Introduction to Remote Sensing

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***Abstract*—Remote sensing is a technique to observe the earth surface or the atmosphere from out of space using satellites (space borne) or from the air using aircrafts (airborne). Remote sensing uses a part or several parts of the electromagnetic spectrum. It records the electromagnetic energy reflected or emitted by the earth's surface. The amount of radiation from an object (called radiance) is influenced by both the properties of the object and the radiation hitting the object (irradiance). The human eyes register the solar light reflected by these objects and our brains interpret the colours, the grey tones and intensity variations. In remote sensing various kinds of tools and devices are used to make electromagnetic radiation outside this range from 400 to 700 nm visible to the human eye, especially the near infrared, middle-infrared, thermal-infrared and microwaves.**
Remote sensing imagery has many applications in mapping land-use and cover, agriculture, soils mapping, forestry, city planning, archaeological investigations, military observation, and geomorphological surveying, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth, etc. This paper starts with a brief historic overview of remote sensing and then explains the various stages and the basic aspects of remote sensing and geographic information systems technology.

Index Terms*—*Keywords: Remote sensing, EMS & Radiation, Spectral reflectance curve, Platform and sensors.

I. Introduction

Remote sensing (RS), also called earth observation, refers to obtaining information about objects or areas at the Earth's surface without being in direct contact with the object or area. Humans accomplish this task with aid of eyes or by the sense of smell or hearing; so, remote sensing is day-today business for people. Reading the newspaper, watching cars driving in front of you are all remote sensing activities. Most sensing devices record information about an object by measuring an object's transmission of electromagnetic energy from reflecting and radiating surfaces.
Remote sensing techniques allow taking images of the earth surface in various wavelength region of the electromagnetic spectrum (EMS). One of the major characteristics of a remotely sensed image is the wavelength region it represents in the EMS. Some of the images represent reflected solar radiation in the visible and the near infrared regions of the electromagneticspectrum, others are the measurements of the energy emitted by the earth surface itself i.e. in the thermal infrared wavelength region. The energy measured in the microwave region is the measure of relative return from the earth's surface, where the energy is transmitted from the vehicle itself. This is known as active remote sensing, since the energy source is provided by the remote sensing platform. Whereas the systems where the remote sensing measurements depend upon the external energy source, such as sun are referred to as passive remote sensing systems.

A. *Principles of Remote Sensing*

Detection and discrimination of objects or surface features means detecting and recording of radiant energy reflected or emitted by objects or surface material (Fig. 1). Different objects return different amount of energy in different bands of the electromagnetic spectrum, incident upon it. This depends on the property of material (structural, chemical, and physical), surface roughness, angle of incidence, intensity, and wavelength of radiant energy.
The Remote Sensing is basically a multi-disciplinary science which includes a combination of various disciplines such as optics, spectroscopy, photography, computer, electronics and telecommunication, satellite launching etc. All these technologies are integrated to act as one complete system in itself, known as Remote Sensing System. There are number of stages in a Remote Sensing process, and each of them is important for successful operation.

B. *Basic Processes in Remote Sensing*

1. Data acquisition (energy propagation, platforms)
2. Processing (conversion of energy pattern to images)
3. Analysis (quantitative and qualitative analysis)
4. Accuracy assessment (radiometric and geometric correction)
5. Information distribution to users

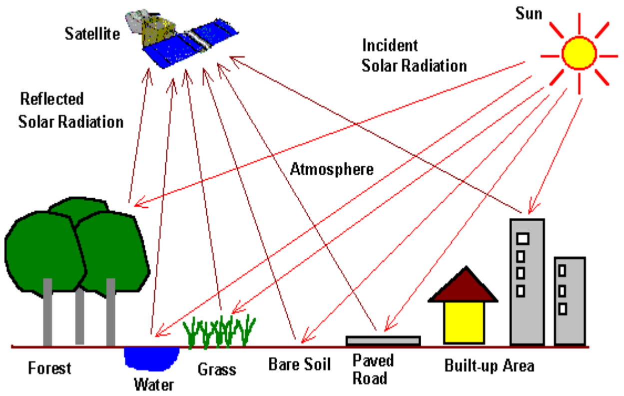


Fig1. Remote Sensing Process

C. *Stages in Remote Sensing*

- Emission of electromagnetic radiation, or **EMR** (sun/self- emission)
- Transmission of energy from the source to the surface of the earth, as well as absorption and scattering
- Interaction of **EMR** with the earth's surface: reflection and emission
- Transmission of energy from the surface to the remote sensor
- Sensor data output
- Data transmission, processing and analysis

D. *Components of Remote Sensing*

1) *Platform*: A Platform is defined as the carrier for remote sensing sensors. There are three major remote sensing platforms: ground-level platform (towers and cranes), aerial platforms (Helicopters, low altitude aircraft, high altitude aircraft), and spaceborne platforms (space shuttles, polar-orbiting satellites, and geostationary satellites).

