REMOTE SENSING
AND
GIS

Contents

1. Introduction

"Remote sensing is the art, science and technology through which the characteristics of objects/targets either on, above or even below the Earth's surface are identified, measured and analyzed without direct contact existing between the sensors and the objects or events being observed"

- Remote sensing is a method of obtaining information about the properties of an object without coming into physical contact with it.

- Remote sensing provides valuable data over vast area in short time about resources, meteorology and environment leading to better resource management.

- Sensors can be used to obtain specific information about an object or the geographic extent of a phenomenon

- The EMR reflected, emitted, or back-scattered from an object or geographic area is used as a *substitute for the actual* property under investigation.

- The electromagnetic energy measurements must be calibrated and turned into information using visual and/or digital image processing techniques.

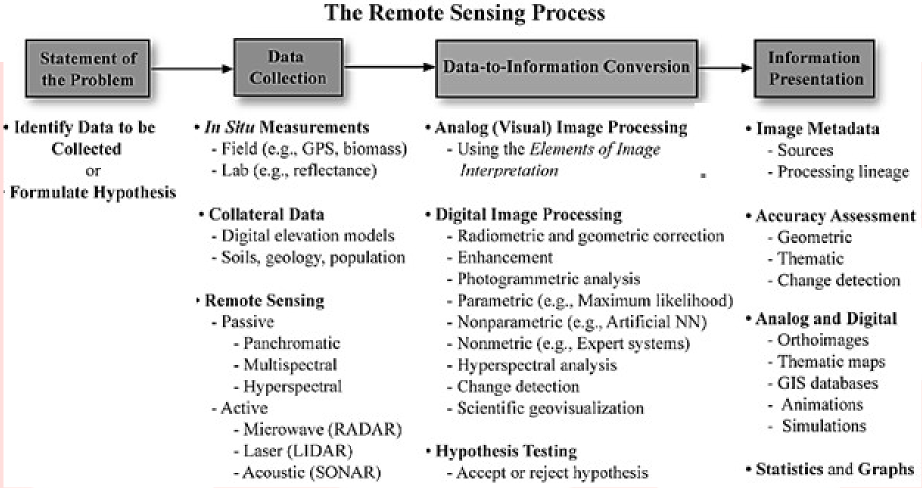
1.1Types of Remote Sensing

Remote sensing is broadly two types. Active & Passive Remote sensing. Active sensors have its own source of light or illumination. In particular, it actively sends a pulse and measures the backscatter reflected back to the sensor. But passive sensors measure reflected sunlight emitted from the sun.

1.2Advantages of remote sensing

- Synoptic Overview
- Feasibility Aspects
- Time Saving
- Unobtrusiveness
- Systematic Data Collection
- Multi-disciplinary Applications
- Day & night operation
- Repetitive coverage

1.3 Remote sensing process



The Remote Sensing Process

Statement of the Problem

- **Identify Data to be Collected**
  or
- **Formulate Hypothesis**

Data Collection

- ***In Situ* Measurements**
  - Field (e.g., GPS, biomass)
  - Lab (e.g., reflectance)
- **Collateral Data**
  - Digital elevation models
  - Soils, geology, population
- **Remote Sensing**
  - Passive
    - Panchromatic
    - Multispectral
    - Hyperspectral
  - Active
    - Microwave (RADAR)
    - Laser (LIDAR)
    - Acoustic (SONAR)

Data-to-Information Conversion

- **Analog (Visual) Image Processing**
  - Using the *Elements of Image Interpretation*
- **Digital Image Processing**
  - Radiometric and geometric correction
  - Enhancement
  - Photogrammetric analysis
  - Parametric (e.g., Maximum likelihood)
  - Nonparametric (e.g., Artificial NN)
  - Nonmetric (e.g., Expert systems)
  - Hyperspectral analysis
  - Change detection
  - Scientific geovisualization
- **Hypothesis Testing**
  - Accept or reject hypothesis

