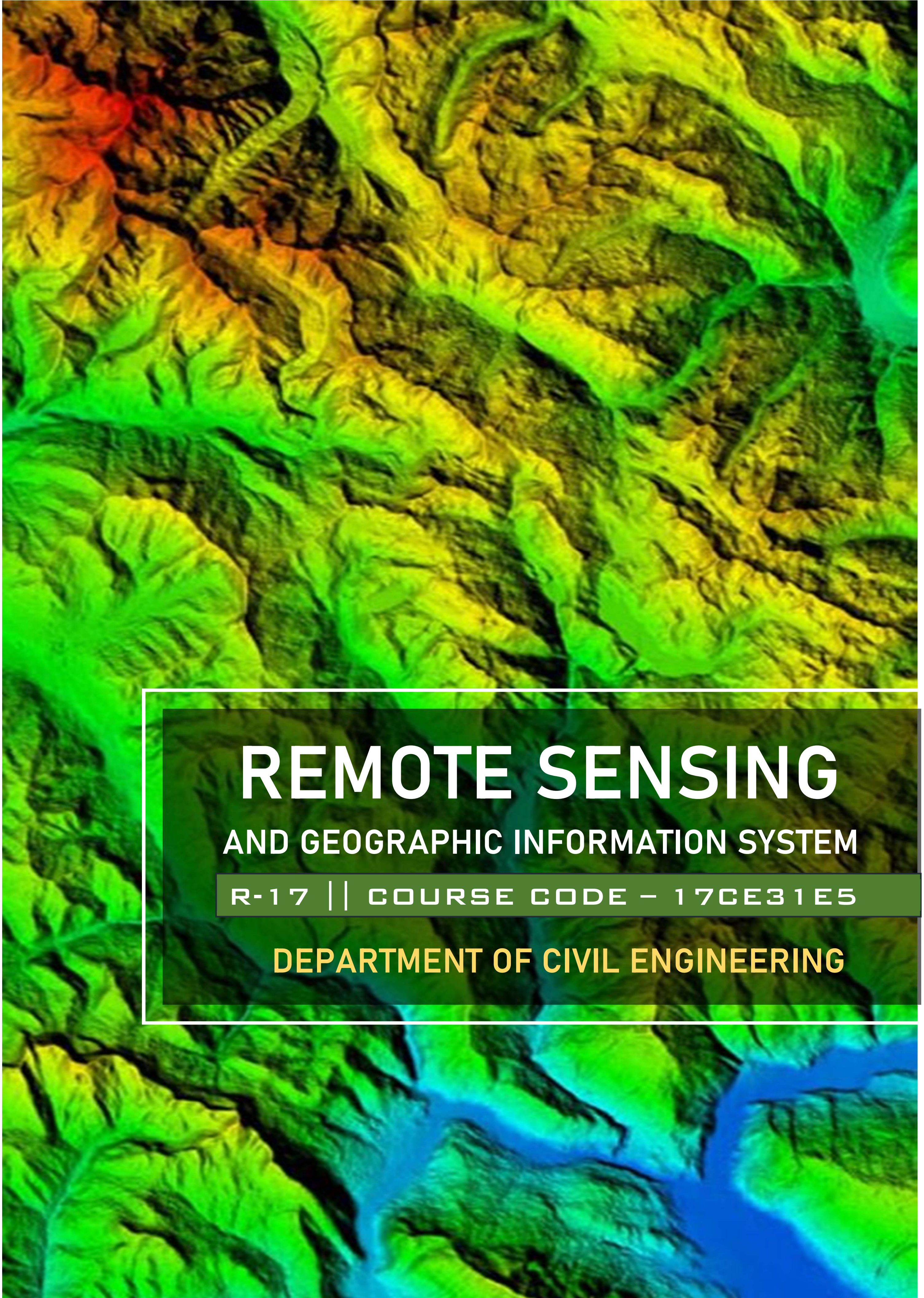


REMOTE SENSING

AND GEOGRAPHIC INFORMATION SYSTEM

R-17 || COURSE CODE – 17CE31E5

DEPARTMENT OF CIVIL ENGINEERING

MODULE – 1 : FUNDAMENTALS OF RS

Course objective	To introduce the basic principles of Remote Sensing and GIS techniques
Content	**FUNDAMENTALS:** Definition – History – Physics of remote sensing – Electromagnetic radiation – Interaction of electromagnetic radiation with atmosphere, earth surface features – Vegetation, soil and water – Spectral signature – Atmospheric windows.
Course outcome	Understand remote sensing terms and concepts of the physical applications of such a system.

Remote Sensing:

It is science of acquiring information about the earth's surface without actually being in contact with target.

This is done by sensing and recording reflected or emitted energy and processing, analysing.

Remote sensing provides flexibility to observe large area at finer spacial and temporal frequencies.

History: The development of remote sensing over time can be broadly divided into following 3 phases.

1. The early age (1839-1907)
2. The middle age (1908-1945)
3. The modern age (1946 onwards)

Early age (1839-1907):

- In 1840 the director of Paris observatory advocated the use of photography for topographic surveying and that time balloon photography flourished.
- In 1858 gasper Felix photographed the house of French village from a balloon at a height of 80m.
- After 2 years in 1860, Nadar took aerial photos of the enemy troop moments for the French army during the Franco-Prussian war-I.
- Later cameras moved from balloons to kites and other platforms.

- In 1903 Julius Neubronne patented a breast mounted camera for pigeons, which are capable to expose automatically at 30-second intervals. But pigeons were not well accepted remote sensing platforms.
- In 1906 Albert maul used a rocket, powered by compressed air to lift a camera and took an aerial photograph from height of 2,600ft.

The middle age (1908-1945):

- First time aeroplane was used as a platform to obtain aerial photography was in 1908 first aerial motion picture was recorded in Italy by Wilbur wright.
- The camera strobe was first developed by Dr. Edgerton to take pictures at night during world war-II(1940)
- World war-II brought more sophisticated techniques in aerial photo interpretation as well which was widely used for military intelligence purposes. And it gave real boots to photo interpretation; some notable successes from the war are identification of radar, water depth detectors, and vegetation indicators.

