Fundamental of Remote Sensing and its Application

By

Saroj Kumar Sahu,

UGC-Assistant Professor

P.G. Environmental Science,

Department of Botany, Utkal University,

Vani Vihar, Bhubaneswar-4, Odisha

What is Principles of Remote Sensing (RS)?

“Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it.”

!!! Do you know that we have been using RS technology in our day to day life?

Reading Book!!

Hearing Sound!!

- **Energy source and sensor are two important component of RS technology.**
- **Methods of collection of information: (two types)**
- **1) In-situ measurements** and **2) Remote Sensing observations**.
- **Measurement of body temperature using a clinical thermometer is “in-situ” measurement because object is touched by thermometer.**

Some daily experience to understand the basic principle behind Remote Sensing!!

During Reading Book!!

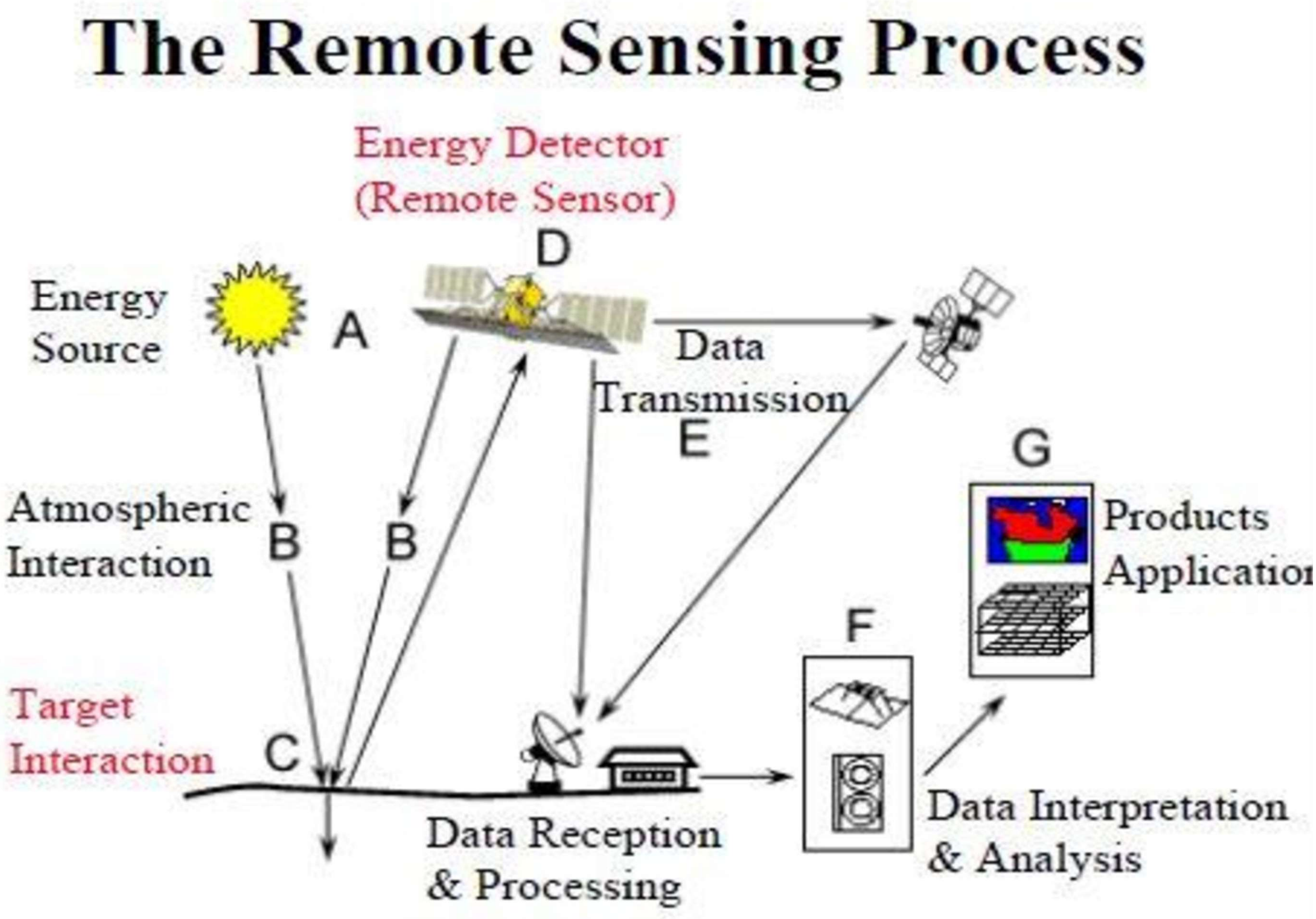
1. We see an object (Target) which reflects light.
2. Where "EYE" is sensor, "HEAD" is platform where the sensor is mounted.
3. "LIGHT" as energy source is most important..
4. The nervous system carries the information to the brain which act as " INTERPRETER" for identification of text in book.

- Modern Remote Sensing is an extension of above natural phenomenon.
- Major Objective of Modern/advance Remote Sensing technology is to sense the earth's surface for the purpose of improving natural resources management, land use and protection of the environment.

- The energy sources used could be Visible light, Electromagnetic radiation extending from Ultraviolet (UV) to the far infrared (IR), Microwave regions.

- Basic component of RS:
- 1. ENERGY SOURCE, 2.SENSOR, 3.PLATFORM, 4.TARGET, 5. INTERPRETER

A complete Remote Sensing System!!

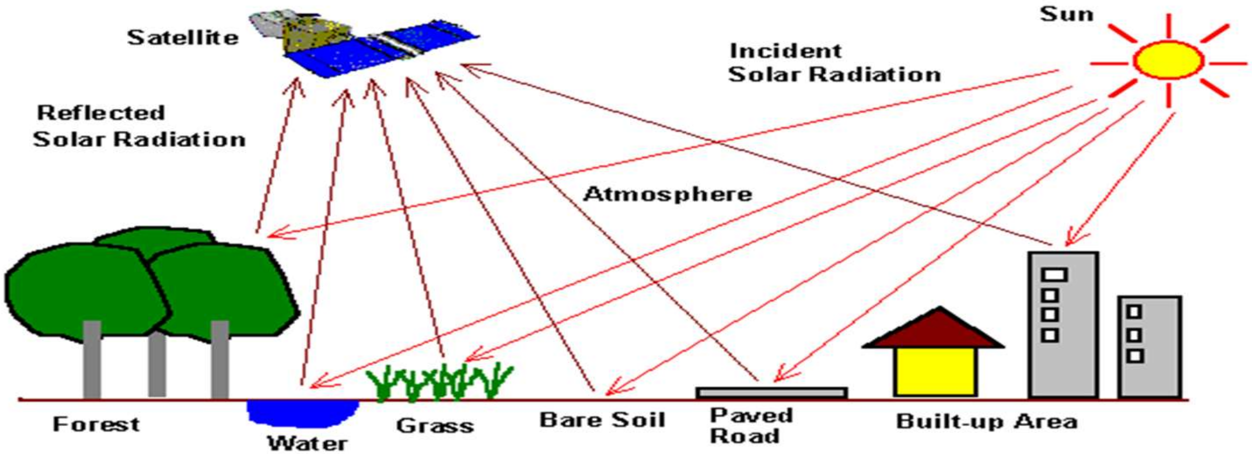


(A) **Energy Source or Illumination** – the first requirement to illuminates or provides electromagnetic energy to the target of interest.

(B) **Radiation and the Atmosphere** - as the energy travels from its source to the target, its interaction with the intervening atmosphere and one more time during its travel from target to sensor.

(C) **Interaction with the Target** – During course of interaction with target Three different process (i.e. reflection, absorption, transmission) occur and it depend on the properties of both the target and the radiation.

(D) **Recording of Energy by the Sensor** - after the energy has been reflected/scattered by, or emitted from the target, we require a remote sensor to collect and record the electromagnetic radiation.

