Chapter 3: Remote Sensing, GIS and GPS

Chapter 3:

This chapter briefly discusses the basics of various techniques, viz. the remote sensing, the digital image processing, visual Interpretation and delineation using Geographical Information System (GIS) domain

3.1: Remote Sensing:

“**Remote sensing** is defined as the science and art of obtaining information about an object, area, or phenomenon through the analyses of data acquired by the sensor that is not in direct contact with the target of investigation” (Schultz and Engman, 2000; Ritchie and Rango, 1996). This can be done by the use of either recording or real-time sensing device(s) mounted on aircraft, spacecraft, satellite, buoy, or ship. During last forty years, space travel has been giving humanity new opportunities, not only to peer into the depths of the cosmos, but also to look at the length and breadth of our own world. Remote sensing enables us to acquire information about a phenomenon, object or surface while at a distance from it. More than just a source of pleasing pictures, these sophisticated techniques now allow scientists to understand the Earth in ways we never before dreamed. From 1960 onwards, since the beginning of spaceflight, an ever growing body of information is being gathered using space-based remote sensing. Agriculture, meteorology, oceanography, ecology, cartography, botany, geomorphology and geology are just a few of the disciplines which have been transformed by this technology. Some of the most important environmental issues of our time are only becoming understood because of vast networks of remote sensing devices and data analysis systems. In practice, remote sensing is the stand-off collection through the use of a variety of devices for gathering information on a given object or area. The remote sensing is basically a multi-disciplinary science which includes a combination of various disciplines such as optics, spectroscopy, photography, computers, electronics and telecommunication, etc. All these technologies are integrated to act as one complete system in itself, known as Remote Sensing. In the decades to come, remote sensing will be a key tool for making critical decisions affecting the Earth and its resources.

In a remote sensing system number of components work as links and each one is important for successful operation. They are listed below (figure 3.1).

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

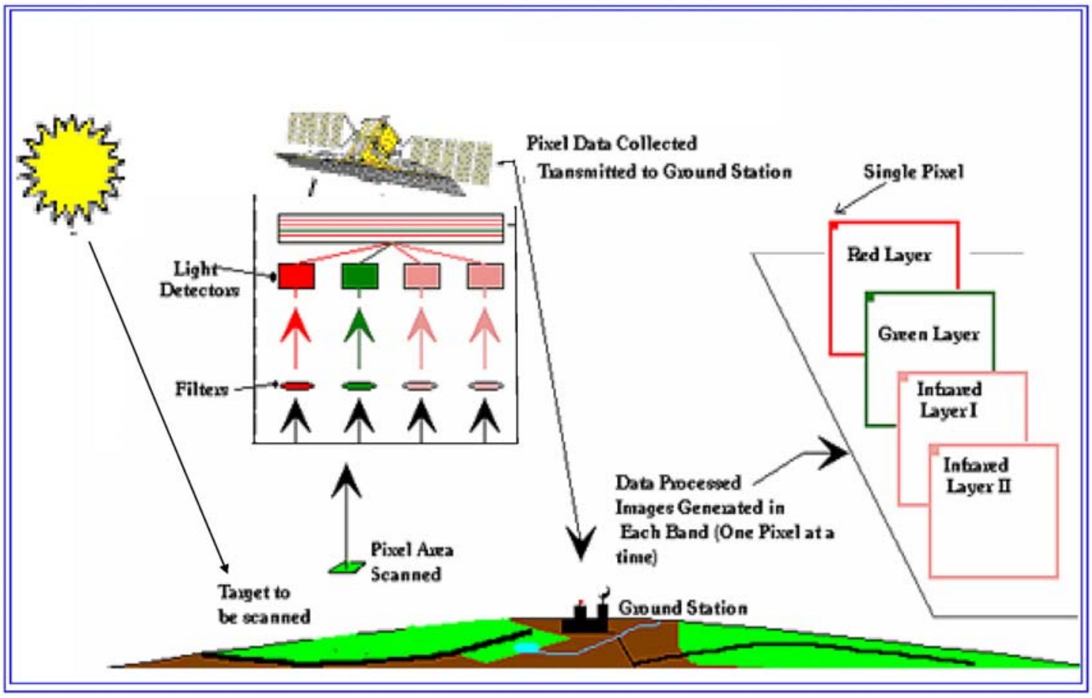

Figure 3.1: Different stages in Remote sensing and data acquisition

(Source: http://www.ansp.org/museum/kye/tech_environment/2001_remote_sensing.php)