The modern age (1946 onwards):

- A commission on the utilization of aerial photographs was set up by International Geographical Union (IGU) in 1949.
- The members of the commission emphasized the need of knowledge of those parts of world which were not earlier photographed and also attention was given to cover more area by aerial photographs and techniques essential for interpretation.
- The techniques of photo interpretation became much more an applied technique. A number of instruments was developed and introduced for interpretation during this period. It opened a new horizon for accurate and fast analysis and also for monitoring the changes.
- Hence a considerable advanced interpretation was made in many disciplines such as Geography, Geology, Geophysics, Agriculture and Archaeology. This phase is very significant in the history of Remote

Sensing as artificial satellites were launched in the space for acquiring information of earth surface.

- Though two American satellites, i.e. Explorer I and II were launched in 1958 and 1959 respectively under Explorer and Discover Programme, they were not important from Remote Sensing point of view.
- On 1st April, 1960, one satellite of eight members of TIROS (Television and Infrared Observation Satellites) family was launched as a research and development project. ***As TIROS's name suggested, the satellite carried two types of sensing devices – firstly, television, camera etc. which took picture of the visible spectrum; and secondly, infrared detectors*** which measured the non-visible part of spectrum and provided information of local and regional temperature of earth's surface.
- The supply of remotely sensed data of earth surface was greatly increased with the launching of ERTS-I (Earth Resources Technology Satellite) on 23rd July, 1972. It was placed in a sunsynchronous polar orbit about 600 miles above the earth surface. It makes 14 revolutions in a day around the earth and its sensors were covering a series 160 kms. wide strip.
- Then it was followed by ERTS-2 in 1975. With the launch of this satellite, the name of these satellites has been changed from ERTS-1, 2 to LANDSAT-1, 2 respectively. Four other satellites in these series were launched one after another in this phase, with improved cameras and sensors. Beside this, many other satellites were launched in the space by European and Asian Countries during this period.
- In this period, ***Remote Sensing technique has been improved in two ways. Firstly, there have been developments of sensors which can use infrared and microwave spectrum other than visible spectrum to get information about earth's surface***.
- ***Secondly, there have been very important advances with respect to the platforms in which sensors are mounted***. Besides, satellites have been launched for specific purposes and with specific capability. The ground resolution is continuously increasing till today. Hence, interpretation and mapping is becoming very easy, accurate and purposive.
- The European Radar satellite (ERS-I) launched in 1991 opened the avenue for systematic global observation in the microwave region.
- The French Satellite 'SPOT' is producing the imagery to provide the three dimensional view under stereoscope.

- The satellite – IKONOS, launched on 24th September, 1999 has 1 m. resolution in panchromatic and 4 m. resolution in multi-spectral cameras.
- USA, France and India have planned and launched a series of satellites, with improved capability, so that the users are assured continuity of data.

Passive/ Active Remote Sensing:

Depending on the source of electromagnetic energy, remote sensing can be classified as passive or active remote sensing.

Passive remote sensing:

- Source of energy is that naturally available such as the Sun.
- Most of the remote sensing systems work in passive mode using solar energy as the source of EMR.
- Solar energy reflected by the targets at specific wavelength bands are recorded using sensors onboard air-borne or space borne platforms.
- In order to ensure ample signal strength received at the sensor, wavelength / energy bands capable of traversing through the atmosphere, without significant loss through atmospheric interactions, are generally used in remote sensing
- Any object which is at a temperature above 0^0 K (Kelvin) emits some radiation.
- Passive sensors can also be used to measure the Earth's radiance but they are not very popular as the energy content is very low.

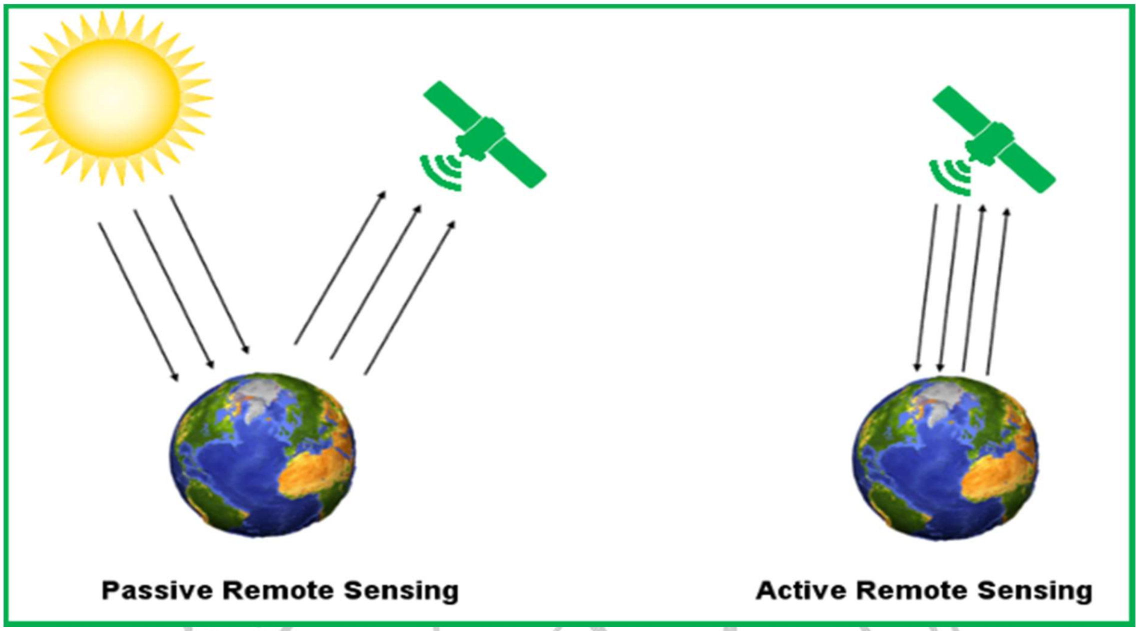
  Example: passive remote sensing is similar to taking a picture with an ordinary camera

Active remote sensing:

- Energy is generated and sent from the remote sensing platform towards the targets.
- The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform.