Information Presentation

- **Image Metadata**
  - Sources
  - Processing lineage
- **Accuracy Assessment**
  - Geometric
  - Thematic
  - Change detection
- **Analog and Digital**
  - Orthoimages
  - Thematic maps
  - GIS databases
  - Animations
  - Simulations
- **Statistics and Graphs**

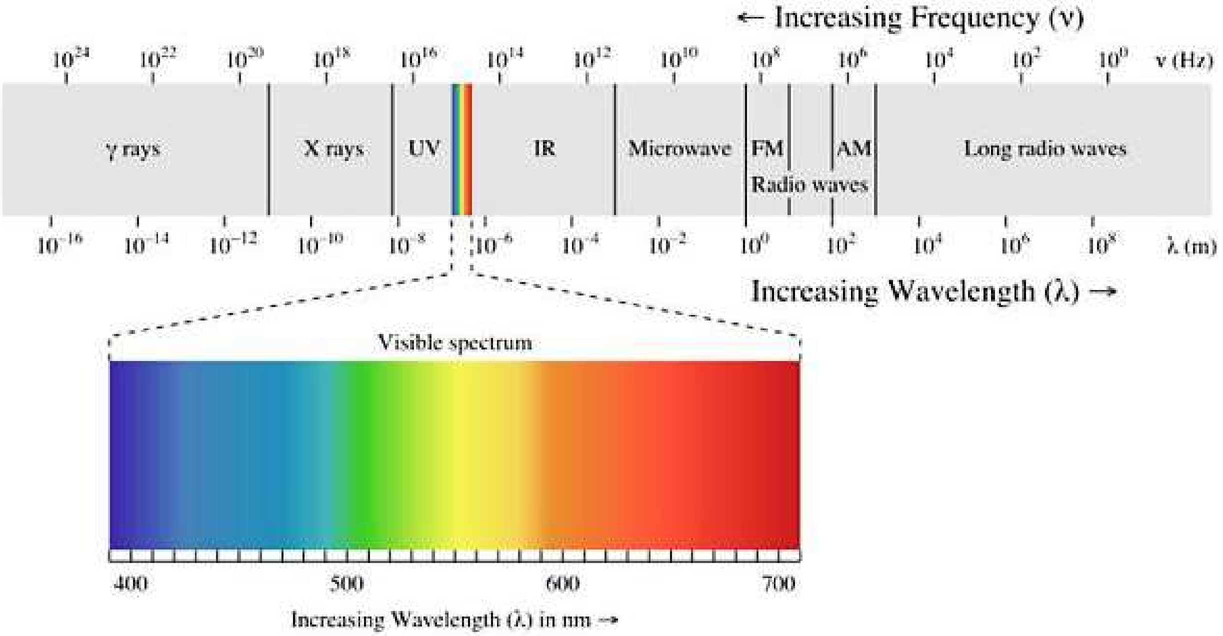
2.PHYSICAL PRINCIPLES

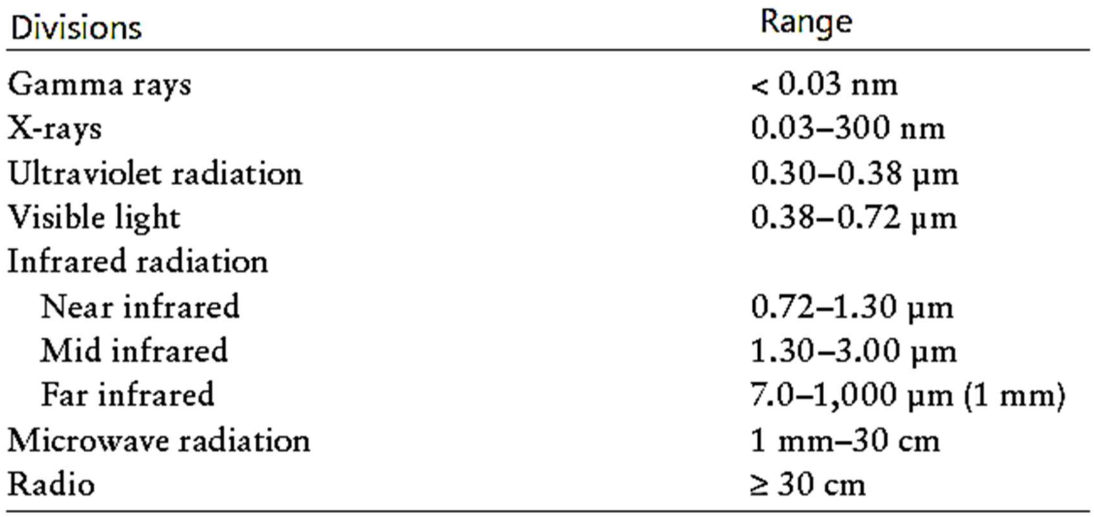
Basic principle involved in remote sensing methods is that in different wavelength ranges of the electromagnetic spectrum each type of object reflects or emits a certain intensity of light, which is dependent upon the physical or compositional attributes of the object.