3.1.1: Basic components of Remote Sensing:

The sun is the major source of energy, radiation and illumination. At any given moment our sun is bombarding the earth with a variety of wavelengths of EMR, including visible light, infrared, radio and microwaves. Detection and discrimination of surface features means detecting and recording of radiant energy reflected or emitted by surface (Joseph, 2004; Lillesand and Kiefer, 1987; 2000). Different features return different amount and kind of energy in different bands of the electromagnetic spectrum, incident upon it. This unique property depends on the property of material (structural, chemical and physical), surface roughness, angle of incidence, intensity and wavelength of radiant energy (Elachi, 1987). Everything in nature has its own unique distribution of reflected, emitted and absorbed radiation. These spectral characteristics, if ingeniously exploited, can be used to distinguish one thing from another or to obtain information about shape, size and other physical and chemical properties. Because the emission and reflection of many different types of EMR can be detected by instruments, they can also be used for remote sensing. Thus, to understand remote sensing, it is important to first understand the basics of EMR.

3.1.1.1: Electromagnetic Radiation :

Electromagnetic radiation is one of the fundamental forms of energy in the universe. EMR is a dynamic form of energy that propagates as wave motion at a velocity of light, i.e. $C=3X10^{10}$ m/s. Electromagnetic energy radiates in accordance with the basic wave theory. This theory describes the EM energy as traveling in a harmonic sinusoidal fashion at the velocity of light.

