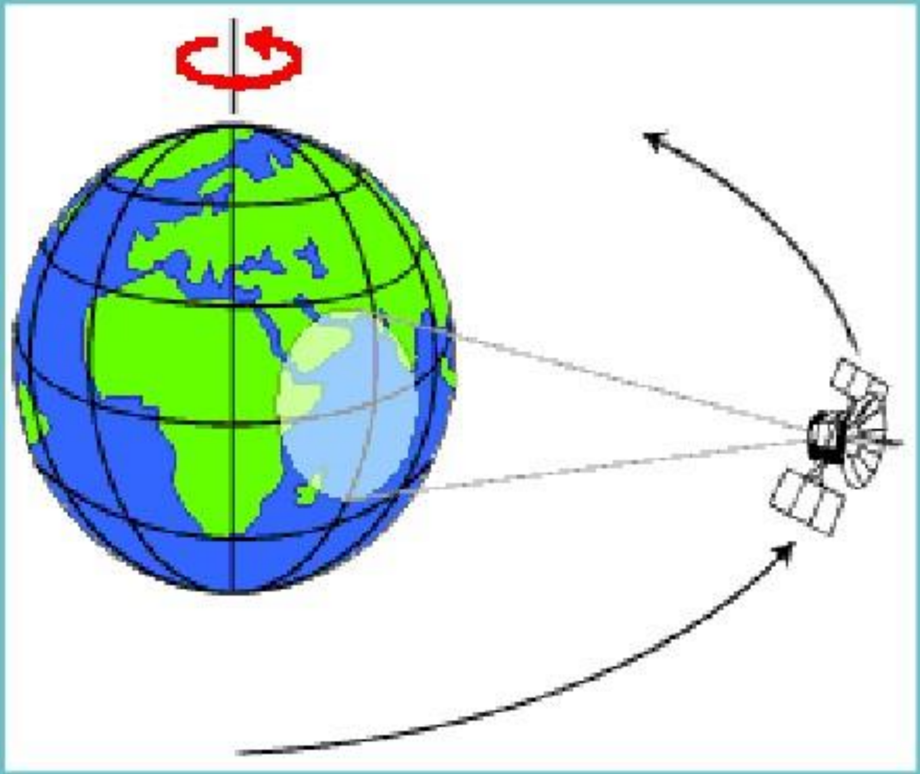
** test the performance of scanners before they are on board on satellite missions*

Aerial Photography/Airphoto

Airphoto - Saudi Arabia

Space borne platforms

They are freely moving in their orbits around the earth; give lots of information and made Rs popular science



Geostationary orbit

(appr.36.000 km)

Near Polar orbit

(appr. 500-1000 km)

Important terms of RS

- **Swath width:** refers to area coverage
- **Spatial resolution: -** is the smallest possible object or area a sensor can detect. It is also called ground resolution element (GRE).
- **Spectral resolution**: - how narrow and how many spectral bands a given sensor has.
- **Temporal resolution**: - is the frequency of obtaining data from a given area.
- **Radiometric resolution**: - means the data range where the images is encoded (indicated by range of gray values or bit (8 bit, 0-255 i.e. 256 gray values).