Electromagnetic radiation is the flow of energy at the universal speed of light through free space or a medium in the form of electric and magnetic fields.

In an electromagnetic wave, time varying electric and magnetic fields are mutually linked with each other at right angles and perpendicular to direction of motion.

- Electromagnetic energy can be generated by – change in the energy levels of electrons, acceleration of electrical charges, decay of radioactive substance, thermal motion of atoms and molecules etc.
- Definition: The entire range of wavelengths or frequencies of electromagnetic radiation
- The spectrum ranges from short wavelength gamma rays to long wavelength radio-waves.
- Major divisions of Electromagnetic spectrum





Divisions	Range
Gamma rays	< 0.03 nm
X-rays	0.03–300 nm
Ultraviolet radiation	0.30–0.38 μm
Visible light	0.38–0.72 μm
Infrared radiation	
Near infrared	0.72–1.30 μm
Mid infrared	1.30–3.00 μm
Far infrared	7.0–1,000 μm (1 mm)
Microwave radiation	1 mm–30 cm
Radio	≥ 30 cm

- Nuclear reactions within the Sun produce a full spectrum of electromagnetic radiation, i.e., from gamma rays to radio-waves.

2.1 Nature of EM radiation

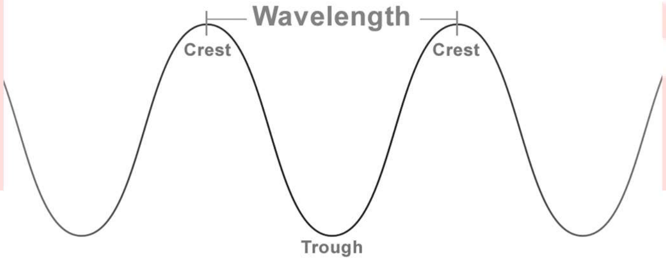
There are two electromagnetic radiation models

- Wave model
- Particle model

These models describe that the electromagnetic radiation or light has dual behavior – wave like behavior and particle like behavior.

2.1.1Wave model

- In the wave model says electromagnetic radiation (or simply light) travel as a wave.
- In an electromagnetic wave, time varying electric and magnetic fields are mutually linked with each other at right angles and perpendicular to the direction of motion, as shown in the above diagram.
- Wavelength (λ): The distance from one crest (or trough) to the next.