2) *Sensors*:It is a device that receives electromagnetic radiations and converts it into a signal that can be recorded and displayed as either numerical data or an image.

E. *Historic Overview*

In 1859 Gaspard Tournachon took an oblique photograph of a small village near Paris from a balloon. With this picture the era of earth observation and remote sensing had started. His example was soon followed by other people all over the world. During the Civil War in the United States aerial photography from balloons played an important role to reveal the defence positions in Virginia (Colwell, 1983). Likewise other scientific and technical developments this Civil War time in the United States speeded up the development of photography, lenses and applied airborne use of this technology. Table 1 shows a few important dates in the development of remote sensing. The next period of fast development took place in Europe and not in the United States. It was during World War I that aero planes were used on a large scale for photoreconnaissance. Aircraft proved to be more reliable and more stable platforms for earth observation than balloons. In the period between World War I and World War II a start was made with the civilian use of aerial photos. Application fields of airborne photos included at that time geology, forestry, agriculture and cartography. These developments lead to much improved cameras, films and interpretation equipment. The most important developments of aerial photography and photo interpretation took place during World War II. During this time span the development of other imaging systems such as near-infrared photography; thermal sensing and radar took place. Near-infrared photography and thermal-infrared proved very valuable to separate real vegetation from camouflage. The first successful airborne imaging radar was not used for civilian purposes but proved valuable for nighttime bombing. As such the system was called by the military 'plan position indicator' and was developed in Great Britain in 1941.

After the wars in the 1950s remote sensing systems continued to evolve from the systems developed for the war effort. Colour infrared (CIR) photography was found to be of great use for the plant sciences. In 1956 Colwell conducted experiments on the use of CIR for the classification and recognition of vegetation types and the detection of diseased and damaged or stressed vegetation. It was also in the 1950s that significant progress in radar technology was achieved.

F. *Types of Remote Sensing Systems*

1. Visual Remote Sensing System such as human visual system
2. Optical Remote Sensing
3. Infrared Remote Sensing
4. Microwave Remote Sensing
5. Radar Remote Sensing
6. Satellite Remote Sensing
7. Airborne Remote Sensing
8. Acoustic and near-acoustic remote sensing

G. *Satellite sensor characteristics*

The basic functions of most satellite sensors are to collect information about the reflected radiation along a pathway, also known as the field of view (FOV), as the satellite orbits the Earth. The smallest area of ground that is sampled is called the instantaneous field of view (IFOV). The IFOV is also described as the pixel size of the sensor. This sampling or measurement occurs in one or many spectral bands of the EM spectrum. The data collected by each satellite sensor can be described in terms of spatial, spectral and temporal resolution.

1) *Spatial resolution:*

The spatial resolution (also known as ground resolution) is the ground area imaged for the instantaneous field of view (IFOV) of the sensing device. Spatial resolution may also be described as the ground surface area that forms one pixel in the satellite image. The IFOV or ground resolution of the Landsat Thematic Mapper (TM) sensor, for example, is 30 m. Theground resolution of weather satellite sensors is often larger than a square kilometre. There are satellites that collect data at less than one meter ground resolution but these are classified military satellites or very expensive commercial systems.

2) *Temporal resolution:*

Temporal resolution is a measure of the repeat cycle or frequency with which a sensor revisits the same part of the Earth's surf ace. The frequency will vary from several times per day, for a typical weather satellite, to 8—20 times a year for a moderate ground resolution satellite, such as Landsat TM. The frequency characteristics will be determined by the design of the satellite sensor and its orbit pattern

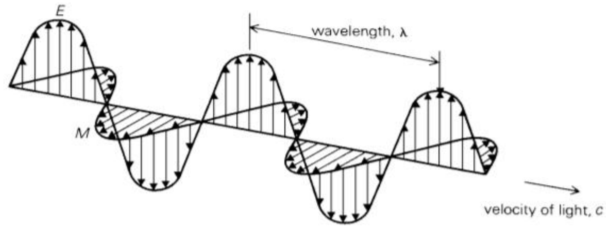
3) *Spectral resolution:*

The spectral resolution of a sensor system is the number and width of spectral bands in the sensing device. The simplest form of spectral resolution is a sensor with one band only, which senses visible light. An image from this sensor would be similar in appearance to a black and white photograph from an aircraft. A sensor with three spectral bands in the visible region of the EM spectrum would collect similar information to that of the human vision system. The Landsat TM sensor has seven spectral bands located in the visible and near to mid infrared parts of the spectrum

H. *Electromagnetic radiation and electromagnetic spectrum*

EMR is a dynamic form of energy that propagates as wave motion at a velocity of c = 3 x 1010 cm/sec. The parameters that characterize a wave motion are wavelength (λ), frequency (ν) and velocity (c) (Fig. 2). The relationship between the above is

$c = \nu\lambda$



Magnetic field M, both perpendicular to the direction of propagation

Electromagnetic energy radiates in accordance with the basic wave theory. This theory describes the EM energy as travelling in a harmonic sinusoidal fashion at the velocity of light. Although many characteristics of EM energy are easily described by wave theory, another theory known as particle theory offers insight into how electromagnetic energy interacts with matter.