Here, $\mathbf{c = v\lambda}$……………………………………………………………………………..3.1

where, v is frequency, λ is wavelength and c is velocity

Although many characteristics of EM energy are easily described by wave theory,

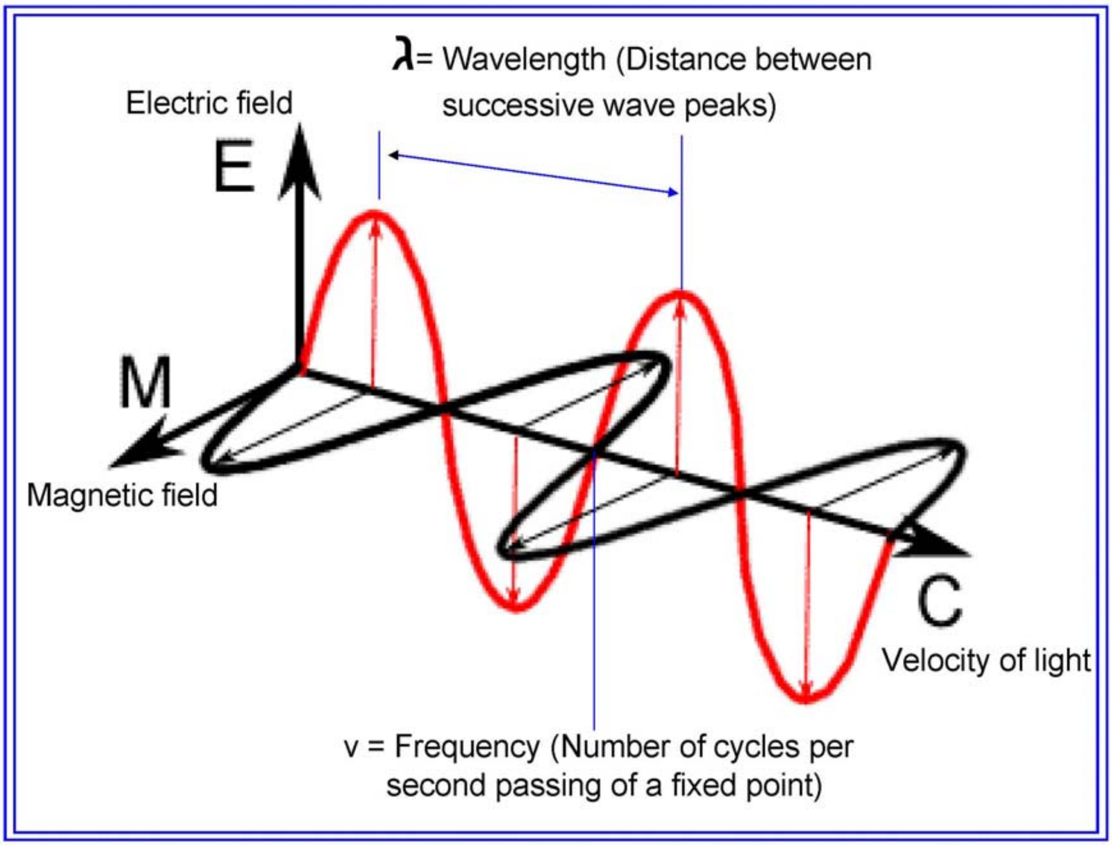

Figure 3.2: An electromagnetic wave. Includes electric wave(E) and magnetic wave(M) at right angles, both perpendicular to the direction of propogation.
(Source: http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php)

another theory known as particle theory offers insight into how electromagnetic energy interacts with matter (figure 3.2). It suggests that EMR is composed of many discrete units called photons/quanta. The energy of quantum is:

Q = h c/λ …………...……………………………………………………………..3.2
where Q is the energy of quantum, h is plank's constant

Hence, from equation 3.1

Q = h cv..3.3

3.1.1.2: Electromagnetic Spectrum

Electromagnetic energy is the energy source required to transmit information from the target to the sensor. It is a crucial medium that is described as an electromagnetic spectrum. Many of the basic forms of energy in the universe are related as part of the electromagnetic spectrum. On this spectrum, many forms exist that describe energy in a specific region of the electromagnetic spectrum. These are visible light, radiowaves, microwaves, infra-red, uv rays, x-rays and gamma rays (figure 3.3).