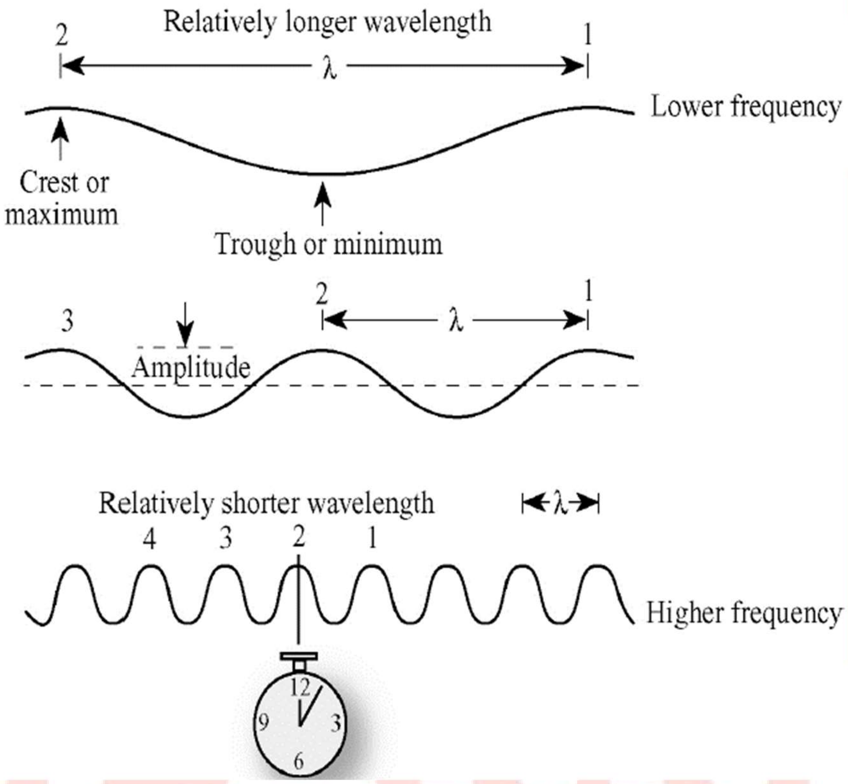


Unit: nanometer(nm), micrometer (μm), Armstrong (A^o)

- Frequency (ν): Number of crest (or trough) passing a fixed point in a given period of time
  Unit: hertz
  hertz is one cycle per second, i.e., one wave passing through a point in one second.
- Amplitude: The vertical distance between the tip of a crest and the wave's central axis is known as its amplitude. This is the property associated with the brightness, or intensity, of the wave.

$$c = \lambda.\nu$$

- Where c is the speed of light.
- The above equation defines that frequency, ν, is inversely proportional to wavelength, λ.
- The longer the wavelength, the lower the frequency, and vice-versa
- The inverse relation ship between frequency and wavelength is defined in the below picture



- The longer the wavelength the lower the frequency; the shorter the wavelength, the higher the frequency. The amplitude of an electromagnetic wave is the height of the wave crest above the undisturbed position. Successive wave crests are numbered 1, 2, 3, and 4. An observer at the position of the clock records the number of crests that pass by in a second. This frequency is measured in cycles per second, or Hertz.

2.1.2 Particle model

- Particle model suggests that light can be also considered as a beam of particles. These particles or units are called tiny packages (or quanta) energy or photons.
- The size of each unit is directly proportional to the frequency of the radiation.

$$Q = h.v$$

Where, Q is the energy of a quantum (in joules), h is the Planck constant (6.626×10^{-34} J s), and v is the frequency of the radiation.

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

Thus, the energy of a quantum is inversely proportional to its wavelength, i.e., the longer the wavelength involved, the lower its energy content.

- This model explains the photoelectric effect, the generation of electric currents by the exposure of certain substances to light, as the effect of the impact of photons on surfaces of certain metals, causing emission of electrons.

2.2 Radiation Laws

2.2.1 Planck's Radiation law

The law states that energy associated with electromagnetic radiation is composed of discrete quanta of energy, each quantum equal to Planck's constant times the corresponding frequency of the radiation

$$M_\lambda = \frac{2hc}{\lambda^5\left[e^{\left(\frac{hc}{\lambda kT}\right)}-1\right]}$$

$M_\lambda \rightarrow$ Radiance (Planck function), $\mathrm{Wm^{-2}Sr^{-1}}\ \mu m^{-1}$

h $\rightarrow$ Planck's constant = 6.626×10^{-34}Js

c $\rightarrow$ speed of light = $2.997925 \times 10^{8}\mathrm{ms^{-1}}$

k $\rightarrow$ Boltzmann's constant=$1.381 \times 10^{-23}\mathrm{JK^{-1}}$

λ $\rightarrow$ wavelength, m

T $\rightarrow$ temperature, K

2.2.2 Stefan–Boltzmann law

Using the wave model, it is possible to characterize the energy of the Sun which represents the initial source of most of the electromagnetic energy recorded by remote sensing systems (except RADAR and LIDAR)