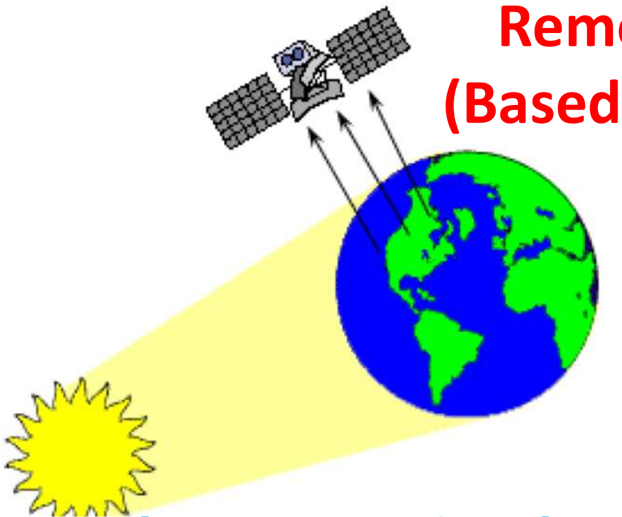


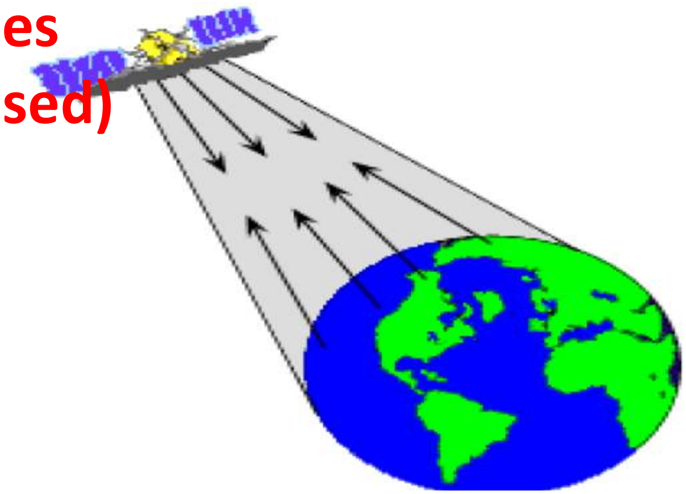
(E) Transmission, Reception, and Processing - **the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).**

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

(G) Application - **the final element of the remote sensing process is achieved when we apply the information for better understand it, reveal some new information, or assist in solving a particular problem.**

Remote Sensing of 2 types
(Based on energy source used)





Passive Remote Sensing

- Natural energy source like electromagnetic radiation from Sun is used as main source of energy.
- Operation in night is not possible after naturally emitted thermal infrared is not available.
- Example: Weather satellite,

Active Remote Sensing

- Artificial energy source in the form of electromagnetic radiation is generated to illuminate the objective/target.
- Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season.
- Example: Radar technology, SAR, camera, GPS etc.

- A Satellite is an object that orbits around another object in space.
- There are two kinds of satellites:

- Natural Satellites

  (such as the moon orbiting the Earth)
- Artificial satellites: are man-made robots that are purposely placed into orbit around Earth to perform numerous tasks in communication industry, military intelligence and scientific studies both Earth and space.

- India's first satellite is Aryabhatta (1975)
- First experimental remote sensing satellite is BHASKAR-1 in 1979 (Carried TV and microwave cameras).
- Indian National Satellite (INSAT) series, IRS series, Kalpana-1 (meteorological satellite), RESOURCESAT (IRS-P6), EDUSAT in 2004, CARTOSAT-1 in 2005, OCEANSAT-2 (IRS-P4) in 2009, etc.
- INSAT-3DR is a meteorological satellite lunched in Sept. 2016

India's own navigational system is called

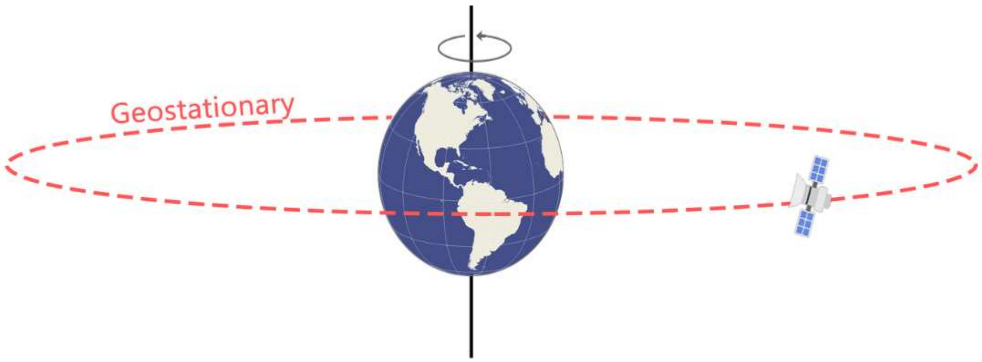
Navigation Indian Constellation (NAVIC)

(set of 7 satellites)

Indian Regional Navigation Satellite System or IRNSS with an operational name of NAVIC

- NAVIC system will be similar to the Global Positioning System (GPS) operated by the United States with 24 satellites and the Glonass by Russia, Galileo by Europe and BeiDou of China etc.
- Mathematical technique of trilateration to determine user position, speed and elevation.

Satellite Name	Year	Application
GSAT-31,	2019	Telecommunication Satellite
Microsat-R	2019	Earth observation, Student Satellite
GSAT-7A	2018	Military Satellite
GSAT-11	2018	Communication
GSAT-29	2018	Communication
IRNSS-11	2018	Navigation/Global Positioning
INS-1C	2018	Technology Applications
CartoSat-2E,2F	2017	Earth Sciences
ResourceSat-2A	2016	Earth Sciences
Astrosat	2015	Space Sciences
Oceansat 2	2009	Earth Sciences (Ocean)
Kalpana-1 (MetSat-1)	2002	Earth Sciences
Many More…..		