  Most of the microwave remote sensing is done through active remote sensing.

Example: Active remote sensing is analogous to taking a picture with camera having built-in flash



Remote sensing process:

1. Radiation by energy source.
2. Interaction of energy with atmosphere.
3. Interaction of EMR with the object /target.
4. Interaction of energy with atmosphere again.
5. Recording of energy by the sensor.
6. Transmission, reception and processing.
7. Interpretation and analysis.
8. Application.

1) **Radiation by energy source:**

❖ In remote sensing technique, electromagnetic radiations emitted / reflected by the targets are recorded at remotely located sensors and these signals are analysed to interpret the target characteristics.

❖ Characteristics of the signals recorded at the sensor depend on the characteristics of the source of radiation / energy, characteristics of the target and the atmospheric interactions.

Source of energy:

Sun is natural source of energy. Artificial sources also used in remote sensing. Whether the energy is radiated from an external source or emitted from object itself it is in the form of EMR.

Electromagnetic Energy:

"Electromagnetic (EM) energy includes all energy moving in a harmonic sinusoidal wave pattern with a velocity equal to that of light. Harmonic pattern means waves occurring at frequent intervals of time.

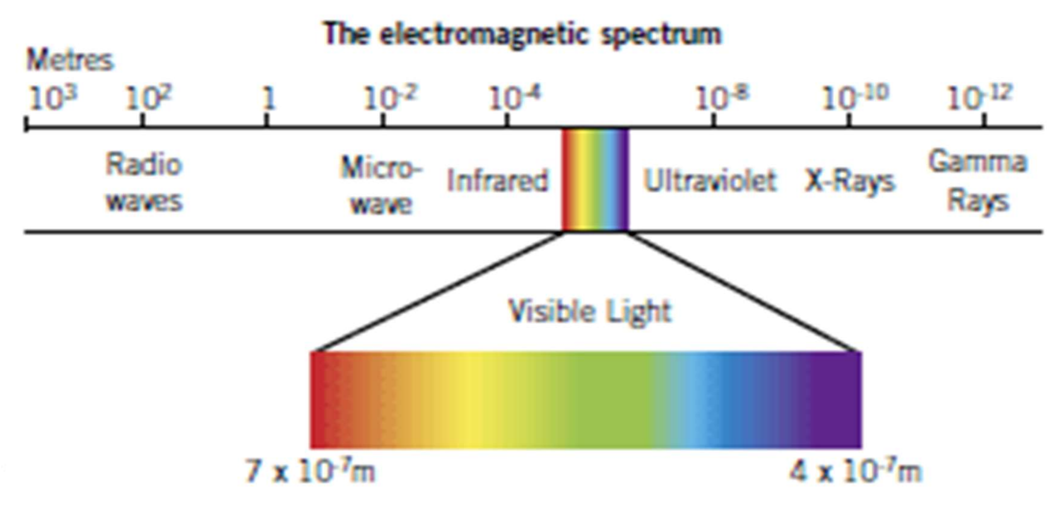
Electromagnetic energy has both electric and magnetic components which oscillate perpendicular to each other and also perpendicular to the direction of energy propagation"

Concept of EMR can be described by using 2 different models

Wave model and ***Particle model.***

Electromagnetic spectrum:

- ✓ Distribution of radiant energy can be plotted as a function of wavelength (or frequency) and is known as the electromagnetic radiation (EMR) spectrum.
- ✓ EMR spectrum is divided into regions or intervals of different wavelengths and such regions are denoted by different names.
- ✓ The EM spectrum ranges from gamma rays with very short wavelengths to radio waves with very long wavelengths.



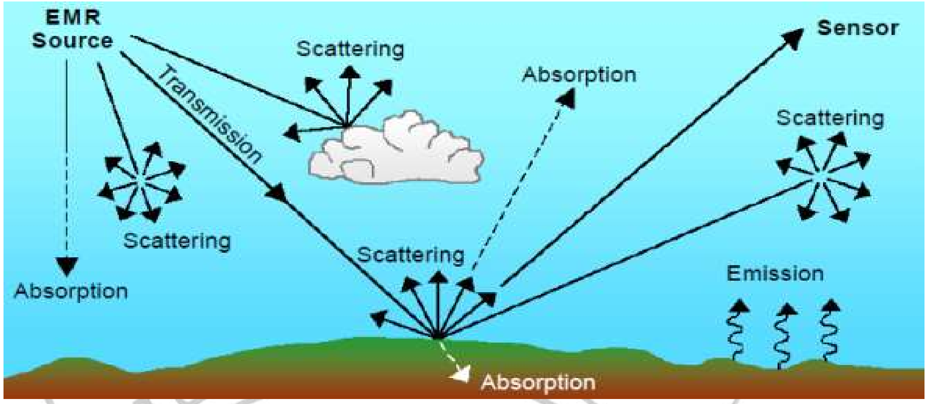
- ✓ The visible region (human eye is sensitive to this region) occupies a very small region in the range between 0.4 and 0.7 μm. The longest visible wavelength is red and the shortest wavelength is violet. However blue, green, red are primary colours or wavelengths of the visible spectrum.
- ✓ Remote sensing is generally performed within the range of ultraviolet to microwave region.

- ✓ Different bands of electromagnetic spectrums are used for different types of remote sensing.
- ✓ Gamma rays are not available for remote sensing. Incoming radiation is absorbed by the atmosphere.
- ✓ X-ray are also not available for remote sensing since it is absorbed by atmosphere.
- ✓ Ultraviolet (UV) rays 0.03 - 0.4 Wavelengths less than 0.3 are absorbed by the ozone layer in the upper atmosphere. Wavelengths between 0.3-0.4 μm are transmitted and termed as "Photographic UV band".
- ✓ Visible 0.4 - 0.7 detectable with film and photo detectors. Hence this is used for aerial remote sensing
- ✓ Infrared (IR) 0.7 – 100 atmospheric windows exist which allows maximum transmission. Portion between 0.7 and 0.9 μm is called photographic IR band, since it is detectable with film.
- ✓ Microwave can penetrate rain, fog and clouds. Both active and passive remote sensing is possible. Radar uses wavelength in this range.
- ✓ Radio have the longest wavelength. Used for remote sensing by some radars.