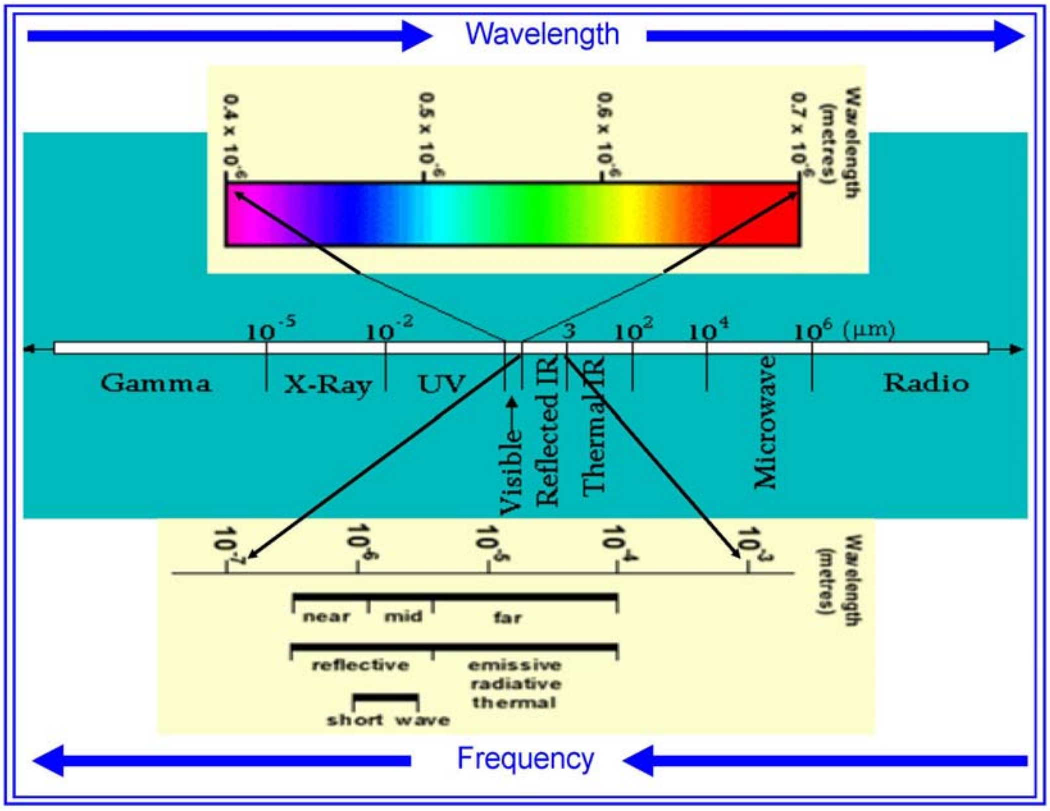

Fig 3.3: Electromagnetic spectrum

(Source: http://hcgl.eng.ohio-state.edu/~ceg603/handouts/IntroRemoteSensing.pdf)

This spectrum is an overview of the continuum of electromagnetic energy from extremely short wavelengths (cosmic gamma rays) to extremely long wavelengths (radio and television waves). Note that as the wavelengths of energy decrease, the frequency increases. These divisions are not absolute and definite; overlapping may occur (table 3.1).

Table 3.1: Major regions of the electromagnetic spectrum

Region Name	Wavelength	Comments
Gamma Ray	< 0.03 nanometers	Entirely absorbed by the Earth's atmosphere and not available for remote sensing.
X-ray	0.03 to 30 nanometers	Entirely absorbed by the Earth's atmosphere and not available for remote sensing.
Ultraviolet	0.03 to 0.4 micrometers	Wavelengths from 0.03 to 0.3 micrometers absorbed by ozone in the Earth's atmosphere.
Photographic Ultraviolet	0.3 to 0.4 micrometers	Available for remote sensing the Earth. Can be imaged with photographic film.
Visible	0.4 to 0.7 micrometers	Available for remote sensing the Earth. Can be imaged with photographic film.
Reflected Infrared	0.7 to 3.0 micrometers	Available for remote sensing the Earth. Near Infrared 0.7 to 0.9 micrometers. Can be imaged with photographic film.
Thermal Infrared	3.0 to 14 micrometers	Available for remote sensing the Earth. This wavelength cannot be captured with photographic film. Instead, sensors are used to image this wavelength band.
Microwave or Radar	0.1 to 100 centimeters	Longer wavelengths of this band can pass through clouds, fog, and rain. Images using this band can be made with sensors that actively emit microwaves.
Radio	> 100 centimeters	Not normally used for remote sensing the Earth.

(Source: http://www.physicalgeography.net/fundamentals/2e.html)

3.1.1.3: Electromagnetic radiation quantities

- **Radiant energy (Q)** is the energy carried by EMR. Radiant energy causes the detector element of the sensor to respond to EMR in some appropriate manner. Unit of Radiant Energy Q is Joule.

- **Radiant Flux (Φ) (Phi)** is the time rate of the flow of radiant energy. Unit of Radiant flux is Joule/Second or Watt (W).

- **Irradiance (E)** is the Radiant flux intercepted by a plane surface per unit area of the surface. It arrives at the surface from all directions within a hemisphere over the surface. Unit of Irradiance E is W/m^2 or Wm^{-2} (Watt per square meter).

- **Radiance (L)** is defined as the radiant flux per unit solid angle leaving an extended source in a given direction per unit projected area of the source in that direction. The concept of radiance is intended to correspond to the concept of brightness. The projected area in a direction which makes an` angle θ (Theta) with the normal to the surface of area A is A cosθ. Unit for Radiance is $Wm^{-2}sr^{-1}$.

- **Spectral Reflectance (ρ(λ))** is the ratio of reflected energy to incident energy as a function of wavelength.