It suggests that EMR is composed of many discrete units called photons/quanta.

The energy of photon is

$Q = hc / \lambda = h\nu$

Where Q is the energy of quantum,

h = Planck's constant

I. *Types of Remote Sensing*

Remote sensing can be either passive or active. ACTIVE systems have their own source of energy (such as RADAR) whereas the PASSIVE systems depend upon external source of illumination (such as SUN) or self-emission for remote sensing.

J. *Interaction of EMR with Earth's Surface*

Radiation from the sun, when incident upon the earth's surface, is either reflected by the surface, transmitted into the surface or absorbed and emitted by the surface (Fig. 3). The EMR, on interaction, experiences a number of changes in magnitude, direction, wavelength, polarization and phase. These changes are detected by the remote sensor and enable the interpreter to obtain useful information about the object of interest. The remotely sensed data contain both spatial information (size, shape and orientation) and spectral information (tone, colour and spectral signature).

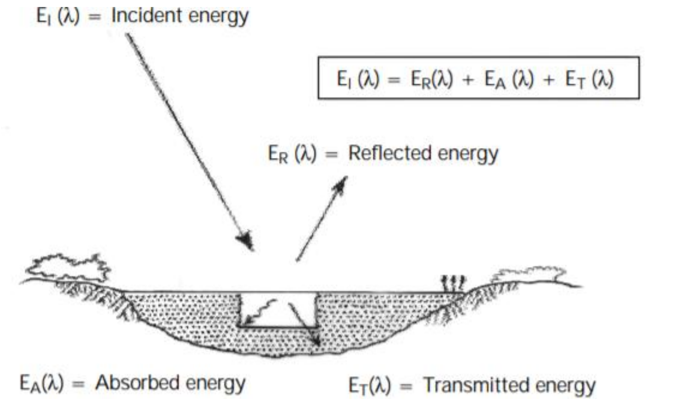


Fig3. Interaction of Energy with the earth's surface. (source: Liliesand& Kiefer, 1993)

From the viewpoint of interaction mechanisms, with the object-visible and infrared wavelengths from 0.3 µm to 16 µm can be divided into three regions. The spectral band from 0.3 µm to 3 µm is known as the reflective region. In this band, the radiation sensed by the sensor is that due to the sun, reflected by the earth's surface. The band corresponding to the atmospheric window between 8 µm and 14 µm is known as the thermal infrared band. The energy available in this band for remote sensing is due to thermal emission from the earth's surface.

Both reflection and self-emission are important in the intermediate band from 3 µm to 5.5 µm.

In the microwave region of the spectrum, the sensor is radar, which is an active sensor, as it provides its own source of EMR. The EMR produced by the radar is transmitted to the earth's surface and the EMR reflected (back scattered) from the surface is recorded and analyzed. The microwave region can also be monitored with passive sensors, called microwave radiometers, which record the radiation emitted by the terrain in the microwave region.

1) *Reflection:*

Reflection occurs when incoming energy bounces off a surface and is reflected back. The amount of reflection varies with:

- Wavelength of Energy
- Geometry of the Surface
- Surface Materials

The color of an object is actually the wavelengths of the light reflected while all other wavelengths are absorbed.Of all the interactions in the reflective region, surface reflections are the most useful and revealing in remote sensing applications. Reflection occurs when a ray of light is redirected as it strikes a non-transparent surface. The reflection intensity depends on the surface refractive index, absorption coefficient and the angles of incidence and reflection.

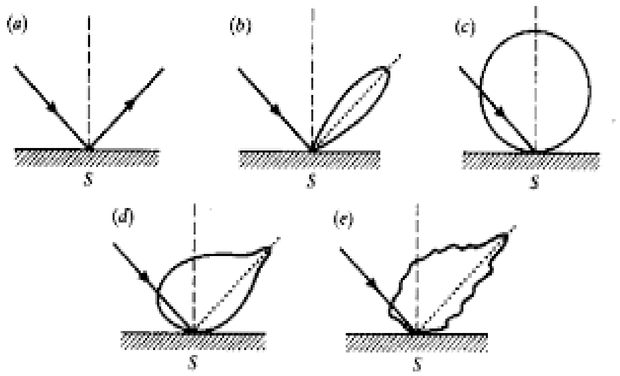


Fig4. Different types of scattering surfaces (a) Perfect specular reflector (b) Near perfect specular reflector (c) Lambertain (d) Quasi-Lambertian (e) Complex

2) *Transmission:*

When electromagnetic energy is able to pass through the atmosphere and reach the Earth's surface. Visible light, largely passes (or is transmitted) through the atmosphere.Transmission of radiation occurs when radiation passes through a substance without significant attenuation. For a given thickness, or depth of a substance, the ability of a medium to transmit energy is measured as transmittance (τ).