2) Interaction of energy with atmosphere:

- ❖ EMR is generated first it is propagated through the vacuum and through the earths atmosphere.
- ❖ In vacuum EMR travels with speed of light with any change in its property.
- ❖ But when it enters into earth's atmosphere it may affect not only in speed of radiation but also its wavelength, its intensity, and spectral distribution.
- ❖ Because atmosphere consists of presence of different types gases in addition to gases, the atmosphere also contains water vapour, methane, dust particles, pollen from vegetation, smoke particles etc. Size of these particles in the atmosphere varies from approximately 0.01μm to 100μm.
- ❖ The gases and the particles present in the atmosphere cause scattering and absorption of the electromagnetic radiation passing through it. These Scattering and absorption are the main processes that alter the properties of the electromagnetic radiation in the atmosphere.

❖ EMR also diverted its original path due to refraction.



Scattering:

✓ Scattering is unpredictable diffusion of radiation by particles in the atmosphere.
✓ It occurs when particles or large gas molecules present in the atmosphere interacts with EMR and causes to be redirected from its original path.
✓ Amount of scattering depends on several factors like wavelength of the radiation, diameter of particles or gaseous particles, and the distance the distance travelled through atmosphere.

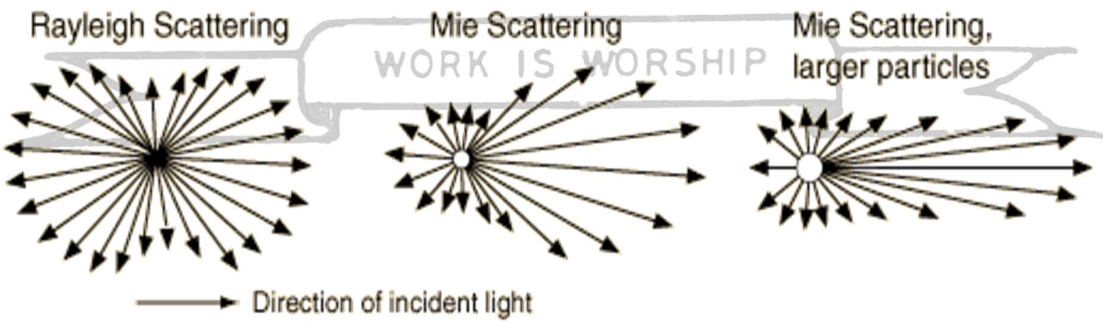
There are three different types of scattering:

 Selective

 Non-selective scattering

In **selective** scattering again there are 3 different types

 Rayleigh scattering Mie scattering Raman scattering



- **Rayleigh scattering**

  - This occurs when the particles causing the scattering are much smaller in diameter (less than one tenth) than the wavelengths of radiation interacting with them.
  - Smaller particles present in the atmosphere scatter the shorter wavelengths more compared to the longer wavelengths.
  - Rayleigh scattering is also known as selective scattering or molecular scattering.
  - Within the visible range, smaller wavelength blue light is scattered more compared to the green or red. The blue light is scattered around 4 times and UV light is scattered about 16 times as much as red light.

- **Mie scattering**

  - When the wavelengths of the energy is almost equal to the diameter of the atmospheric particles.
  - Mie scattering is usually caused by the aerosol particles such as dust, smoke and pollen. Actual size of particle may varies from 0.1 to 10 times of wavelength of incident energy.
  - This scattering happens lower 4.5km of the atmosphere.

- **Raman scattering**

  - This also caused by atmospheric particles, which are larger, smaller, or equal to the that of the wavelength the radiation.

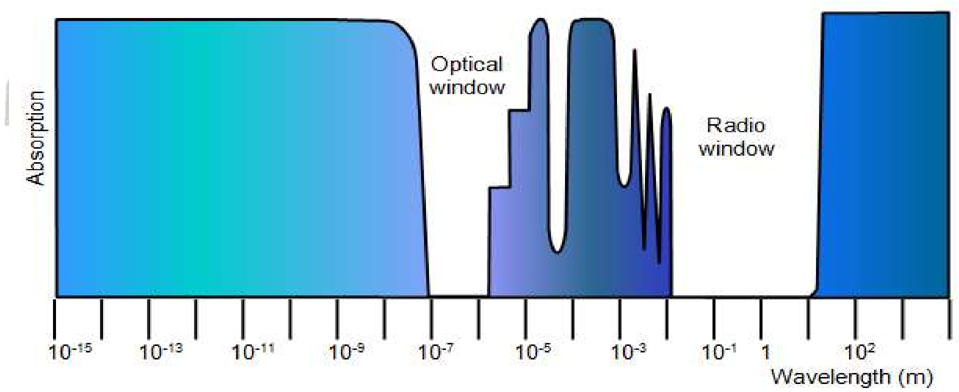
- **Non-selective scattering:**

  - This takes place in the lowest portions of the atmosphere where air particles greater than 10 times the wavelength of the incident EMR.
  - Particles such as pollen, cloud droplets, ice crystals and raindrops can cause non-selective scattering of the visible light.
  - For visible light (of wavelength 0.4-0.7μm), non-selective scattering is generally caused by water droplets which is having diameter commonly in the range of 5 to 100 μm. This scattering is non-selective with respect to wavelength since all visible and IR wavelengths get scattered equally.

Absorption:

- Radiant energy is absorbed and converted into other forms of energy.