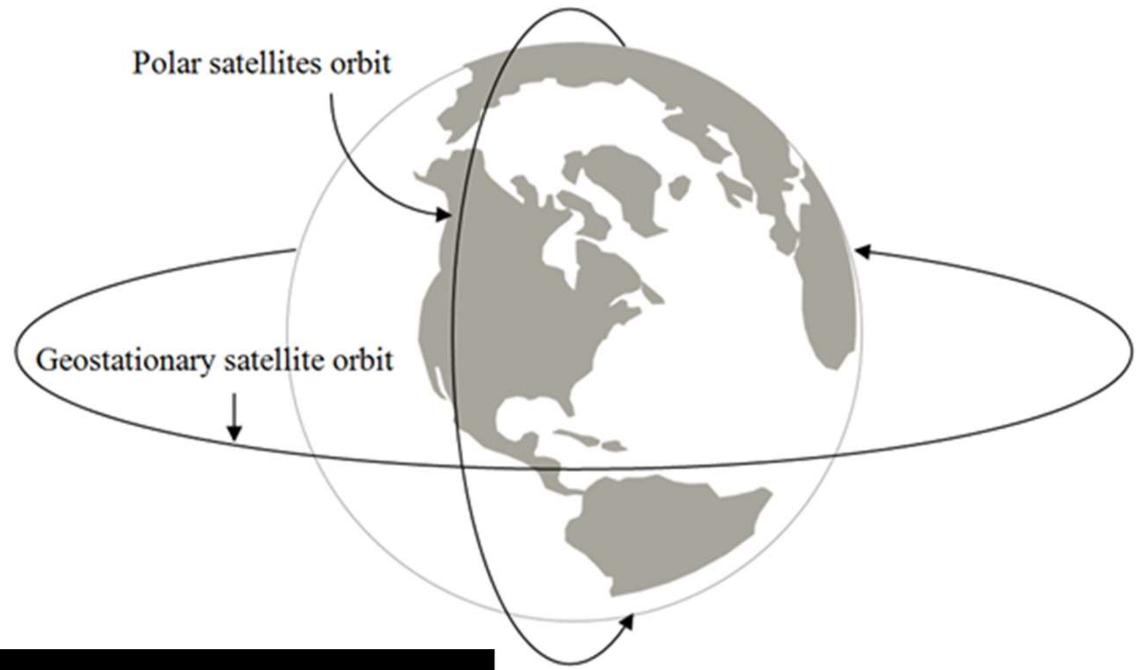


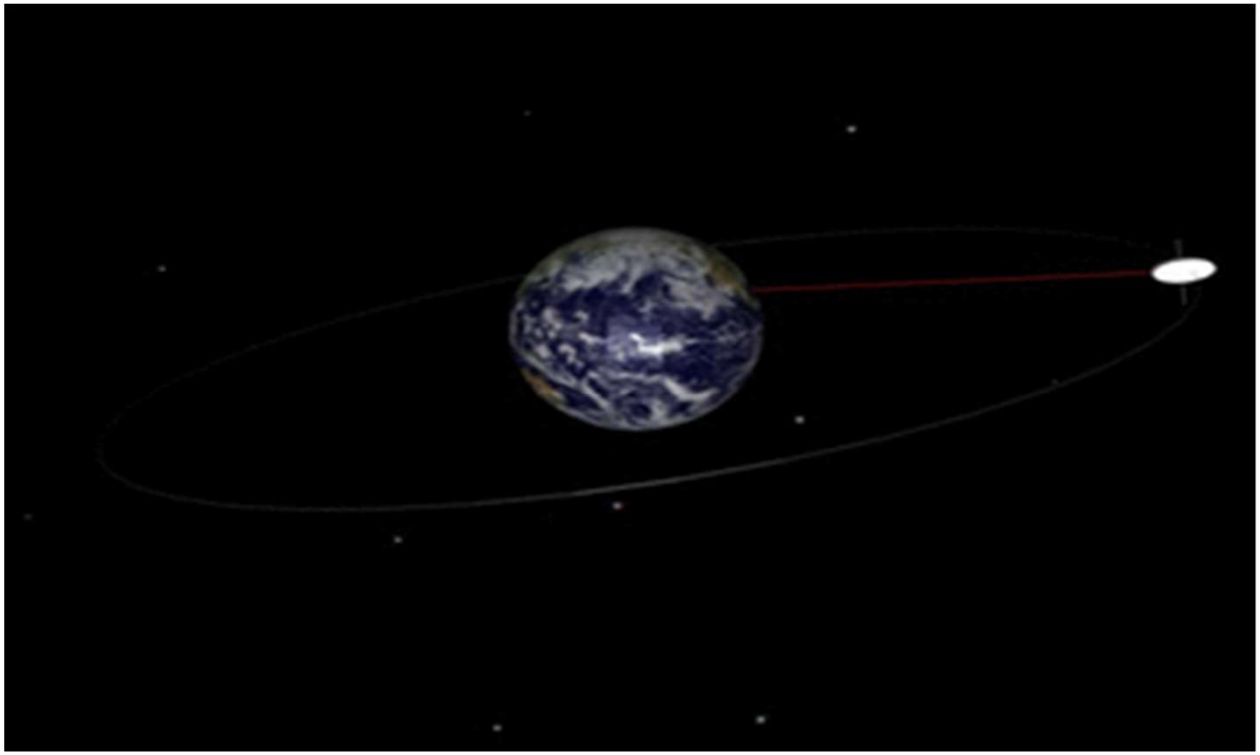
Geostationary satellite

1. Satellites at very high altitudes, which view the same portion of the Earth's surface at all times.
2. Altitude of approximately 36,000 kms directly over the equator, that revolves in the same direction the earth rotates (west to east).
3. The satellite rotates at exactly the same speed as the Earth.
4. Do not provide complete global coverage. It cover approximately 42% of the Earth's surface
5. Satellite orbits can only be above the equator and therefore polar regions cannot be covered.
6. Example: Weather/cloud satellite, communication satellite, GPS, TV satellite etc.

Sun-synchronous satellite

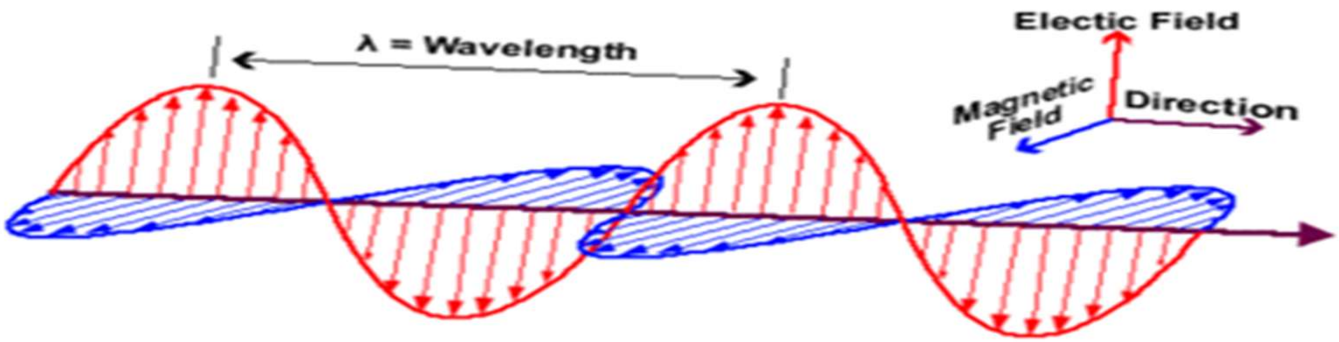
1. Placed at an altitude of 700-800 km
2. Satellite combines altitude and inclination in such a way that satellite can cover each area of the world at a constant local time of day called local sun time.
3. It therefore has an inclination of (or very close to) 90 degrees to the equator.
4. A satellite in a polar orbit will pass over the equator at a different longitude on each of its orbits.
5. Cover more areas and widely used in military applications, natural resource satellite etc.
   Also Called Near Polar orbit satellite





Geostationary satellite

Electro-Magnetic Radiation (EMR)



- A **black body** is one that absorbs all the EM radiation (light) that strikes it.
- To stay in **thermal equilibrium**, it **must emit radiation at the same rate as it absorbs it** so a black body also radiates well.
- All objects with a temperature above absolute zero (0 K, -273.15 ^{o}C) emit energy in the form of electromagnetic radiation.

The sun act as a blackbody has effective temperature of 6000 K "showers" enormous quantity of electromagnetic energy.

Electromagnetic radiation are created by the vibration of an electric charge and these changing electric fields induces changing magnetic fields in the surrounding medium.

This vibration creates a wave which has both an electric and a magnetic component.

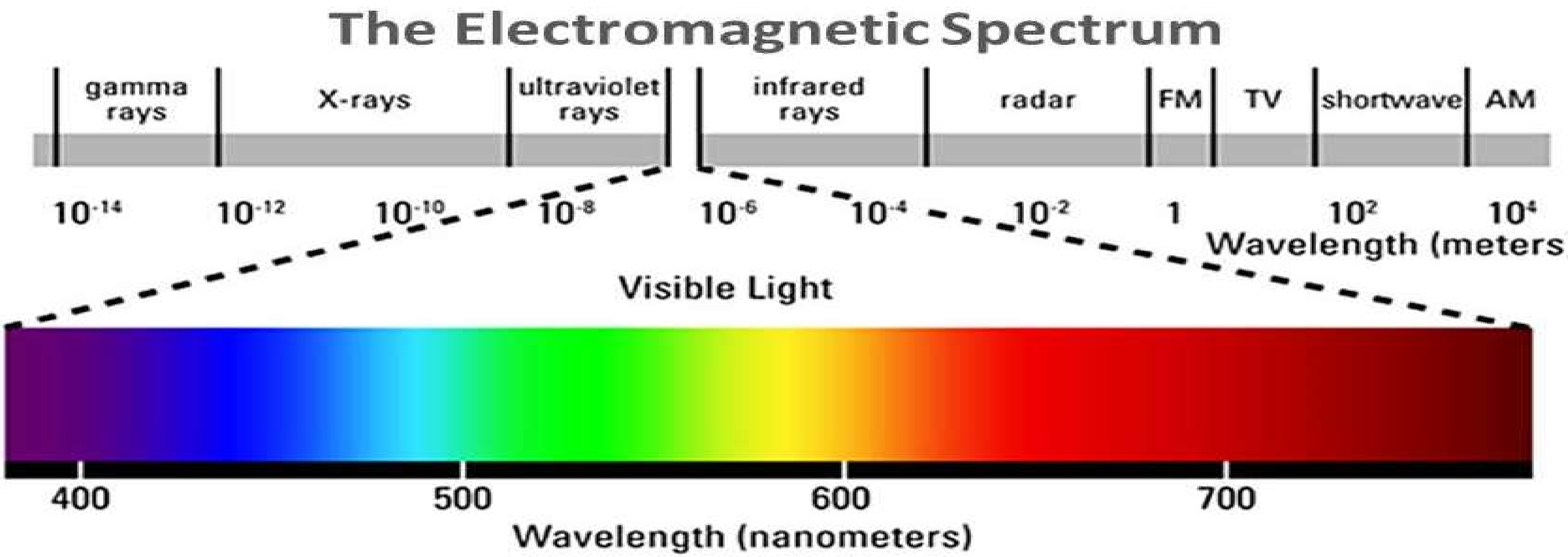
- Two characteristics of electromagnetic radiation are important. These are the wavelength and frequency.