30 meter, spatial resolution
Northwest San Antonio

1 meter, spatial resolution
UTSA campus,
red polygon is the Science Building

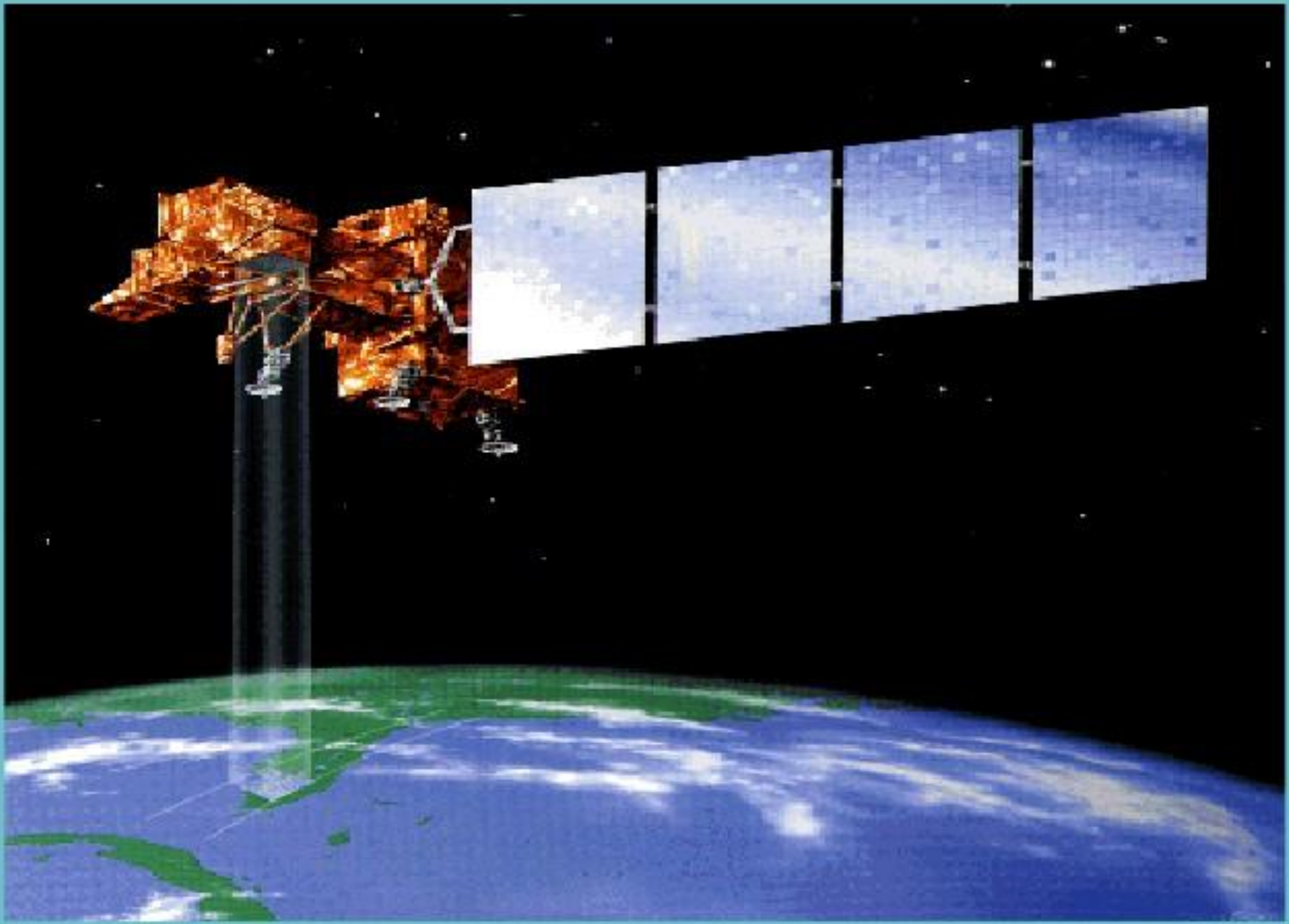
MAJOR EARTH OBSERVING SATELLITES

- Landsat
- SPOT
- Ikonos
- AVHRR
- Seawifs
- GOES
- Meteosat
- Terra EOS Satellite (ASTER, MODIS, CERES, MOPITT, MISR)

MAJOR EARTH OBSERVING SATELLITES (contd

- Radarsat
- ESA Satellites (ERS, ATSR)
- India Satellites (IRS, LISS, OCM)
- Japanese Satellites (JERS, ADEOS, AVNIR, OCTS, MOS, ALOS)
- Russian Satellites (Priroda, etc)

LANDSAT



LANDSAT

- Swath Width: 185 km
- Repeat Cycle 16 days
- Orbit Altitude: 705 km
- Equatorial Crossing: at around 10 a.m. local solar time

Spectral Bands of Landsat-7

Band	Spectral Range (mm)	Ground Resolution
1 (Blue)	.450- .515	30
2 (Green)	.525- .605	30
3 (Red)	.630- .690	30
4 (Near IR)	.750- .900	30
5 (Mid IR)	1.55- 1.75	30
6 (Thermal IR)	10.4- 12.5	60
7 (Mid IR)	2.09- 2.35	30
Panchromatic	.520-.900	15

Landsat Program Summary

System	Lounch (End Of Service)	Res (m)	Alt (km)	R (days)
Landsat 1	7/23/1972 (1/6/1978)	80 (RBV), 80 (MSS)	917	18
Landsat 2	1/22/1975 (2/25/1982)	80 (RBV), 80 (MSS)	917	18
Landsat 3	3/5/1978 (3/31/1983)	30 (RBV), 80 (MSS)	917	18
Landsat 4	7/16/1982	80 (MSS), 30 (TM)	705	16
Landsat 5	3/1/1984	80 (MSS), 30 (TM)	705	16
Landsat 6	10/5/1993 (10/5/1993)	15 (PAN), 30 (TM)	705	16
Landsat 7	Dec-98	15 (PAN), 30 (ETM)	705	16

Application areas of Remote Sensing

Plant Sciences

Crop yield estimation
Irrigation potential assessment

Natural resource

Forest

Forest fire risk mapping
Change detection

Land use and land cover

Change detection
LULC Classification

Meteorology

Weather forecasting
Climate studies
global change studies

Water resource mgt

Pollution detection
Detection of siltation

Disaster Risk management

Assessment of flood risk; Volcanic Eruption; earth quakes; land slides etc.

Military/Defence

Strategic mapping
Terrain analysis
Radar applications

Thank you!!!