- The absorbing medium will not only absorb a portion of the total energy, but will also reflect, refract or scatter the energy.
- The most efficient absorbers of solar radiation are water vapour, carbon dioxide, and ozone.
- Even though all the wavelengths from the Sun reach the top of the atmosphere, due to the atmospheric absorption, only limited wavelengths can pass through the atmosphere. The ranges of wavelength that are partially or wholly transmitted through the atmosphere are known as "***atmospheric windows***."
- Remote sensing data acquisition is limited through these atmospheric windows.
- It can be observed that electromagnetic radiation at different wavelengths is completely absorbed, partially absorbed or totally transmitted through the atmosphere.
- In the visible part of the spectrum, little absorption occurs.



- Infrared (IR) radiation is mainly absorbed due to the ***rotational and vibrational transitions of the molecules***. The main atmospheric constituents responsible for infrared absorption are water vapour (H_2O) and carbon dioxide (CO_2) molecules. Most of the radiation in the far infrared region is also absorbed by the atmosphere.
- However, absorption is almost nil in the microwave region.

Refraction:

- ✓ When EMR passed through different substances of different densities, like air and water, refraction takes place.
- ✓ Refraction is nothing but bending of light when it passes from one medium to another medium of different densities.

- ✓ Errors in location due to refraction can occur in images formed from energy detected at high altitude.
- ✓ However these errors are predictable by snell's law and can be removed.
  $n_1 \sin a1 = n_2 \sin a2$

Reflection:

- ❖ Whereby radiation "*bounces off* "an object like cloud, water body.
- ❖ Reflection is different from scattering. Where angle of incident and reflection all lie in same plane. And angle of incident and reflection are approximately same.
- ❖ This results in blurred image and appearance of cloud on the imagery are main problems of atmospheric reflection.
- ❖ When electromagnetic energy is incident on the surface, it may get reflected or scattered depending upon the roughness of the surface relative to the wavelength of the incident energy.
- ❖ If the roughness of the surface is less than the wavelength of the radiation or the ratio of roughness to wavelength is less than 1, the radiation is reflected. When the ratio is more than 1 or if the roughness is more than the wavelength, the radiation is scattered.
- ❖ Variations in the spectral reflectance within the visible spectrum give the colour effect to the features.
- ❖ For example, blue colour is the result of more reflection of blue light. An object appears as "green" when it reflects highly in the green portion of the visible spectrum. Leaves appear green since its chlorophyll pigment absorbs radiation in the red and blue wavelengths but reflects green wavelengths.

3) Interaction of EMR with the object /target:

- ✓ Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the earth's surface.
- ✓ There are 3 types of interaction can take place when energy strikes, or incident upon the earth's surface. This incident electromagnetic energy may interact with the earth surface features in three possible ways: Absorption, Transmission and Reflection.
- ✓ Reflection occurs when radiation is redirected after hitting the target. According to the law of reflection, the angle of incidence is equal to the angle of reflection.

- ✓ Absorption occurs when radiation is absorbed by the target. The portion of the EM energy which is absorbed by the Earth's surface is available for emission and as thermal radiation at longer wavelengths.
- ✓ Transmission 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.
- ✓ These three processes are not mutually exclusive. Energy incident on a surface may be partially reflected, absorbed or transmitted.

Which process takes place on a surface depends on the following factors:

- Wavelength of the radiation
- Angle at which the radiation intersects the surface
- Composition and physical properties of the surface

- ✓ The relationship between reflection, absorption and transmission can be expressed through the principle of conservation of energy. Let EI denotes the incident energy, ER denotes the reflected energy, EA denotes the absorbed energy and ET denotes the transmitted energy. Then the principle of conservation of energy(one form of energy neither be created nor be destroyed but one form of energy can be converted into another form) (as a function of wavelength λ) can be expressed as

$$\mathbf{E_I (\lambda) = E_R (\lambda) + E_A(\lambda) + E_T (\lambda)} \qquad (1)$$

Since most remote sensing systems use reflected energy, the energy balance relationship can be better expressed in the form

$$\mathbf{E_R (\lambda) = E_I (\lambda) - E_A(\lambda) - E_T (\lambda)} \qquad (2)$$

The reflected energy is equal to the total energy incident on any given feature reduced by the energy absorbed or transmitted by that feature.

<u>Reflection:</u>

Types of reflections

Diffuse and Specular Reflection

Energy reflection from a surface depends on the wavelength of the radiation, angle of incidence and the composition and physical properties of the surface.

Roughness of the target surface controls how the energy is reflected by the surface. Based on the roughness of the surface, reflection occurs in mainly two ways.

i) Specular reflection:

It occurs when the surface is smooth and flat. A mirror-like or smooth reflection is obtained where complete or nearly complete incident energy is reflected in one direction. The angle of reflection is equal to the angle of incidence. Reflection from the surface is the maximum along the angle of reflection, whereas in any other direction it is negligible.

ii) Diffuse (Lambertian) reflection:

It occurs when the surface is rough. The energy is reflected uniformly in all directions. Since all the wavelengths are reflected uniformly in all directions. Hence, in remote sensing diffuse reflectance properties of terrain features are measured. Since the reflection is uniform in all direction, sensors located at any direction record the same reflectance and hence it is easy to differentiate the features.

i. Diffuse reflectors are considered ideal for remote sensing. The reflection from an ideal diffuse surface will be the same irrespective of the location of the sensor. On the other hand, in case of an ideal specular reflector, maximum brightness will be obtained only at one location and for the other locations dark tones will be obtained from the same target. This variation in the spectral signature for the same feature affects the interpretation of the remote sensing data.

ii. Most natural surfaces observed using remote sensing are approximately Diffuse at visible and IR wavelengths. However, water provides specular reflection. Water generally gives a dark tone in the image. However due to the specular reflection, it gives a pale tone when the sensor is located in the direction of the reflected energy.

- ✓ The basic property by which an object can be identified is called ***signature.***
- ✓ 3types of signatures are there spatial, spectral, and temporal.
- ✓ Temporal signature is change in reflectance with time.
- ✓ Spatial signature are arrangements of terrain features like shape, size, texture.
- ✓ Spectral signature is change in reflectance with change in wavelength. For any given material, the amount of radiation that reflects, absorbs, or transmits is varies with wavelength. This important property of matter makes it possible to identify different substances or classes and separate them by their ***spectral signatures***.
- ✓ A graph of the spectral reflectance of an object as a function of wavelength is termed as spectral reflectance curve.