Stefan–Boltzmann law defines the relationship between the total emitted radiation(M) and absolute temperature (T)

$$M = \sigma T^4$$

Unit of M → Wm^{-2}, T → kelvin (K)

σ is the Stefan-Boltzmann constant, which is $5.67 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$

2.2.3 Emissivity (ε)

Emissivity is defined as the ratio of the energy radiated from a material's surface (M_r) to that radiated from a perfect emitter, known as a blackbody, (M_b) at the same temperature and wavelength.

$$\varepsilon = \frac{M_r}{M_b}$$

2.2.4 Wien's displacement law

Wien's displacement law defines the relationship between the wavelength of radiation emitted and the temperature of a blackbody

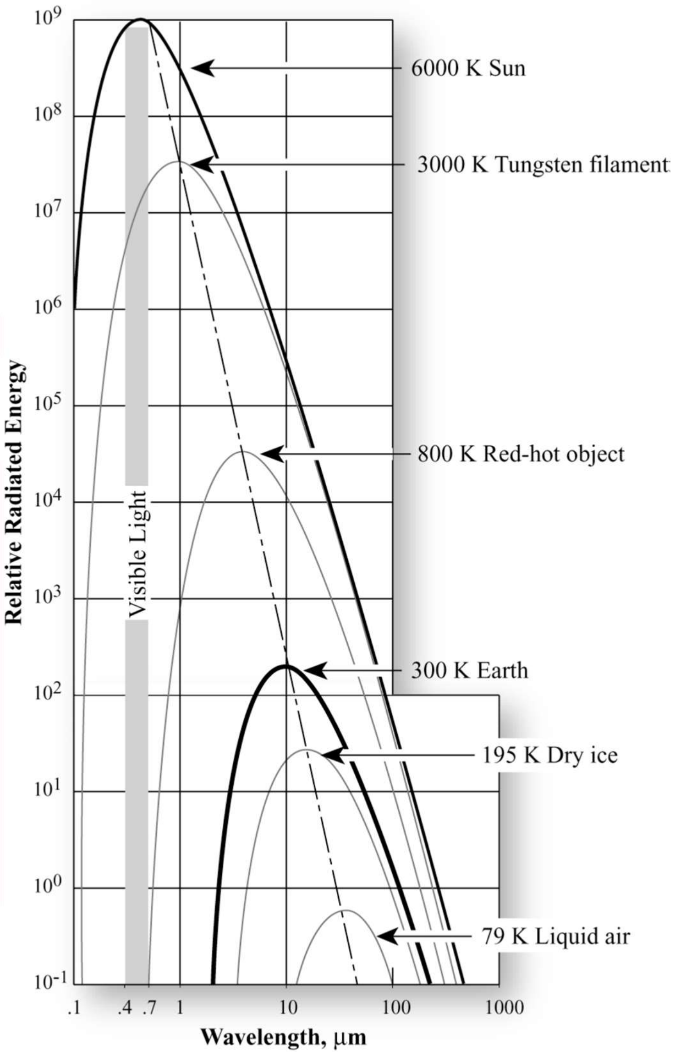
Dominant wavelength (λ_{max}) is inversely proportional to true temperature of a blackbody (T) in Kelvin.

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

Where, k is 2898µm K.