- **Spectral Signature** are the values of the spectral reflectance of objects averaged over different, well defined wavelength intervals comprise the spectral signature of the objects or features by which they can be distinguished.

3.1.1.4: Interaction of EMR with atmosphere and earth surface

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 once 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 atmospheric constituents scatter and absorb the radiation, modify the radiation reflected from the target by attenuating it. Both scattering and absorption vary in their effect from one part of the spectrum to the other. The solar energy is subjected to modifications by several physical process as it passes the atmosphere, viz. scattering, absorption and refraction.

- **Atmospheric Scattering:** Scattering is the redirection of EMR by particles suspended in the atmosphere or by larger molecules of atmospheric gases or water vapor. The amount of scattering depends upon the size and abundance of particles, the wavelength of radiation and depth of the atmosphere through which the energy is traveling which varies both in time and over season thus scattering will be uneven spatially and will vary from time to time. Scattering reduces image contrast and changes spectral signature of ground objects as seen by the sensor.

- **Atmospheric Absorption:** The gas molecules present in the atmosphere strongly absorb the EMR passing through the atmosphere in certain spectral bands. Mainly three gases are responsible for most of the absorption of solar radiation, viz. ozone, carbon dioxide and water vapor. Absorption relatively reduces the amount of light that reaches our eye making the scene look relatively duller.

- **Atmospheric Windows:** The atmosphere selectively transmits energy of certain wavelengths. The spectral bands for which the atmosphere is relatively transparent are known as "Atmospheric Windows". In the visible part transmission is mainly effected by ozone absorption and by molecular scattering (figure 3.4).

- **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.