$$\tau = \frac{Transmitted\ Radiation}{Incident\ Radiation}$$

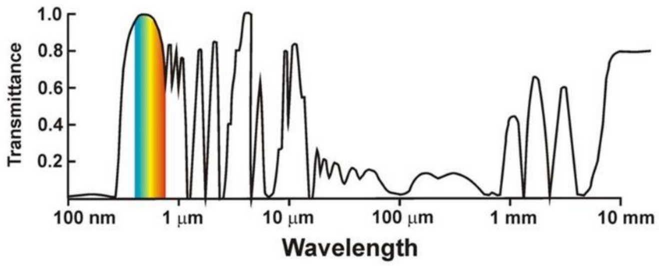


Fig5. The above graph shows the transmittance of electromagnetic radiation across the spectrum. Values close to 1, represent 100% transmittance, indicating the all radiation is able to pass through the atmosphere at the given wavelength. Conversely, values close to 0 indicate that all radiation is blocked and no radiation is able to pass through the atmosphere at the given wavelength.

Some types of electromagnetic radiation easily pass through the atmosphere, while other types do not. The ability of the atmosphere to allow radiation to pass through it is referred to as its transmissivity, and varies with the wavelength of the radiation. The gases that comprise our atmosphere absorb radiation in certain wavelengths while allowing radiation with differing wavelengths to pass through. In contrast to the absorption bands, there are areas of the electromagnetic spectrum where the atmosphere is essentially transparent (with minimal to no absorption of radiation) to specific wavelengths. These regions of the spectrum or wavelengths are known as **"atmospheric windows"** since they allow the radiation to pass through the atmosphere to Earth's surface. For example visible light and radio waves can pass relatively freely through the atmosphere, while X-Rays can not.

3) *Spectral Reflactance:*
   Different surface features reflect and absorb the sun's electromagnetic radiation in different ways. The reflectance properties of an object depend on the material and its physical and chemical state, the surface roughness as well as the angle of the sunlight.

The reflectance of a material also varies with the wavelength of the electromagnetic energy. The amount of reflectance from a surface can be measured as a function of wavelength, this is referred to as **Spectral Reflectance**. Spectral Reflectance is a measure of how much energy (as a percent) a surface reflects at a specific wavelength. Many surfaces reflect different amount of energy in different portions of the spectrum. These differences in reflectance make it possible to identify different earth surface features or materials by analyzing their spectral reflectance signatures. **Spectral reflectance curves** graph the reflectance (in percent) of objects as a function of wavelengths.

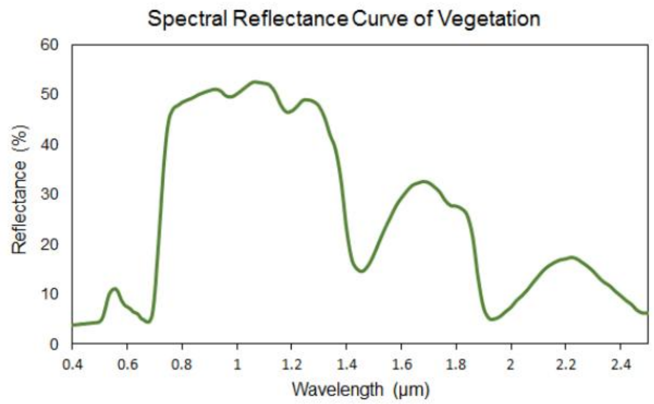


Fig6. Spectral Reflactance curve

The spectral reflectance is dependent on wavelength, it has different values at different wavelengths for a given terrain feature.

The reflectance characteristics of the earth's surface features are expressed by spectral reflectance, which is given by:

$\rho(\lambda) = [ER(\lambda) / EI(\lambda)] \times 100$

Where,

$\rho(\lambda)$ = Spectral reflectance (reflectivity) at a particular wavelength.

$ER(\lambda)$ = Energy of wavelength reflected from object.

$EI(\lambda)$ = Energy of wavelength incident upon the object.

The plot between $\rho(\lambda)$ and λ is called a spectral reflectance curve. This varies with the variation in the chemical composition and physical conditions of the feature, which results in a range of values. The spectral response patterns are averaged to get a generalized form, which is called generalized spectral response pattern for the object concerned. Spectral signature is a term used for unique spectral response pattern, which is characteristic of a terrain feature. Figure 5 shows a typical reflectance curves for three basic types of earth surface features, healthy vegetation, dry bare soil (grey-brown and loamy) and clear lake water.