2.2.5 Blackbody radiation curves

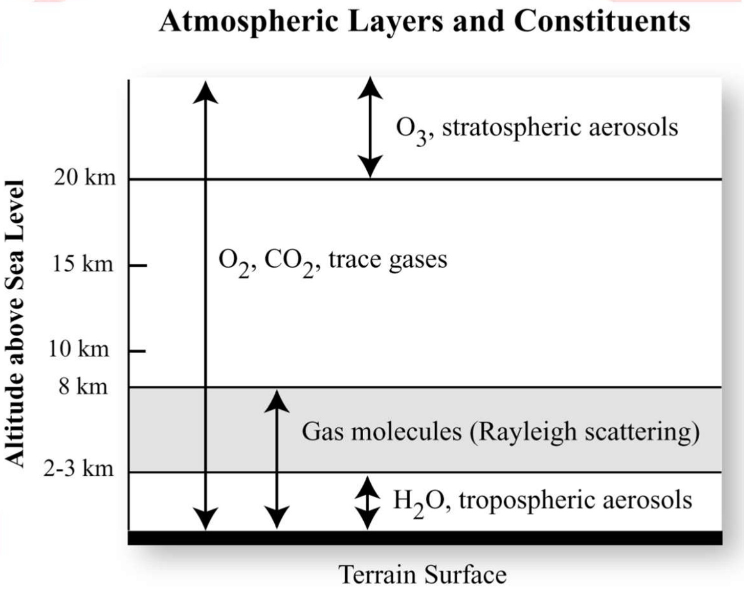
Blackbody radiation curves for several objects including the Sun and the Earth which approximate 6,000 K and 300K blackbodies, respectively. The area under each curve may be summed to compute the total radiant energy (Mb) exiting each object. Thus, the Sun produces more radiant exitance than the Earth because its temperature is greater. As the temperature of an object increases, its dominant wavelength (λmax) shifts toward the shorter wavelengths of the spectrum.



The Sun approximates a 6,000 K blackbody with a dominant wavelength of 0.48 µm (green light). Earth approximates a 300K blackbody with a dominant wavelength of 9.66 µm . The 6,000 K Sun produces 41% of its energy in the visible region from 0.4 - 0.7 µm (blue, green, and red light). The other 59% of the energy is in wavelengths shorter than blue light (<0.4 µm) and longer than red light (>0.7 µm). Our eyes are only sensitive to light from the 0.4 to 0.7 µm. Remote sensor detectors can be made sensitive to energy in the non-visible regions of the spectrum

2.3 EM radiation Interaction with atmosphere

- The electromagnetic radiation can be scattered, absorbed, reflected or refracted.



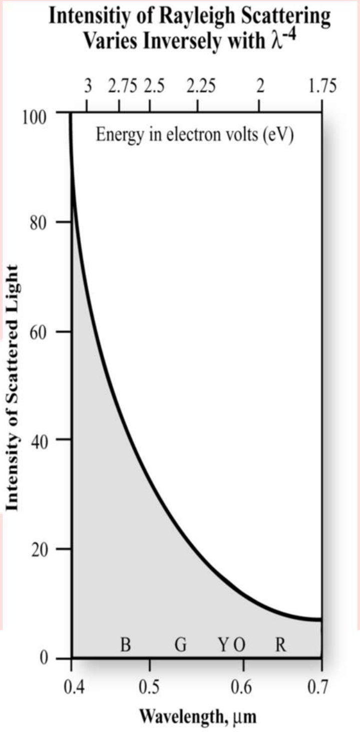
2.3.1 Scattering

- Scattering is the phenomenon in which the light (electromagnetic radiation) is deflected in multiple paths while interacting with atmosphere.
- It differs from reflection in way that the directions of the deflected rays of light are difficult to predict. But the directions of reflected rays are easy to predict.
- There are three types of scattering – Rayleigh, Mie and Non-selective scattering.
- The classification is based on the relationship between wavelength of the light and the diameter of the particle in the atmosphere it encounters.

2.3.1.1 Rayleigh Scattering

- When diameter of the particle is several times smaller than the wavelength of the incident radiation Rayleigh scattering occurs.
- Rayleigh scattering cross section - the approximate amount of Rayleigh scattering, τ_m

$$\tau_m = \frac{8\pi^3(n^2-1)^2}{(3N^2\lambda^4)}$$



Where, n = refractive index, N = number of air molecules per unit volume and λ=wavelength

This formula shows a relationship between Rayleigh scattering amount and wavelength of radiation.

$\tau_m \alpha \frac{1}{\lambda^4}$, the amount of Rayleigh scattering is inversely proportional to the fourth power of the wavelength.