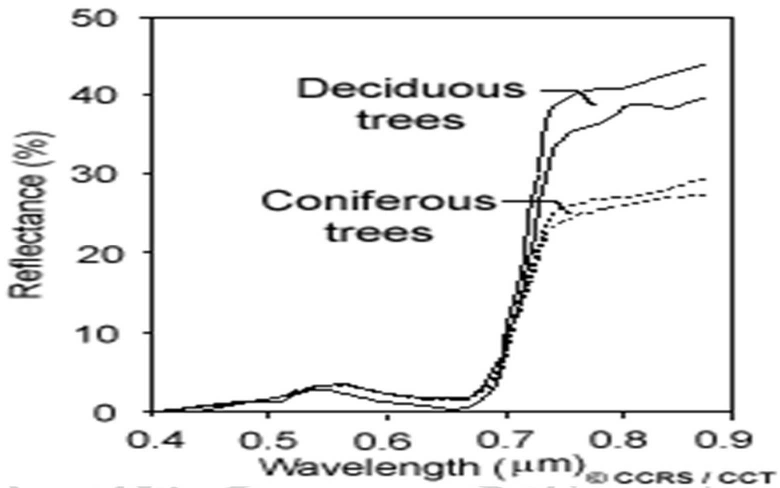
<u>Spectral Reflectance Curves</u>

- ❖ The *reflectance characteristics of earth surface features are expressed as the ratio of energy reflected by the surface to the energy incident on the surface. This is measured as a function of wavelength and is called* ***spectral reflectance*** *(R_λ). It is also known as albedo of the surface.*
- ❖ Spectral reflectance vary within a given material class.
- ❖ Spectral reflectance or albedo can be mathematically defined as

R_λ = Energy of wavelength reflected from the object*100/

Energy of wavelength incident on the object

- ✓ Albedo is low at lower incidence angle and increases for higher incidence angles.
- ✓ The energy that is reflected by features on the earth's surface over a variety of different wavelengths will give their spectral responses. "***The graphical representation of the spectral response of an object over different wavelengths of the electromagnetic spectrum is termed as spectral reflectance curve***"

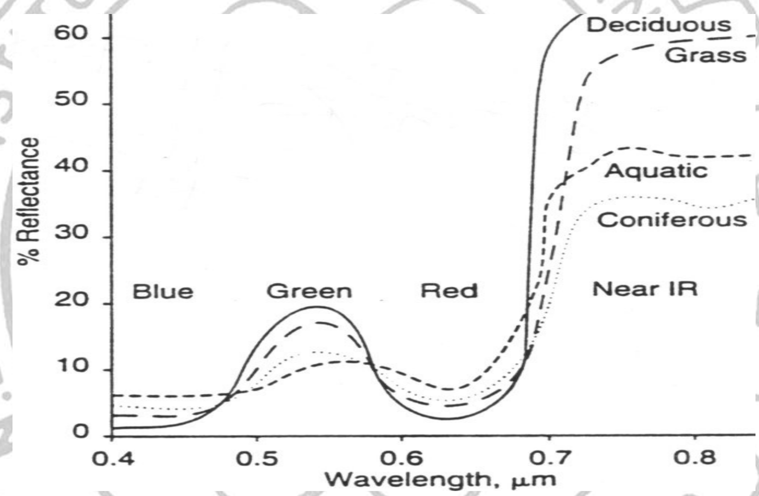


- ✓ These curves give an insight into the spectral characteristics of different objects, hence used in the selection of a particular wavelength band for remote sensing data acquisition.
- ✓ Spectral reflectance’s varies within a given material i.e., spectral reflectance of one deciduous tree will not be identical with another. **These curves help in the selection of proper sensor system in order to differentiate deciduous and coniferous trees.**
- ✓ Spectral reflectance curves for deciduous and coniferous trees spectral reflectance curves for each tree type are ***overlapping*** in most of the ***visible portion***.
- ✓ A choice of visible spectrum is not a feasible option for differentiation since both the deciduous and coniferous trees will essentially be seen in shades of green.
- ✓ A comparison of photographs taken in visible band and NIR band. In visible band, the tone is same for both trees. However, on infrared photographs, deciduous trees show a much lighter tone due to its higher infrared reflectance than conifers.
- ✓ In remote sensing, the spectral reflectance characteristics of the surface features have been used to identify the surface features and to study their characteristics. This requires basic understanding of the general reflectance characteristics of different feature.

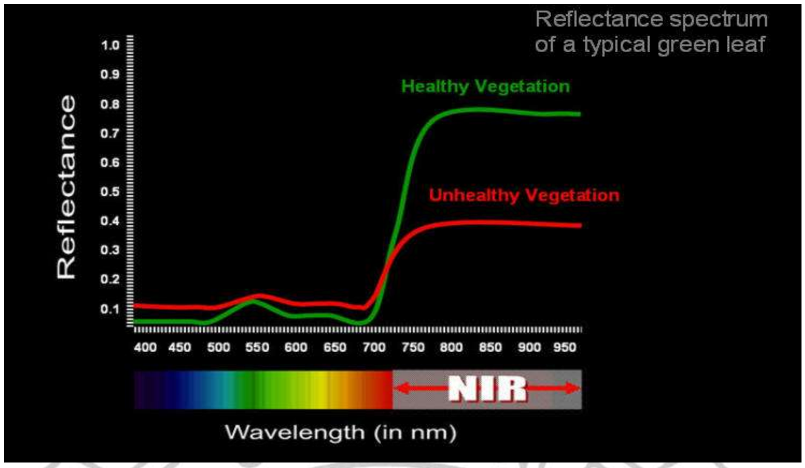
Spectral Reflectance Curve for Vegetation

- ❖ Spectral reflectance curve for healthy green vegetation exhibits the "peak-and-valley". The peaks indicate strong reflection and the valleys indicate predominant absorption of the energy in the corresponding wavelength bands.