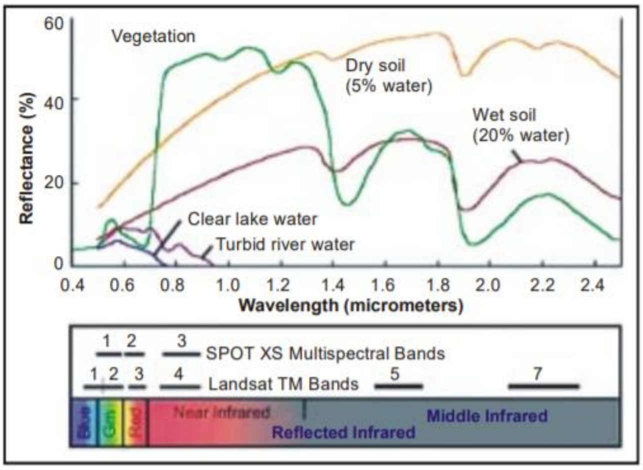


Fig7. Typical Spectral Reflectance curves for vegetation, soil and water

3.1 Spectral Reflectance of Earth Surface Features

3.1.1 Vegetation

In general, healthy vegetation is a very good absorber of electromagnetic energy in the visible region. Chlorophyll strongly absorbs light at wavelengths around 0.45 (blue) and 0.67 µm (red) and reflects strongly in green light, therefore our eyes perceive healthy vegetation as green. Healthy plants have a high reflectance in the near-infrared between 0.7 and 1.3 µm. This is primarily due to healthy internal structure of plant leaves. As this internal structure varies amongst different plant species, the near infrared wavelengths can be used to discriminate between different plant species.

3.1.2 Water

In its liquid state, water has relatively low reflectance, with clear water having the greatest reflectance in the blue portion of the visible part of the spectrum. Water has high absorption and virtually no reflectance in near infrared wavelengths range and beyond. Turbid water has a higher reflectance in the visible region than clear water. This is also true for waters containing high chlorophyll concentrations.

3.1.3 Ice and Snow

Ice and snow generally have high reflectance across all visible wavelengths, hence their bright white appearance. Reflectance decreases in the near infrared portion and there is very low reflectance in the SWIR (shortwave infrared). The low reflection of ice and snow in the SWIR is related to their microscopic liquid water content. Reflectance differs for snow and ice depending on the actual composition of the material including impurities and grain size.

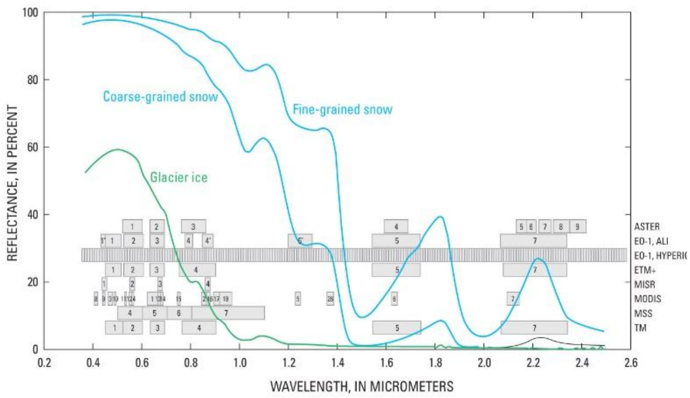


Fig8. Spectral reflectance curves of bare glacier ice, coarse-grained snow, and fine-grained snow. Spectral bands of selected sensor on Earth-orbiting satellites are shown in gray. The numbers in the gray boxes refer to the associated band numbers of each sensor. Image Credit: USGS

3.1.4 Soil

Bare soil generally has an increasing reflectance, with greater reflectance in near-infrared and shortwave infrared. Some of the factors affecting soil reflectance are:

- Moisture content
- Soil texture (proportion of sand, silt, and clay)
- Surface roughness
- Presence of iron oxide
- Organic matter content

K. *Interactions with the Atmosphere*

The sun is the source of radiation, and electromagnetic radiation (EMR) from the sun that is reflected by the earth and detected by the satellite or aircraft-borne sensor must pass through the atmosphere twice, once on its journey from the sun to the earth and second after being reflected by the surface of the earth back to the sensor. Interactions of the direct solar radiation and reflected radiation from the target with the atmospheric constituents interfere with the process of remote sensing and are called as “Atmospheric Effects”. The interaction of EMR with the atmosphere is important to remote sensing for two main reasons. First, information carried by EMR reflected/ emitted by the earth’s surface is modified while traversing through the atmosphere. Second, the interaction of EMR with the atmosphere can be used to obtain useful information about the atmosphere itself**.**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.