- Blue color of the sky in daylight is because of Rayleigh scattering
  Rayleigh scattering is more effective at short wavelengths (the violet-blue end of the visible spectrum). Therefore, the light scattered down to the earth at a large angle with respect to the direction of the sun's light is predominantly in the blue end of the spectrum. Though the atmospheric particles scatter violet more than blue, the sky appears blue, because our eyes are more sensitive to blue light and because some of the violet light is absorbed in the upper atmosphere.
- Red color of the sky in the sunset is also due to Rayleigh scattering
  At sunset the same things happen, but because of the angle of the sun and the volume of gas and therefore the density of gas that the light passes through changes, the sky takes on a reddish glow from the longer wavelengths in the visible light spectrum

2.3.1.2 Mie scattering

- Mie scattering occur when the wavelength of the radiation is approximately equal to the diameter of the spherical particle it encounters.
- The amount of scatter is greater than Rayleigh scattering
- Mie scattering is not strongly wavelength dependent like Rayleigh scattering
- It gives the white light from mist and fog.
- Pollution also contributes to beautiful sunsets and sunrises due to Mie scattering

2.3.1.3Non-selective scattering

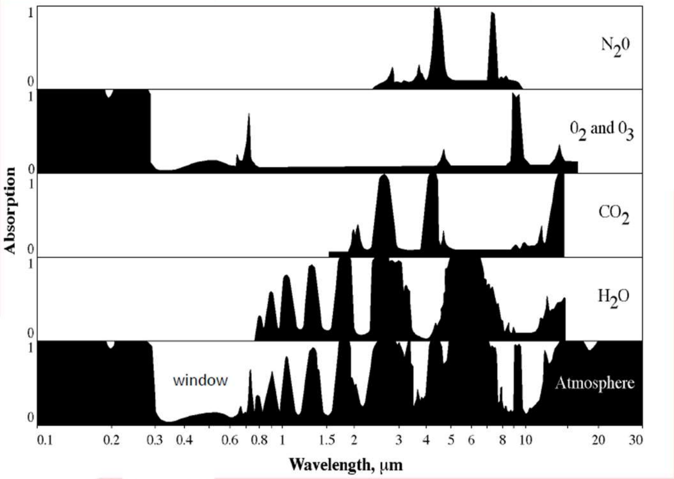
- When the diameter of the particle are several times greater than the wavelength of electromagnetic radiation, non-selective scattering occurs.
- In this type of scattering, all the wavelengths of the light are scattered equally.
- Example: Non-selective scattering occurs when the light enters a water droplet (whose diameter is greater than the wavelength of the light) in the cloud. So all the wavelength of the light are scattered equally and the cloud appear as white.

- Scattering is NOT good for Remote sensing because it reduces the amount of radiation reaching the Earth surface.

2.3.2 Absorption

- Different gases in the atmosphere causes absorption of electromagnetic radiation (light).
- In the process absorption electromagnetic radiation is absorbed and converts into other forms of energy, like heat.
- The major gases that cause absorption are H_2O, CO_2, O_2, O_3, N_2O etc.
- Such absorption of light in the atmosphere causes closedown of certain regions of the spectrum.
- Absorption is NOT good for Remote sensing.

The absorption of the Sun's incident electromagnetic energy in the region from 0.1 to 30µm by various atmospheric gases. The first four graphs depict the absorption characteristics of N2O, O2 and O3, CO2, and H2O, while the final graphic depicts the cumulative result of all these constituents being in the atmosphere at one time. The atmosphere essentially "closes down" in certain portions of the spectrum while "atmospheric windows" exist in other regions that transmit incident energy effectively to the ground. It is within these windows that remote sensing systems must function.



The combined effects of atmospheric absorption, scattering, and reflectance reduce the amount of solar irradiance reaching the Earth's surface at sea level

2.3.2.1 Atmospheric windows

- Atmosphere does not absorb all the incident radiation in some parts of the electromagnetic spectrum, but transmit it. Such parts of the spectrum are called atmospheric windows.
- Example: Visible region of the spectrum (0.4 µm to 0.7 µm)
- These atmospheric windows are range of wavelengths which is used for Remote sensing.