- Both are inversely related to each other.

- The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency.
- An electromagnetic wave transports its energy through a vacuum at a speed of 3.00×10^8 m/s .

- The total amount of energy emitted by the sun and received at Earth's atmosphere is constant, 1370 W/m2/sec.

- That received per unit area of the Earth's surface is 343 W/m2/sec.



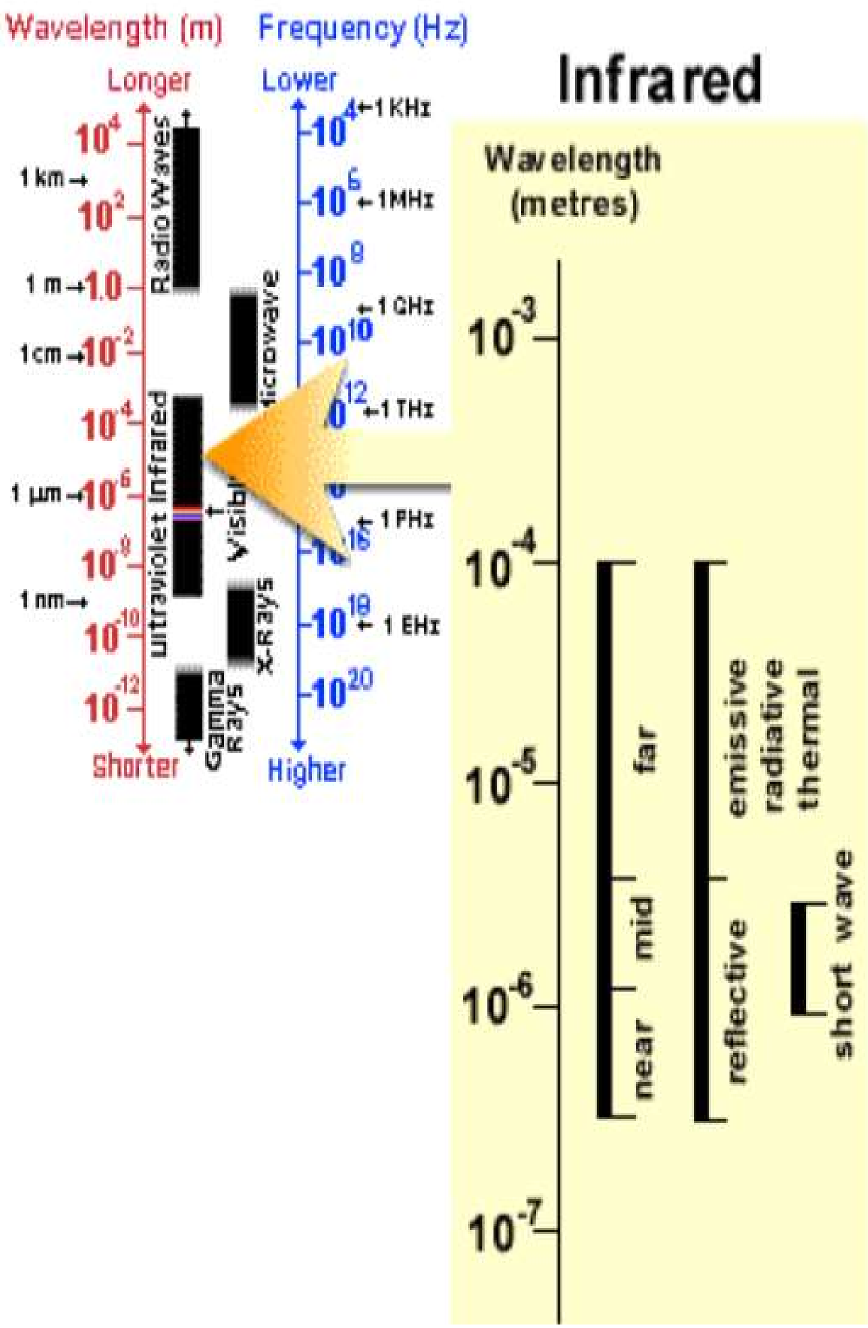
- **Electromagnetic Radiation spans large spectrum of wavelengths from very short wavelength like gamma rays (10^{-10}m) to long radio waves (10^{6}m).**
- **The entire range of the electromagnetic radiation is called electromagnetic spectrum.**

Optical Infrared (OIR)			
Visible	**0.4-0.7 µm**	**Far IR**	**Beyond 15 µm**
Near Infrared (NIR)	**0.7-1.5 µm**	**Microwaves**	
Shortwave IR	**1.5-3 µm**	**P band**	**0.3-1 GHz (30-100 cm)**
Midwave IR	**3-8 µm**	**….L band, S Band, C Band, X Band, Ku Band, K Band…..**	
Long Wave IR (LWIR) Or Thermal IR	**8-15 µm**	**Ka Band**	**26.5-40 GHz (0.75-1.1 cm)**

- Our eyes can detect is part of the 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.
- Over 99% of the energy flux from the sun (0.15 to 4 µm,)
- With approximately 50% in the visible light region of 0.4 to 0.7 µm.

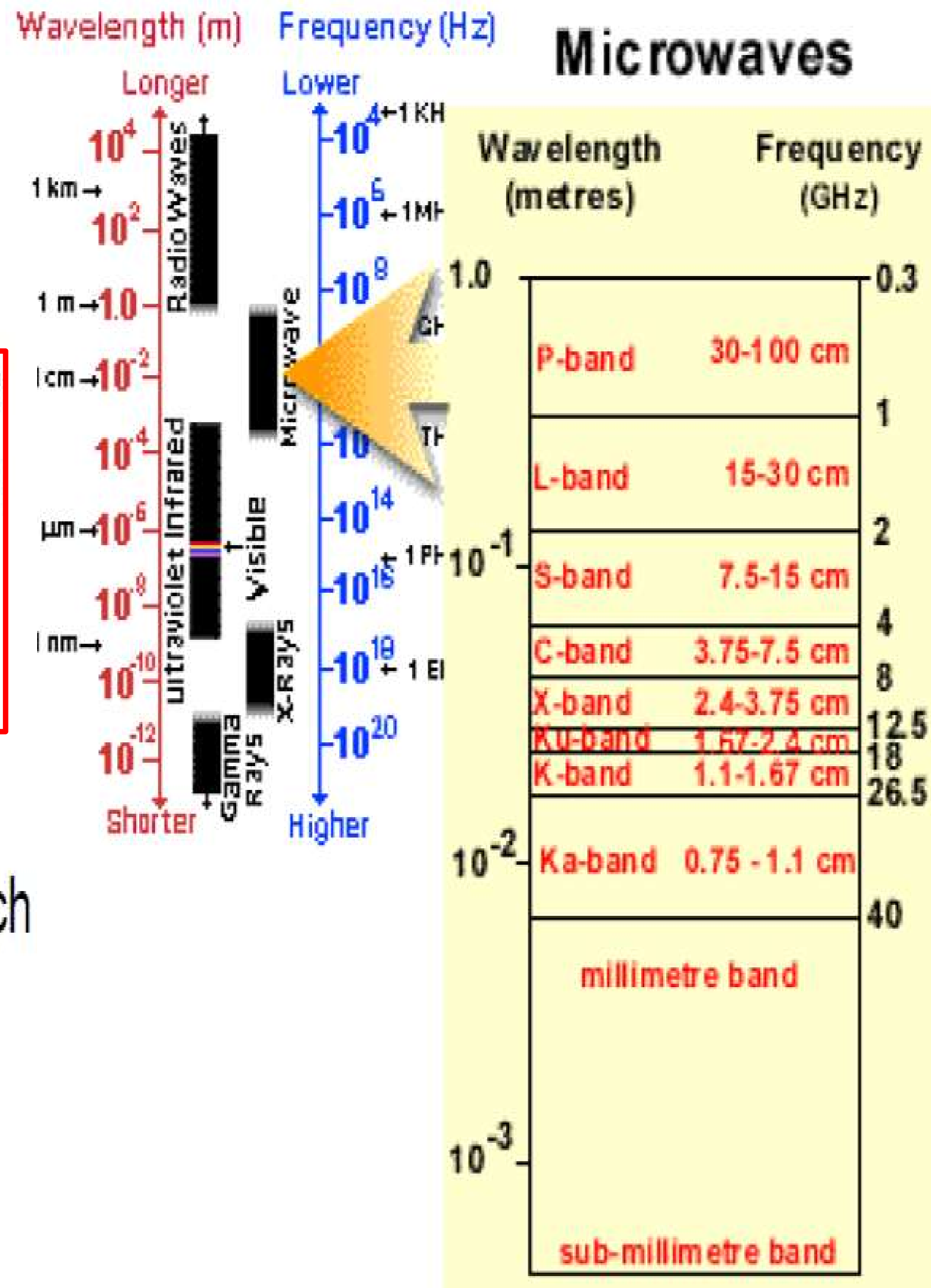
Violet: 0.4 - 0.446 µm
Blue: 0.446 - 0.500 µm
Green: 0.500 - 0.578 µm
Yellow: 0.578 - 0.592 µm
Orange: 0.592 - 0.620 µm
Red: 0.620 - 0.7 µm