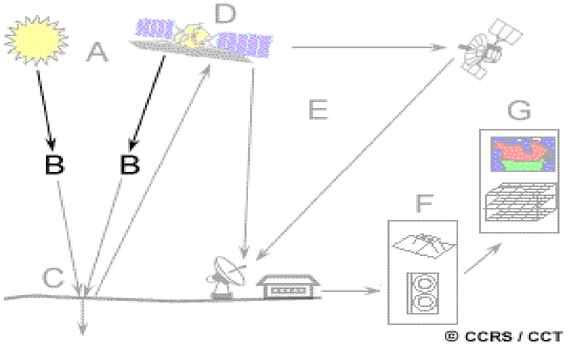


Fig9. Scattering

The solar energy is subjected to modification by several physical processes as it passes the atmosphere, viz. Scattering; Absorption, andRefraction

1) *Scattering:*

It 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. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. There are three types of scattering which take place:

Scattering process	Wavelength	Approximate dependence particle size	Kinds of particles
Selective			
• Rayleigh	λ^{-4}	< 1 µm	Air molecules
• Mie	λ^{0} to λ^{-4}	0.1 to 10 µm	Smoke, haze
• Non-selective	λ^{0}	> 10 µm	Dust, fog, clouds

Fig10. Types of scattering

1.1 Rayleigh scattering:

It mainly consists of scattering from atmospheric gases. This occurs when the particles causing the scattering are smaller in size than the wavelengths of radiation in contact with them. This type of scattering is therefore wavelength dependent. As the wavelength decreases, the amount of scattering increases. Because of Rayleigh scattering, the sky appears blue, as in the picture below. This is because blue light is scattered around four times as much as red light, and UV light is scattered about 16 times as much as red light.

1.2 *Miescattering*:

It is caused by pollen, dust, smoke, water droplets, and other particles in the lower portion of the atmosphere. It occurs when the particles causing the scattering are larger than the wavelengths of radiation in contact with them. Mie scattering is responsible for the white appearance of the clouds.

1.3 Non-selectivescattering:

It occurs in the lower portion of the atmosphere when the particles are much larger than the incident radiation. This type of scattering is not wavelength dependent and is the primary cause of haze. Non-selective scatter is primarily caused by water droplets in the atmosphere. Non-selective scattering scatters all radiation evenly throughout the visible and infrared portions of the spectrum - hence the term non-selective.

Occurrence of this scattering mechanism gives a clue to the existence of large particulate matter in the atmosphere above the scene of interest which itself is a useful data. Using minus blue filters can eliminate the effects of the Rayleigh component of scattering. However, the effect of heavy haze i.e. when all the wavelengths are scattered uniformly, cannot be eliminated using haze filters. The effects of haze are less pronounced in the thermal infrared region. Microwave radiation is completely immune to haze and can even penetrate clouds.

2) Atmospheric Absorption:

The gas molecules present in the atmosphere strongly 3absorb the EMR passing through the atmosphere in certain spectral bands. Mainly three gases are responsible for most of absorption of solar radiation, viz. ozone, carbon dioxide and water vapour. Ozone absorbs the high energy, short wavelength portions of the ultraviolet spectrum ($\lambda < 0.24$ µm) thereby preventing the transmission of this radiation to the lower atmosphere. Carbon dioxide is important in remote sensing as it effectively absorbs the radiation in mid and far infrared regions of the spectrum. It strongly absorbs in the region from about 13-17.5 µm, whereas two most important regions of water vapour absorption are in bands 5.5 - 7.0 µm and above 27 µm. Absorption relatively reduces the amount of light that reaches our eye making the scene look relatively duller.

3) Refraction:

The phenomenon of refraction, that is bending of light at the contact between two media, also occurs in the atmosphere as the light passes through the atmospheric layers of varied clarity, humidity and temperature. These variations influence the density of atmospheric layers, which in turn, causes the bending of light rays as they pass from one layer to another. The most common phenomena are the mirage like apparitions sometimes visible in the distance on hot summer days.

L. SunSynchronous and Geosynchronous Satellites

1. SunSynchronous:

Sun-synchronous orbit (SSO, also called a heliosynchronousorbit) is a nearly polar orbit around a planet, in which the satellite passes over any given point of the planet's surface at the same local mean solar time More technically, it is an orbit arranged so that it precesses through one complete revolution each year, so it always maintains the same relationship with the Sun.

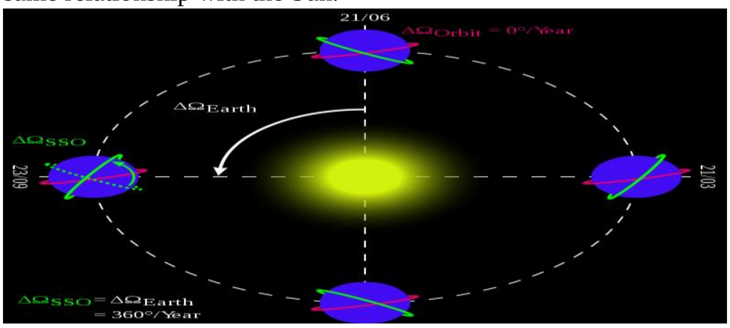


Fig11:It shows the orientation of a Sun-synchronous orbit (green) at four points in the year. A non-Sun-synchronous orbit (magenta) is also shown. Dates are shown in white: day/month

1.1. Applications

A Sun-synchronous orbit is useful for imaging, spy, and weather satellites,because every time that the satellite is overhead, the surface illumination angle on the planetunderneath it will be nearly the same. This consistentlighting is a useful characteristic for satellites that image the Earth's surface in visible or infrared wavelengths, such as weather and spy satellites; and for other remote-sensing satellites, such as those carrying ocean and atmospheric remote-sensing instruments that require sunlight. For example, a satellite in Sun-synchronous orbit might ascend across the equator twelve times a day each time at approximately 15:00 mean local time.