- In general, ***healthy vegetation's are very good absorbers of electromagnetic energy in the visible region.*** The absorption greatly reduces and reflection increases in the red/infrared boundary near 0.7 µm.
- ***Spectral response of vegetation depends on the structure of the plant leaves.***
- The valleys in the visible portion of the spectrum are due to the pigments in plant leaves. The palisade cells containing sacs of green pigment (chlorophyll) strongly absorb energy in the wavelength bands centered at 0.45 and 0.67 µm within visible region.



- On the other hand, reflection peaks for the green colour in the visible region, which makes our eyes perceive healthy vegetation as green in colour. However, only 10-15% of the incident energy is reflected in the green band.
- ***In the reflected infrared portion (or near infrared, NIR) of the spectrum, at 0.7 µm, the reflectance of healthy vegetation increases dramatically.***
- In the range from 0.7 to 1.3 µm, a plant leaf reflects about 50 percent of the energy incident upon it.
- Healthy vegetation therefore shows brighter response in the NIR region compared to the green region.
- If a plant is subjected to some form of stress that interrupts its normal growth and productivity, it may decrease or cease chlorophyll production.



- ***The result is less absorption in the blue and red bands in the palisade. Hence, red and blue bands also get reflected along with the green band, giving yellow or brown colour to the stressed vegetation.***
- Also in stressed vegetation, the NIR bands are no longer reflected by the mesophyll cells, instead they are absorbed by the stressed or dead cells causing dark tones.
- Similar to the reflection and absorption, transmittance of the electromagnetic radiation by the vegetation also varies with wavelength. "Transmittance of electromagnetic radiation is less in the visible region and it increases in the infrared region".

Spectral Reflectance of Soil

- ✓ Some of the factors effecting soil reflectance are moisture content, soil texture (proportion of sand, silt, and clay), surface roughness, presence of iron oxide and organic matter content. These factors are complex, variable, and interrelated.
- ✓ For example, the presence of moisture in soil decreases its reflectance.
- ✓ Soil moisture content is strongly related to the soil texture. For example, coarse, sandy soils are usually well drained, resulting in low moisture content and relatively high reflectance. On the other hand, poorly drained fine textured soils generally have lower reflectance. In the absence of water, however, the soil itself exhibits the reverse tendency i.e., coarse textured soils appear darker than fine textured soils.
- ✓ Two other factors that reduce soil reflectance are surface roughness and the content of organic matter. Presence of iron oxide in a soil also significantly decreases reflectance, at least in the visible region of wavelengths.

Spectral Reflectance for Water

- Water provides a semi-transparent medium for the electromagnetic radiation. Thus the electromagnetic radiations get reflected, transmitted or absorbed in water.
- The spectral responses vary with the wavelength of the radiation and the physical and chemical characteristics of the water.
- *Spectral reflectance of water varies with its physical condition*: In the solid phase (ice or snow) water give good reflection at all visible wavelengths. On the other hand, ***reflection in the visible region is poor in case of water in liquid stage.*** This difference in reflectance is due to the difference in the atomic bond in the liquid and solid states.
- Water in the liquid form shows high reflectance in the visible region between 0.4µm and 0.6µm. Wavelengths beyond 0.7µm are completely absorbed. Thus clear water appears in darker tone in the NIR image.
- Locating and delineating water bodies with remote sensing data is done more easily in reflected infrared wavelengths because of this absorption property.
- The reflectance from a water body can stem from an interaction with the water's surface (specular reflection), with material suspended in the water, or with the bottom surface of the water body.
- Even in deep water, where bottom effects are negligible, the reflectance properties of a water body are not only a function of the water, but also of the material in the water Clear water absorbs relatively less energy having wavelengths shorter than 0.6 µm.
- However, as the turbidity of water changes (because of the presence of organic or inorganic materials), transmittance and therefore reflectance change dramatically.
- For example, water bodies containing large quantities of suspended sediments normally have much higher visible reflectance than clear water.
- Likewise, the reflectance of water changes with the chlorophyll concentration involved. Increase in chlorophyll concentration tends to decrease reflectance in blue wavelengths and increase reflectance in green wavelengths.
- These changes have been used in remote sensing to monitor the presence and to estimate the concentration of algae. Reflectance data have also

been used to determine the presence vegetation in lowland areas, and to detect a number of pollutants, such as oil and certain industrial wastes.

- Many important characteristics of water such as dissolved oxygen concentration, pH, and salt concentration cannot be observed directly through changes in water reflectance.
- Variation in the spectral reflectance in the visible region can be used to differentiate shallow and deep waters, clear and turbid waters, as well as rough and smooth water bodies.

4) Interaction of energy with atmosphere again:

The radiant flux reflected or emitted from the earth's surface once again enter the atmosphere, where it interacts with different gases, water vapours. Thus atmospheric scattering, absorption, reflection and refraction influences the radiant flux once again before recorded the sensor.

5) Recording of energy by the sensor:

- Radiant energy recorded by the camera or detector is a true function of the amount of radiance leaving the terrain at a specific solid angle.
- Other radiant energy may enter the field of view from various other paths like atmospheric interaction, solar irradiance, sky irradiance, scattering etc., and also introduce confuse noise into the remote sensing process.
- The light from a target outside the field of view of the sensor may be scattered into the field of view of the sensor. This effect is known as ***adjacent effect***.
- Near to the boundary between two regions of different brightness, the adjacency effect results in an increase in the apparent brightness of the darker region while the apparent brightness of the brightness region is reduced.
- Only small amount of total radiance at the sensor is actually reflected by the terrain in the direction of the sensor system.
- Amount of radiance recorded by the sensor (L_s) doesn't equal to the radiance returned from the interest (L_t). Because some additional radiance from different path which may fall within field of view of the sensor system. This is called path radiance (L_p).

$$L_s=L_t+L_p$$

- This path radiance generally introduces unwanted radiometric noise in the remotely sensed data and complicates the image interpretation process. However these noises can be reduced while doing digital image processing.