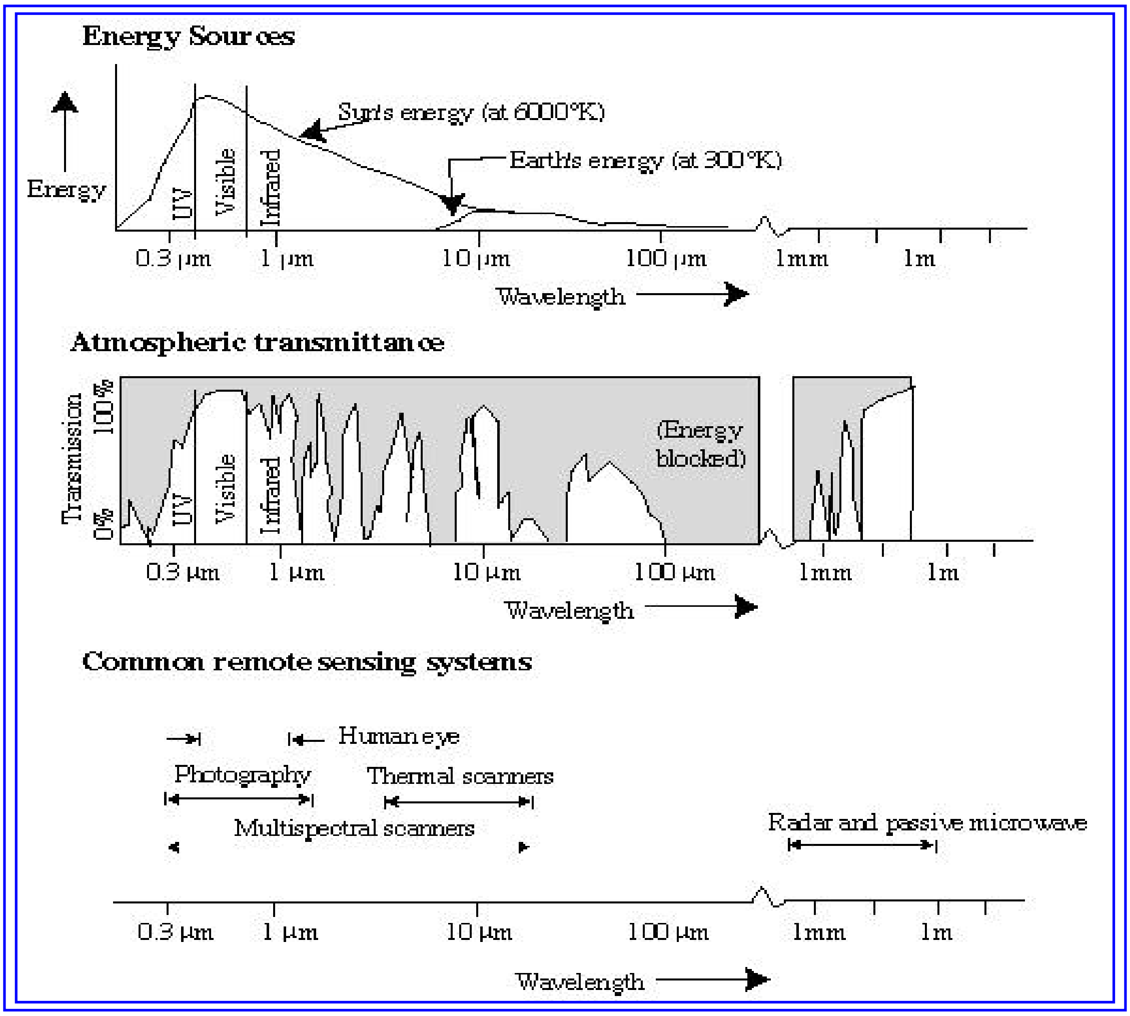

Fig 3.4: Spectral characteristics of energy sources, atmospheric effects and sensing systems wavelength scale are logarithmic.

(Source: www.ucalgary.ca/GEOG/virtual/remoteintro.html)

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. The EMR, on the 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). 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.

- **Reflection:** 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.

- **Transmission:** 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). **τ = transmitted radiation/incident radiation**

3.1.1.5: Data detection and output:

The most important component of a remote sensing is the sensor/detector which, records the variation of radiant energy reflected or emitted by objects or surface material. Different types of sensors are sensitive to different parts of the electromagnetic spectrum. The function of recording system is to convert the energy detected by sensor into a form which can be perceived. This is done by dividing the incoming energy by beam splitters and filters into different wavelength bands and then converting energy in each wavelength band into electrical signal. The electrical signal is processed to give radiometric data for each band, which is recorded in digital format.

3.1.2: Remote Sensing Systems:

The common remote sensing systems are of two types, Imaging (image forming) and Non-Imaging (nonimage forming). Image-forming systems are again of two types, framing type and scanning type. In scanning type, the information is acquired sequentially from the surface in bits of picture elements or pixels, point by point and line by line, which may be arranged after acquisition into a frame format.

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 for remote sensing.

3.1.2.1: Platforms and Sensors:

The information flows from an object to a sensor in the form of radiation transmitted through the atmosphere. For a sensor to collect and record energy reflected or emitted from a target or surface, its must reside on a stable platform away from the target or surface being observed. Based on its altitude above earth surface, platforms can be classified as ground-borne, air-borne and space-borne.
Space-borne platforms are in space, moving in their orbits around the earth. It is through these space-borne platforms, we get enormous amount of remote sensing data. Depending on their altitude and orbit these platforms may be divided in two categories:

- **Geostationary satellites:** An equatorial west to east satellite orbiting the earth at an altitude at which it makes one revolution in 24 hours, synchronous with the earth's rotation, hence it gives continuous coverage over the same area day and night. These are mainly used for communication and meteorological applications, for e.g. the INSAT satellites.

- **Polar orbiting or Sun-synchronous satellites:** A satellite with inclined north-south orbit track westward at a rate such that it covers each area of the world at a constant time of the day called the local sun time as the satellite moves from north to south. This ensures the similar illumination conditions while acquiring image over a particular area over a series of days (figure 3.5). On the descending pass from north to south the satellite travels on the sun lit side of the earth, while on ascending pass from south to north it travels on the shadowed side of the earth. Through these satellites the entire globe is covered on regular basis and gives repetitive coverage on periodic basis. All remote sensing resources satellites may be grouped in this category for e.g. IRS series.