Special cases of the Sun-synchronous orbit are the **noon/midnight orbit**, where the local mean solar time of passage for equatorial latitudes is around noon or midnight, and the **dawn/dusk orbit**, where the local mean solar time of passage for equatorial latitudes is around sunrise or sunset, so that the satellite rides the terminator between day and night. Riding the terminator is useful for active radar satellites, as the satellites' solar panels can always see the Sun, without being shadowed by the Earth. It is also useful for some satellites with passive instruments that need to limit the Sun's influence on the measurements, as it is possible to always point the instruments towards the night side of the Earth. The dawn/dusk orbit has been used for solar-observing scientific satellites such as Yohkoh, TRACE, Hinode and PROBA2, affording them a nearly continuous view of the Sun.

1.2 Optical precession

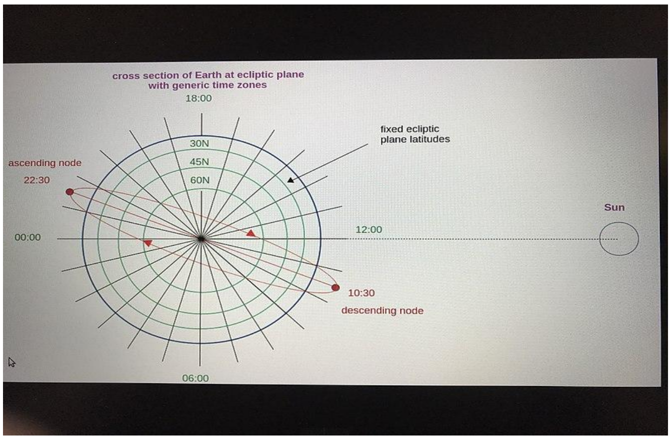


Fig12: Diagram showing a Sun-synchronous orbit from a top view of the ecliptic plane with Local Solar Time (LST) zones for reference and a descending node of 10:30 am. The LST zones show how the local time beneath the satellite varies at different latitudes and different points on its orbit.

1.3 Technical detail

The angular precession per orbit for an Earth orbiting satellite is

$$\Delta\Omega = -3\pi \frac{J_2 R_E^2}{p^2} \cos i,$$

where

J_2 is the coefficient for the second zonal term (1.08263×10^{-3}) related to the oblateness of the Earth (see geopotential model),
R_E is the mean radius of the Earth, roughly 6378 km
p is the semi-latus rectum of the orbit,
i is the inclination of the orbit to the equator
.

An orbit will be Sun-synchronous when the precession rate ρ equals the mean motion of the Earth about the Sun, which is 360° per sidereal year (1.99096871×10^{-7} rad/s), so we must set $\Delta\Omega/T = \rho$, where T is the orbital period.

As the orbital period of a spacecraft is

$$2\pi\sqrt{\frac{a^3}{\mu}}$$

where a is the semi-major axis of the orbit and μ is the standard gravitational parameter of the planet (398600.440 km^3/s^2 for Earth); as $p \approx a$ for a circular or almost circular orbit, it follows that

$$\rho \approx -\frac{3J_2R_E^2\sqrt{\mu}\cos i}{2a^{\frac{7}{2}}} = -(360^\circ \text{ per year}) \times \left(\frac{a}{12\,352\text{ km}}\right)^{-\frac{7}{2}} \cos i = -(360^\circ \text{ per year}) \times \left(\frac{T}{3.795\text{ h}}\right)^{-\frac{7}{3}} \cos i,$$

or when ρ is 360° per year,

$$\cos i \approx -\frac{2\rho}{3J_2R_E^2\sqrt{\mu}} a^{\frac{7}{2}} = -\left(\frac{a}{12\,352\text{ km}}\right)^{\frac{7}{2}} = -\left(\frac{T}{3.795\text{ h}}\right)^{\frac{7}{3}}$$

As an example, for a = 7200 km (the spacecraft about 800 km over the Earth surface) one gets with this formula a Sun-synchronous inclination of 98.696°.

Note that according to this approximation $\cos i$ equals −1 when the semi-major axis equals 12352 km, which means that only smaller orbits can be Sun-synchronous. The period can be in the range from 88 minutes for a very low orbit (a = 6554 km, i = 96°) to 3.8 hours (a = 12352 km, but this orbit would be equatorial with i = 180°). A periodlonger than 3.8 hours may be possible by using an eccentric orbit with p < 12352 km but a > 12352 km.