BLUE, GREEN, and RED are the primary colors. They are defined as such because no single primary color can be created from the other two, but all other colors can be formed by combining blue, green, and red in various proportions.



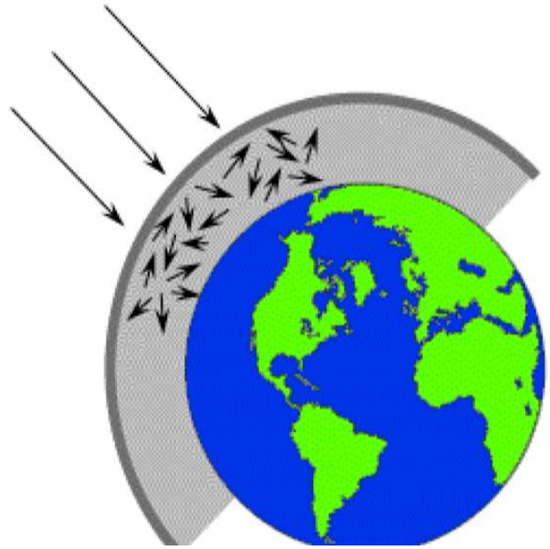
The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range from approximately 0.7 µm to 100 µm - more than 100 times as wide as the visible portion! The infrared region can be divided into two categories based on their radiation properties - the **reflected IR**, and the emitted or **thermal IR**. 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.

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 broadcasts.

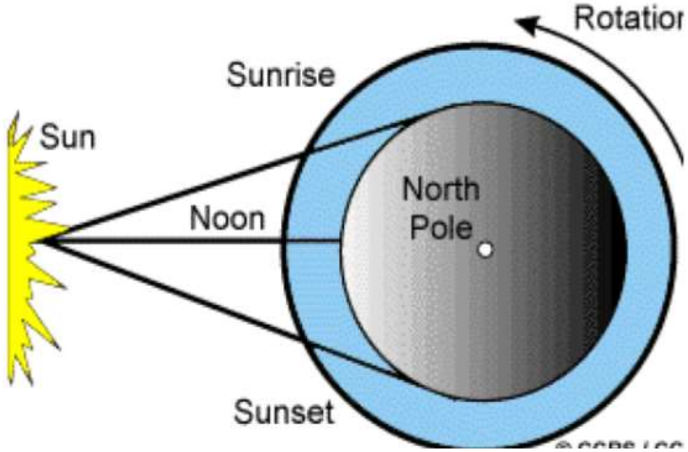


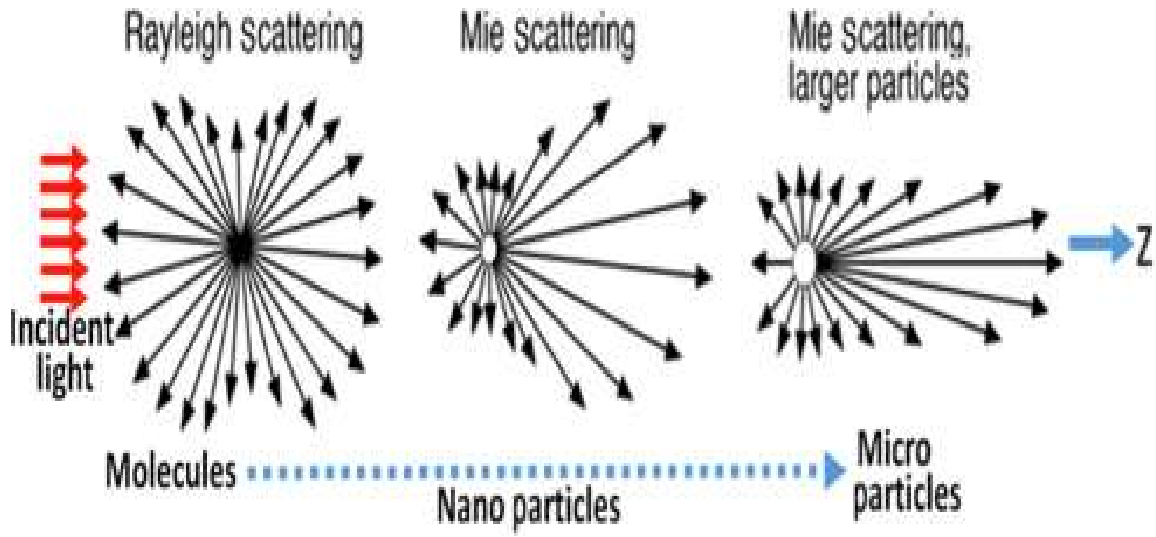
Interaction of EMR with Atmosphere

- 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** 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.**



- **Scattering depends** on several factors including the **wavelength of the radiation**, the **abundance of particles or gases and it size**, and the **distance the radiation travels through the atmosphere**. There are three types of scattering happens i.e.
- 1. **Rayleigh Scatterings**
- **2. Mie Scattering**
- **3. Nonselective Scattering**





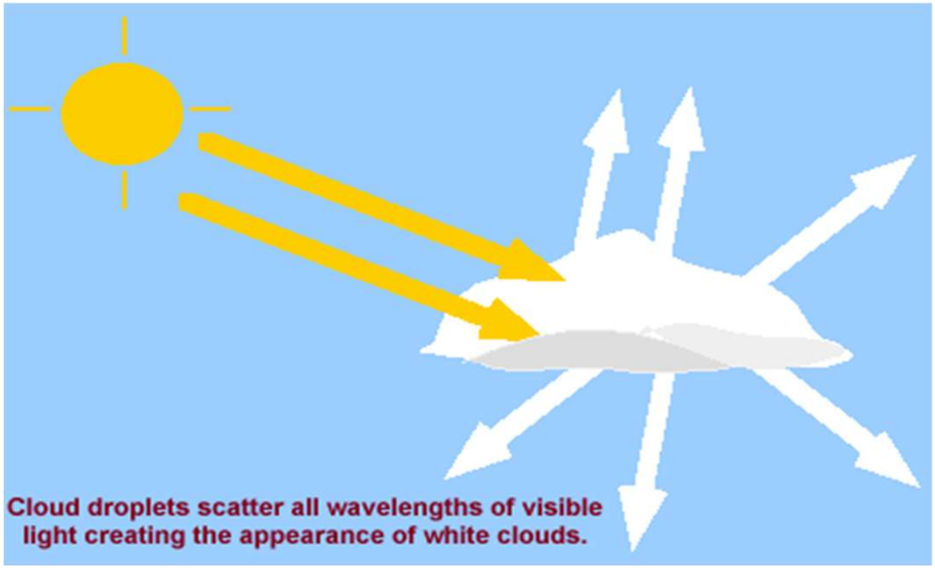
- **Rayleigh scattering** occurs when **particles are very small compared to the wavelength of the radiation.**
- Example: small specks of dust or nitrogen and oxygen molecules.
- **Shorter wavelengths of energy to be scattered much more than longer wavelengths.**
- Dominant scattering **mechanism in the upper atmosphere**.