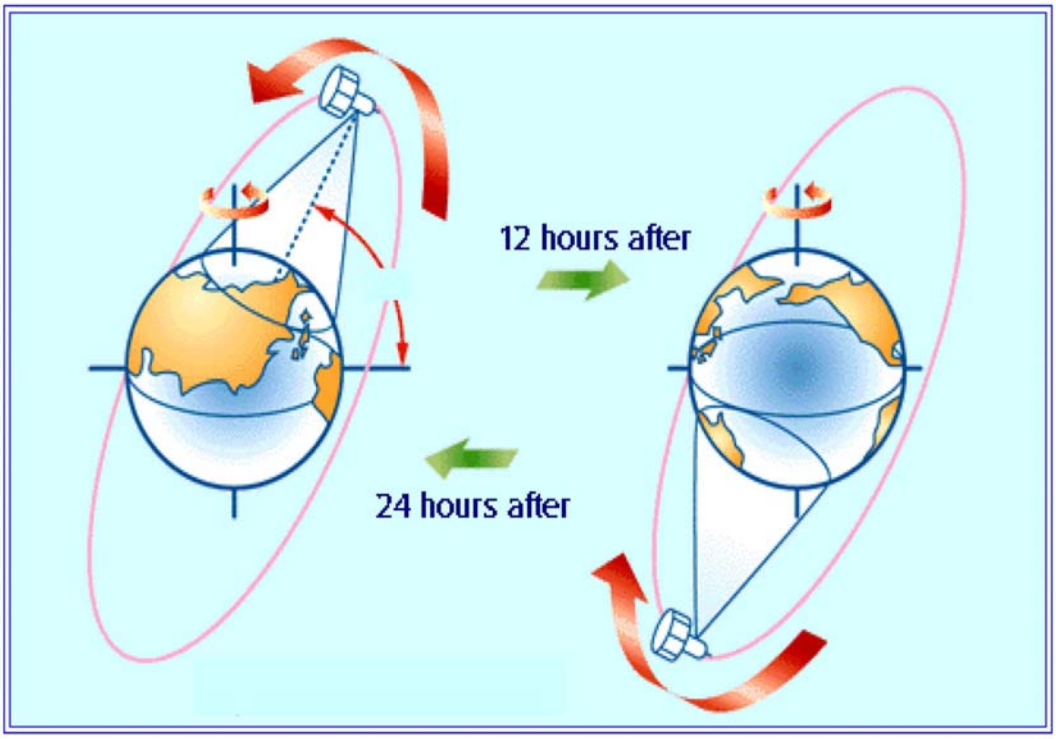

Fig 3.5: Sunsynchronous satellites orbiting earth

(Source:http://www.newmediastudio.org/DataDiscovery/Hurr_ED_Center/Satellites_and_Sensors/Polar_Orbits/Polar_Orbits.html)

Sensor is the device that gathers energy (EMR or others), converts it into a signal and presents it in a form suitable for obtaining information about the target under investigation. Sensors used for remote sensing can be broadly classified as those operating in Optical Infrared (OIR) region and those operating in microwave region. OIR and microwave sensors can further be subdivided into passive and active depending on the source of energy.

- **Active sensors** use their own source of energy to illuminate earth surface and a part of it is reflected and received to gather information.

- **Passive sensors** do not have their own source of energy but instead receive solar electromagnetic energy reflected from surface or energy emitted from surface itself hence it can not be used at night time, except thermal sensors. Energy that is naturally emitted (e.g. Thermal energy) can be detected day or night, as long as the amount of energy is large enough to be recorded (Sabins, 1997).

3.1.3: Types of Remote Sensing:

Remote sensing can be broadly classified into three types with respect to the wavelength region and type of sensor involved for data acquisition; viz. Optical (Visible and Reflective Infrared), Thermal Infrared and Microwave. In present study optical remote sensing technique has been used to achieve the defined objectives.