If one wants a satellite to fly over some given spot on Earth every day at the same hour, it can do between 7 and 16 orbits per day, as shown in the following table. (The table has been calculated assuming the periods given. The orbital period that should be used is actually slightly longer. For instance, a retrograde equatorial orbit that passes over the same spot after 24 hours has a true period about 365/364 ≈ 1.0027 times longer than the time between overpasses. For non-equatorial orbits the factor is closer to 1.)

2. Geosynchronous Satellites

A geosynchronous satellite is a satellite in geosynchronous orbit, with an orbital period the same as the Earth's rotation period. Such a satellite returns to the same position in the sky after each sidereal day, and over the course of a day traces out a path in the sky that is typically some form of analemma. A special case of geosynchronous satellite is the geostationary satellite, which has a geostationary orbit – a circular geosynchronous orbit directly above the Earth's equator. Another type of geosynchronous orbit used by satellites is the Tundra elliptical orbit.

Geostationary satellites have the unique property of remaining permanently fixed in exactly the same position in the sky as viewed from any fixed location on Earth, meaning that ground-based antennas do not need to track them but can remain fixed in one direction. Such satellites are often used for communication purposes; a **geosynchronous network** is a communication network based on communication with or through geosynchronous satellites.

A common misconception about geosynchronous satelites is that there can be such satelites on every point above Earth surface it is not true as a *component* of gravitational pull is always acting, parallel to rotational axis of the planet, on the satellite which can never be balanced by centrifugal force as centrifugal force is only and always perpendicular to the rotational axis of the planet. However, on the equator of earth, there is no gravitational pull's component acting on the satellite parallel to rotational axis and only gravitational pull is perpendicular to the axis of rotation which is balanced by satellite's centrifugal force. Hence, pure geostationary orbit is always around the equator of the Earth.

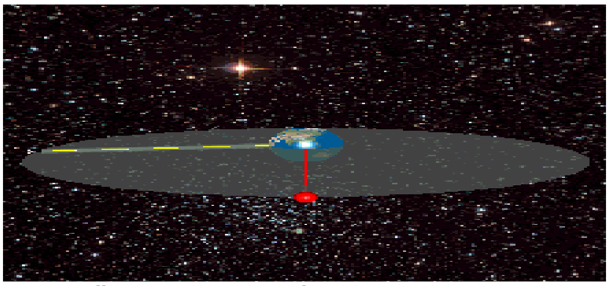


Fig13:Satellites in geostationary orbit.

2.1 Application

Geostationary satellites appear to be fixed over one spot above the equator. Receiving and transmitting antennas on the earth do not need to track such a satellite. These antennas can be fixed in place and are much less expensive than tracking antennas. These satellites have revolutionizedglobal communications, television broadcasting and weather forecasting, and have a number of important defence and intelligence applications

One disadvantage of geostationary satellites is a result of their high altitude: radio signals take approximately 0.25 of a second to reach and return from the satellite, resulting in a small but significant signal delay. This delay increases the difficulty of telephone conversation and reduces the performance of common network protocols such as TCP/IP, but does not present a problem with non-interactive systems such as satellite television broadcasts. There are a number of proprietary satellite data protocols that are designed to proxy TCP/IP connections over long-delay satellite links—these are marketed as being a partial solution to the poor performance of native TCP over satellite links. TCP presumes that all loss is due to congestion, not errors, and probes link capacity with its "slow-start" algorithm, which only sends packets once it is known that earlier packets have been received. RFC 2488, written in 1999, gives several suggestions on this issue.

There are some advantages of geo-stationary satellites:

- Get high temporal resolution data.
- Tracking of the satellite by its earth stations is simplified.
- Satellite always in same position.

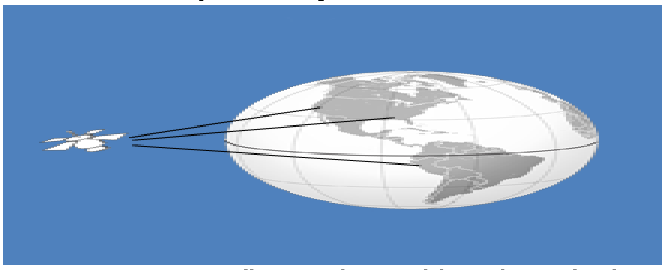


Fig 14: A geostationary satellite is in orbit around the Earth at an altitude where it orbits at the same rate as the Earth turns. An observer at any place where the satellite is visible will always see it in exactly the same spot in the sky, unlike stars and planets that move continuously.

CONCLUSION

Remote sensing sensors provide synoptic, repetitive, panchromatic and multispectral bands with radiometric, spectral and spatial resolution in digital formats hence enormously used to study the earth resources.
Remote sensing technology has developed from balloon photography to aerial photography to multi-spectral satellite imaging. Radiation interaction characteristics of earth and atmosphere in different regions of electromagnetic spectrum are very useful for identifying and characterizing earth and atmospheric feature.

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