The fact that the sky appears **"blue"** during the day is because of this phenomenon. As sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths.

- **Mie scattering** occurs when the particles are just about the same size as the wavelength of the radiation. Effect longer wavelengths than those affected by Rayleigh scattering.
- Occurs mostly in the **lower portions of the atmosphere** where larger particles are more abundant, and dominates when cloud conditions are overcast.
- **Ex: Dust, pollen, smoke and water vapor etc.**

Sky appears **"Orange/red"** during sunrise and sunset, because the light has to travel farther through the atmosphere than at midday and the scattering of the **shorter wavelengths is more complete;** this leaves a **greater proportion of the longer wavelengths to penetrate the atmosphere.** Sunset colors are typically more brilliant than sunrise colors, because the **evening air contains more particles than morning air…**

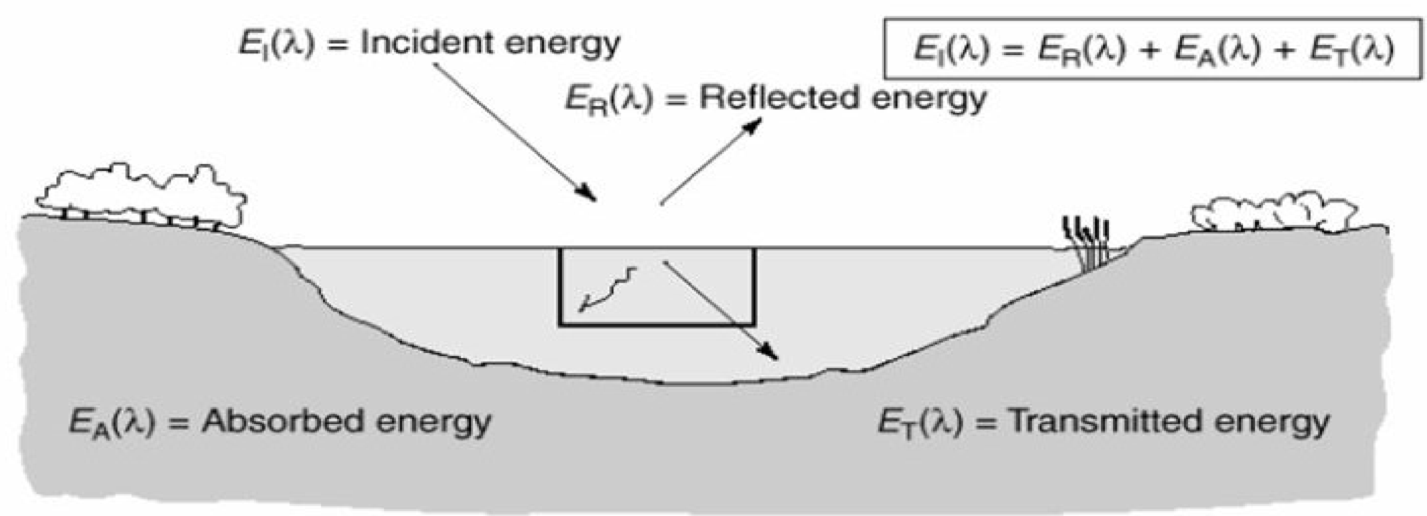
- **Nonselective scattering** occurs when the particles are much **larger than the wavelength** of the radiation.
- **Ex: Water droplets** and **large dust particles** etc.
- All wavelengths are scattered about equally. This type of scattering causes **fog and clouds to appear white** to our eyes because blue, green, and red light are all scattered in approximately equal quantities
- **(Blue + Green + Red light = White light).**



- **Absorption** is the other main mechanism 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**.
- **Water vapor** in the atmosphere absorbs much of the incoming/thermal/outgoing long wave infrared and shortwave microwave radiation (between 22µm and 1m).

- **Greenhouse effect** is consequence of above mechanism

Interactions of EMR with Earth Surface Features



- **Radiation that is not absorbed or scattered in the atmosphere** can reach and interact with the Earth's surface.
- Energy incident on the Earth's surface undergo through above three process i.e. **Reflection, Absorption, Transmission**.
- The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

1. Reflection is the process in which the incident energy is redirected in such a way that the angle of incidence is equal to the angle of reflection. The reflected radiation leaves the surface at the same angle as it approached. ***In remote sensing, we are most interested in measuring the radiation reflected from targets.***

- 2.**Absorption** occurs when radiation is absorbed by the target.
- Energy is transferred into other form-Say HEAT.
- The portion of the EM energy which is absorbed by the Earth's surface is available for emission and as thermal radiation at longer wavelength.
- 3.**Transmitted** occurs when radiation is allowed to pass through the target.
- Depending upon the characteristics of the medium, during the transmission velocity and wavelength of the radiation changes, whereas the frequency remains same. The transmitted energy may further get scattered and /or absorbed in the medium.

- The combine effects of absorption and scattering reduces the intensity of incident radiation is called ATTENUATION.

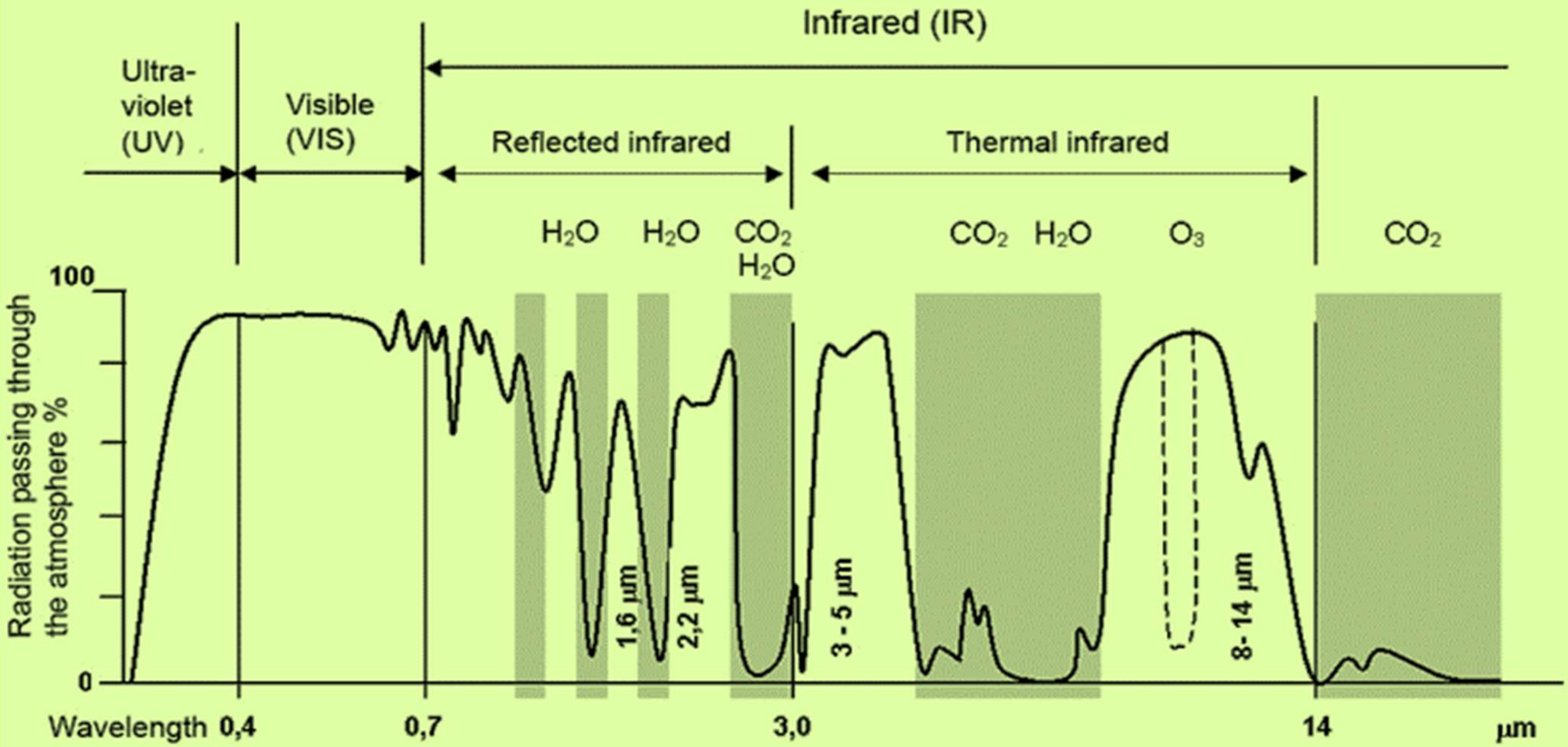
ATMOPSHERIC WINDOW

- **Solar radiation has to pass through the atmosphere before it interacts with earth surface. Some of radiation is scattered and absorbed by gases and particles during passing through the atmosphere.**