6) **Transmission, reception and processing:**
   - ✓ Remotely sensed data can be collected using onboard aircraft sensors/camera and/or onboard satellite remote sensors.
   - ✓ Data obtained during airborne remote sensing missions can be retrieved once the aircraft lands. It can be processed and delivered to the end user.
   - ✓ Data collected from satellite need to be electronically transmitted to the earth. There are 2 main options for transmitting data acquired by satellites to the surface.
     - A) Data can be directly transmitted to the earth if a ground receiving station (GRS) is in the line of sight of the satellite.
     - B) If case A is not possible then data transmitted to another satellite which is same geosynchronous orbit until they reach the vicinity of appropriate ground receiving station (GRS).
   - ✓ Data received at the GRS in a raw digital format.
   - ✓ If required be processed to correct systematic, geometric, and atmospheric distortion to the imagery and be translated into a standardized image format.

7) **Interpretation and analysis:**

   Data alone cannot be used for decision making. It must be interpreted or analysed before one can extract information. Analysis of remotely sensed data is performed using a variety of image interpretation and processing techniques are categorised as ***visual image interpretation*** and ***digital image processing.***

Visual image interpretation:

Fundamental image interpretation are used in this is image analysis, including size, shape, shadow, colour, parallax, pattern, texture, site.

Digital image processing:

Information derived from remote sensor data are usually interpreted as enhancing image, image map, orthophoto map, thematic map, filtering etc.,

8) **Application:**

- ✓ Remote sensing may be used for numerous application including guidance system, medical image analysis, analysis of earth's resources etc.
- ✓ Earth resource information is like information concerning terrestrial vegetation, soil, minerals, water, and urban infrastructure as well as certain atmospheric characteristics.
- ✓ Examples remote sensing uses in civil engineering
    - **Water resources mapping:** Identification and mapping of the surface water boundaries has been one of the simplest and direct applications of remote sensing in water resources studies
    - **Estimation of watershed physiographic parameters:** Various watershed physiographic parameters that can be obtained from remotely sensed data include watershed area, size and shape, topography, drainage pattern and landforms.
    - **Estimation of hydrological and meteorological variables:** Remote sensing applications in estimating precipitation, evapotranspiration and soil moisture.
    - **Water conservation:** Rainwater harvesting, wherein water from the rainfall is stored for future usage, is an effective water conservation measure particularly in the arid and semi-arid regions.
    - **Urban and regional planning:** Our urban areas are expanding at a rapid rate mainly due to the population growth and the large scale migration from the rural areas. This urban area expansion creates additional pressure on the land, water and infrastructural resources.
    - **Identification of geothermal energy sources:** Geo-thermal energy is produced from underground reservoirs of steam or hot water. Being the most reliable, and sustainable source of energy, several studies have been ongoing to develop

technologies to tap these geo-thermal energy resources for human use.

- **Assessment of snow cover and water equivalent:** Periodic snow cover depth and extent are some of the essential information's required for snow-melt runoff forecasting. Field-based surveys for periodic monitoring of Snow covered areas (SCA) are not easy due to the difficulties in the physical access to the snow covered areas. Satellite remote sensing techniques, being operational from space-borne platforms, help to overcome the accessibility issues.
- **Groundwater studies:** Remote sensing application in the groundwater studies are generally classified into three broad areas:
  - Estimation of the geomorphologic parameters essential for the groundwater modelling
  - Estimation of the groundwater potential
  - Estimation of the groundwater storage
- **Earthquake and Tsunami studies:** Remote sensing techniques have been successfully employed for assessing the damage caused during natural calamities like earthquake and tsunami. Very high resolution remote sensing data can be used to identify the structural damage and the extent of affected areas.

✓ Along with those remote sensing applications in rainfall-runoff modelling, remote sensing applications in irrigation management, remote sensing applications in flood mapping, remote sensing applications in drought assessment, remote sensing applications in environmental monitoring are few more applications.

<u>Advantages and Disadvantages of Remote Sensing</u>

<u>Advantages of remote sensing are:</u>

a) Provides data of large areas

b) Provides data of very remote and inaccessible regions

c) Able to obtain imagery of any area over a continuous period of time, natural changes in the landscape can be analyzed

d) Relatively inexpensive when compared to employing a team of surveyors

e) Easy and rapid collection of data

f) Rapid production of maps for interpretation

Disadvantages of remote sensing are:

a) The interpretation of imagery requires a certain skill level

b) Needs cross verification with ground (field) survey data

c) Data from multiple sources may create confusion

d) Objects can be misclassified or confused

e) Distortions may occur in an image due to the relative motion of sensor and source

Ideal Remote Sensing System:

i. **A Uniform Energy Source** which provides energy over all wavelengths, at a constant, known, high level of output
ii. **A Non-interfering Atmosphere** which will not modify either the energy transmitted from the source or emitted (or reflected) from the object in any manner.
iii. **A Series of Unique Energy/Matter Interactions at the Earth's Surface** which generate reflected and/or emitted signals that are selective with respect to wavelength and also unique to each object or earth surface feature type.
iv. **A Super Sensor** which is highly sensitive to all wavelengths. A super sensor would be simple, reliable, accurate, economical, and requires no power or space. This sensor yields data on the absolute brightness (or radiance) from a scene as a function of wavelength.
v. **A Real-Time Data Handling System** which generates the instance radiance versus wavelength response and processes into an interpretable format in real time. The data derived is unique to a

particular terrain and hence provide insight into its physicalchemical-biological state.

vi. **The Multiple Data Users** The success of any remote sensing mission lies on the user who ultimately transforms the data into information. This is possible only if the user understands the problem thoroughly and has a wide knowledge in the data generation. The user should know how to interpret the data generated and should know how best to use them.

Textbook:

1. Remote sensing and GIS by **BASUDEB BHATTA**
2. Remote sensing and GIS by **Prof. Anji Reddy**

References

1. **Lilliesand and kiefer,** Remote Sensing and Image Interpretation.