- **Those areas of the EMR spectrum which are not severely influenced by atmospheric absorption is called ATMOPSHERIC WINDOW.**

- **In RS of earth's surface having atmospheric window regions like 0.4-1.3 µm, 1.5-1.8 µm, 2.2-2.6 µm, 3.0-3.6 µm, 4.2-5.0 µm, 7-15 µm, and 1cm-30cm etc.**

- **Attenuation is the combine effects of absorption and scattering which will reduces the intensity of incident radiation.**



ATMOPSHERIC WINDOW REGIONS

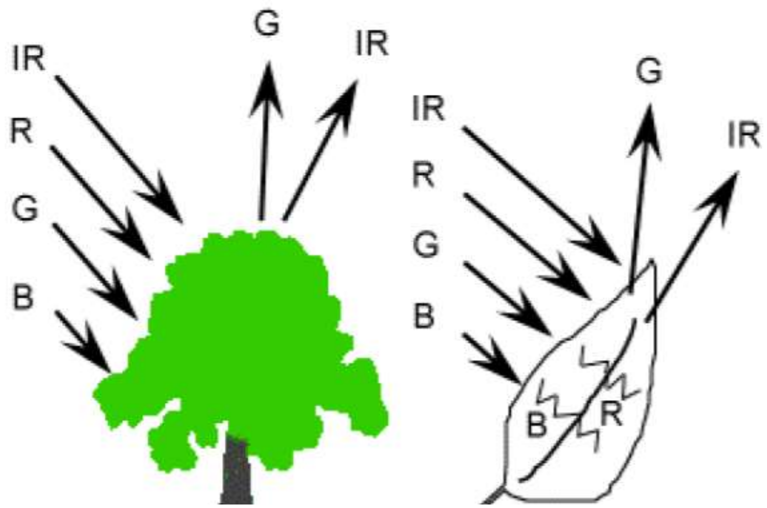
Concept of Signature

- **Signature is** the basic property which allows to identify an object.
- Each individual has an **unique signature**, with which it can be identified.
- In Remote Sensing, **Signature** is **any set of observable characteristics, which directly or indirectly leads to the identification of an object.**
- This could be characteristics like **spectral, spatial, temporal and polarization** variations of an object.
- **Spectral variation** are the changes in reflectance/emittance of objects as a function of wavelength.

  (color of objects is a indication of spectral variation in visible region.)
- **Spatial variation** is the arrangement of terrain features based on attributes like **shape, size, texture** of objects.
- **Temporal variation** are the changes in reflectance with time.

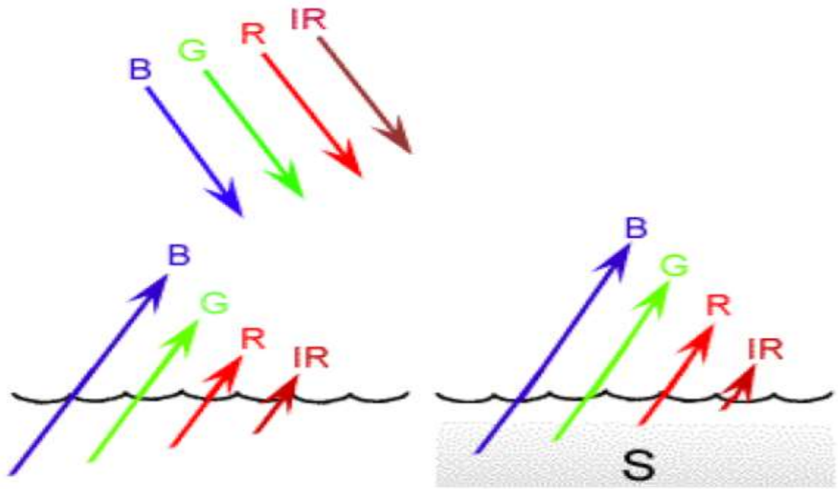
  (Seasonal change of crop pattern/color is good indicator)
- **Polarization variation** is the change in polarization of radiation reflected by objects

  (Generally used in microwave remote sensing)



Why leaf looks green?

- **Leaves:** A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths.
- Leaves appear "greenest“ to us in the summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll in the leaves, so there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear red or yellow (yellow is a combination of red and green wavelengths). The internal structure of healthy leaves act as excellent diffuse reflectors of near-infrared wavelengths. If our eyes were sensitive to near-infrared, trees would appear extremely bright to us at these wavelengths.



Why Water Looks Blue?

- **Water:** **Longer wavelength of visible and near infrared radiation is absorbed more by water than shorter visible wavelengths. Thus water typically looks blue or blue-green due to stronger reflectance at these shorter wavelengths, and darker if viewed at red or near infrared wavelengths.**
- **If there is suspended sediment present in the upper layers of the water body, then this will allow better reflectivity and a brighter appearance of the water. The apparent color of the water will show a slight shift to longer wavelengths.**
- **Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear more green in color when algae is present.**

Remote Sensors

- **Instruments used to measure the EMR reflected/emitted from target are referred as remote sensor.**
- **Again of two type based on kind of radiation sense like Passive sensors sense natural radiation emitted/reflected from earth/objects where as active sensors carry own source of EMR to illuminate the target.**
- **The major parameters of sensor system are**

1. Spatial resolution (Pixel Size): the capacity of sensor to discriminate the small object on the ground of different size.

(area of ground imaged by one pixel)

- **Most remote sensing images are composed of a matrix of picture elements, or pixels, which are the smallest units of an image. (Example:QuickBird:0.65m, GeoEye1:0.4m etc).**
- **Based on specific application, the sensor are customized. (Example: OCM,)**

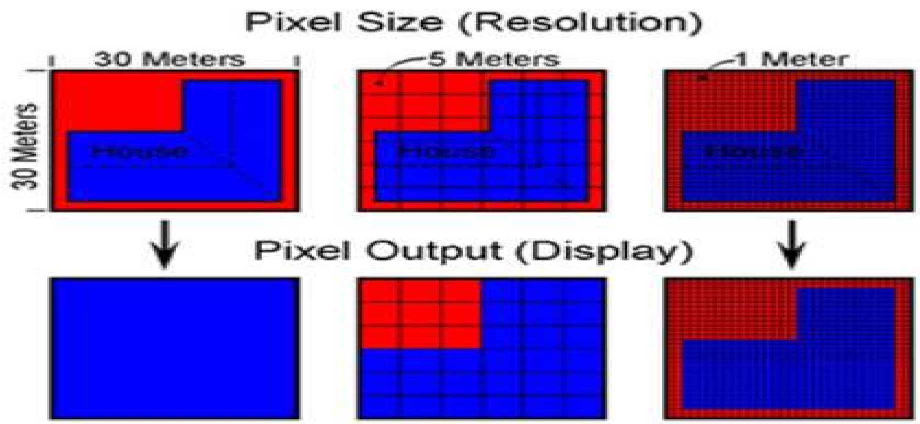
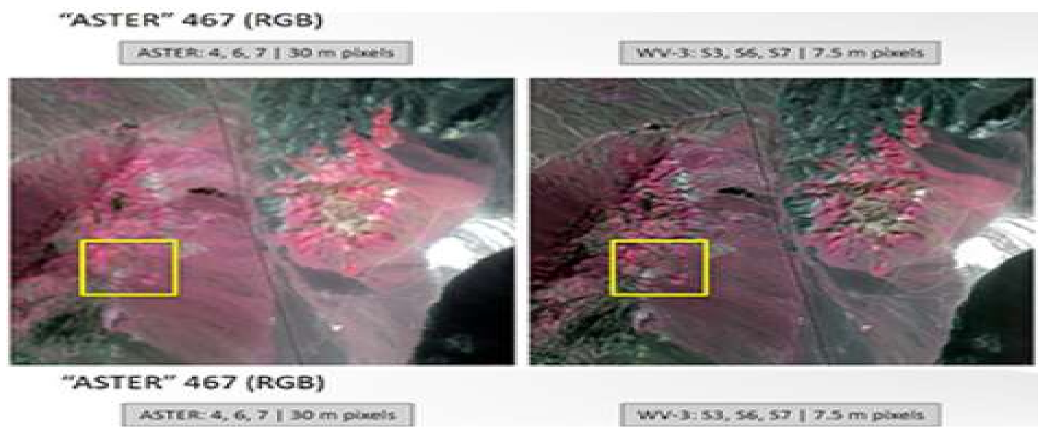


Image courtesy of Satimaging Corporation



2. **Spectral resolution:** **the ability of a sensor to define fine wavelength intervals. (i.e. the number of spectral bands in which the sensor can collect reflected radiance.**

The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.

The choice or number of spectral bands required will depend upon the application of use.

The spectral reflectance curves, or spectral signatures of different types of ground targets provide the knowledge base for information extraction. Reflectance measurements can help reveal the mineral content of rocks, the moisture of soil, the health of vegetation, the physical composition of buildings, and thousands of other invisible details.

3. Radiometric resolution: to discriminate two object based on its reflectance/emittance difference. (actual Information content in image)

Radiometric resolution refers to how much information is in a pixel and is expressed in units of bits.

(higher the RR, smaller the radiance difference that can be detected between two target.

A single bit of information represents a binary decision of **yes or no**, with a mathematical value of **1 or 0**.

Typical Black & White images from a source such as a digital camera **are 8 bits,** meaning the information is represented with a value of **0-255 or 256** in total.

In contrast, **a colour image** is represented using **3 channels**, Red, Green, Blue and **each channel is 8 bits**, **equalling 24 bits of information**. Humans visualise colours as a combination of the three primary colours, red, green and blue.

A radiometric resolution of **11** means the pixel has 2048 possible intensities of blue, 12 bit resolution represents 4,096 shades of blue.

4. Temporal resolution: the capability to view the same target, under same condition at regular intervals.

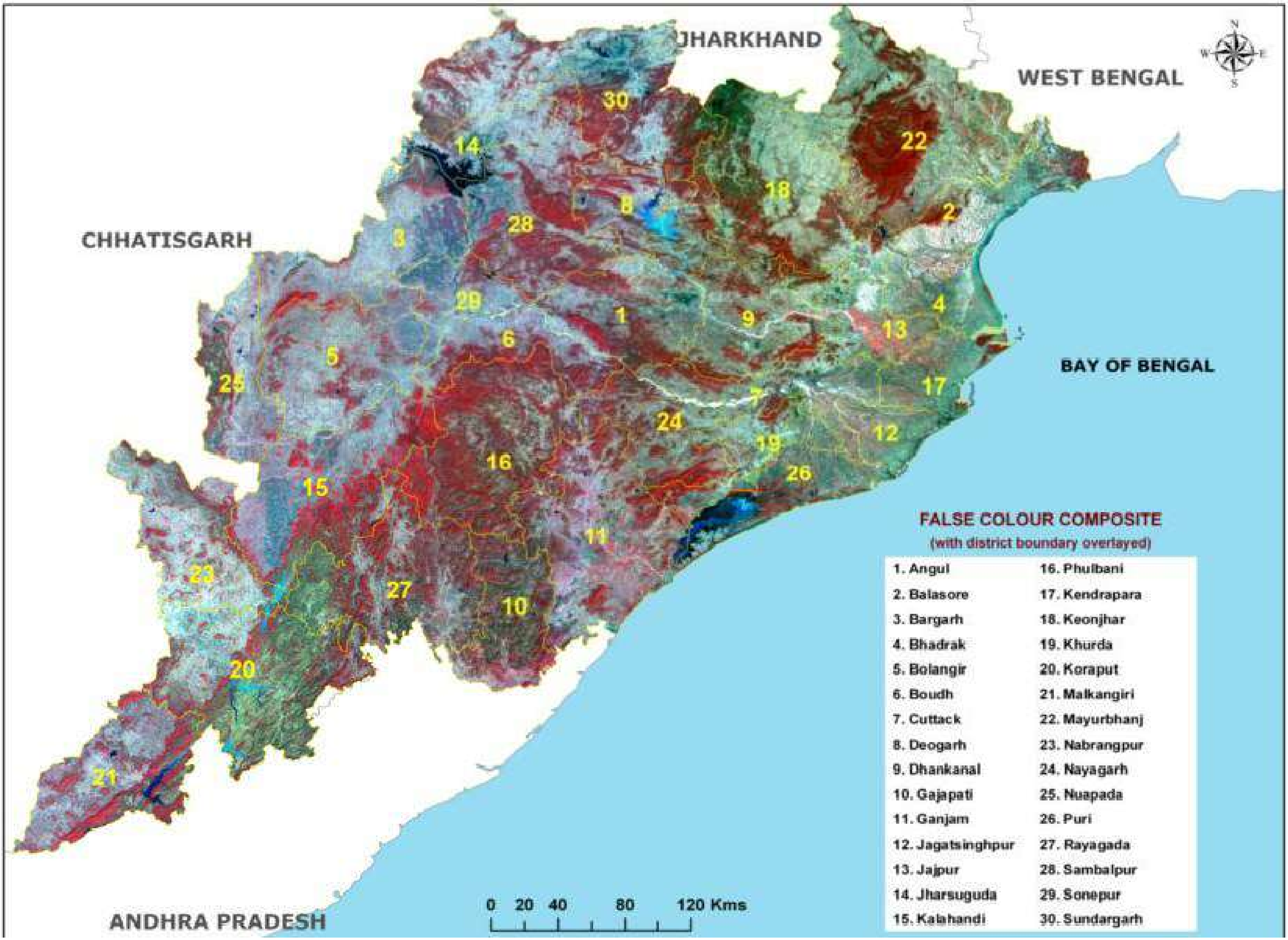
Important factors to consider with regards to temporal resolution :

Leaf on/leaf off
Tidal stage
Seasonal differences
Shadows
Relationship to field sampling
Phonological differences such as flowering, breeding and migration differences in relation to climatic conditions.

Revisit times for satellites and how often can you acquire the same area.

False Colour Composite

- A very common False Color Composite (FCC) scheme for displaying satellite data is
- Actually Plants reflect near infrared and green light, while absorbing red. Since they reflect more near infrared than green, In order to take the advantage of this.
- Near infrared light as RED
- Red light as GREEN
- Green light as BLUE.
- So plant-covered land appears deep red. The signal from plants is so strong that red dominates the false-color view
- Denser plant growth is darker red. This band combination is valuable for gauging plant health.
- Clear water appears dark-bluish (higher green band reflectance), while turbid water appears cyan (higher red reflectance due to sediments) compared to clear water. Bare soils, roads and buildings may appear in various shades of blue, yellow or grey, depending on their composition.


JHARKHAND
WEST BENGAL
CHHATISGARH
BAY OF BENGAL
ANDHRA PRADESH
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
FALSE COLOUR COMPOSITE
(with district boundary overlayed)
1. Angul
2. Balasore
3. Bargarh
4. Bhadrak
5. Bolangir
6. Boudh
7. Cuttack
8. Deogarh
9. Dhankanal
10. Gajapati
11. Ganjam
12. Jagatsinghpur
13. Jajpur
14. Jharsuguda
15. Kalahandi
16. Phulbani
17. Kendrapara
18. Keonjhar
19. Khurda
20. Koraput
21. Malkangiri
22. Mayurbhanj
23. Nabrangpur
24. Nayagarh
25. Nuapada
26. Puri
27. Rayagada
28. Sambalpur
29. Sonepur
30. Sundargarh
0 20 40 80 120 Kms

Application of Remote Sensing!!

- Agriculture
- Oceans & Coastal Monitoring
- Land Cover & Land Use
- Sea Ice
- Geology
- Hydrology
- Forestry
- Hazard/Disaster monitoring
- Air Pollution
- Mapping
- Volcano monitoring
- Urban Planning
- Climate Change
- Urban Planning
- Disaster Management
- Atmospheric Research

Thank You