3.1.3.1: Optical Remote Sensing:

Optical remote sensing involves the use of visible part of the EM spectrum. Energy emitted from sun is used for visible and reflective infrared remote sensing. The International Commission on Illumination has defined the visible spectrum to be from 0.38 to 0.79 µm. The human eye has its peak sensitivity at 0.55 microns, which is approximately the peak of the emission curve of the sun (Jensen, 1996; Sabins, 1997; Gupta, 1999; 2003). Remote sensing data obtained in the visible and reflective infrared regions mainly depends on the reflectance of objects on the ground surface. Therefore, information about objects can be obtained from the spectral reflectance (Elachi, 1987).

3.1.3.2: Thermal Infrared Remote Sensing:

The source of radiant energy used in thermal infrared remote sensing is the object itself, because any object with a normal temperature will emit EM radiation with a peak at about 10 µm (Sabins, 1997; Gupta, 2003).

3.1.3.3: Microwave Remote Sensing:

In microwave region, there are two types of microwave remote sensing, passive and active. In passive microwave remote sensing, the microwave radiation emitted from an object is detected, while in active microwave remote sensing, source of EM radiations and detector are placed on the sensor (Elachi, 1988).

3.1.4 Inherent characteristics and spectral signature of objects

In any photographic image forming process, the negative is composed of tiny silver deposits formed by the action light on photosensitive film during exposure. The amount of light received by the various sections of the film depends on the reflection of EMR from various objects. The light, after passing through the optical system, gives rise to different tones and textures.

In visual interpretation, an interpreted is primarily concerned with recognizing changes in tonal values, thereby differentiating an object of a certain reflective characteristic from another. However, he must be aware that the same object under different moisture or illumination conditions and depending on the wavelength of incident energy, may reflect a different amount of light. For this reason, a general key, based on tone characteristics of objects, cannot be prepared. In such cases, other characteristics of objects such as their shape, size and pattern, etc., help in their recognition.

Spectral signature is the parameter which determines the character of the object under observation. This can be defined as a unique pattern of wavelengths radiated/reflected by an object. It can be categorized as:

- **Spectral variation:** Variation in reflectivity and emissivity as a function of wavelength.

- **Spatial variation:** Variation in reflectivity and emissivity with spatial position (i.e. shape, texture and size of the object).

- **Temporal variation:** Variation of emissivity and reflectivity like that in diurnal and seasonal cycle.

- **Polarization variation:** Variations are introduced by the material in the radiation reflected or emitted by it.

Each of these four features of EMR may be interdependent. A measure of these variations and correlating them with the known features of an object provides signature of the object concerned. The knowledge of the state of polarization of the reflected radiation in addition to spectral signature of various objects in remote sensing adds dimension for analysis and interpretation of remote sensing data. These parameters are extremely useful in providing valuable data for discriminating the objects.

3.1.5: Elements of image interpretation

Recognizing targets is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of tone, shape, size, pattern, texture, shadow, and association. Identifying targets in remotely sensed images based on these visual elements allows us to further interpret and analyze. The nature of each of these interpretation elements is described below:

3.1.5.1: Tone refers to the relative brightness or colour of objects in an image. Generally, tone is the fundamental element for distinguishing between different targets or features. Variations in tone also allow the elements of shape, texture, and pattern of objects to be distinguished.

3.1.5.2: Shape refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural targets, while natural features are generally more irregular in shape.

3.1.5.3: Size of objects in an image is a function of scale. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size can direct interpretation to an appropriate result more quickly.

3.1.5.4: Pattern refers to the spatial arrangement of visibly discernible objects. Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern.

3.1.5.5: Texture refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas smooth textures would have very little tonal variation.

3.1.5.6: Shadow is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings.

3.1.5.7: Association takes into account the relationship between other recognizable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification.

3.1.6: Spectral behavior of surface features

As EMR incidents on earth's surface, behavior of land features is mainly due to the component of the target at that locality. Since each of these components exhibit typical spectral signature influenced by so many other parameters of their own, they are to be considered separately to understand the nature of EMR interaction with each components. Spectral signature or water, vegetation and soil are discussed below (figure 3.6):

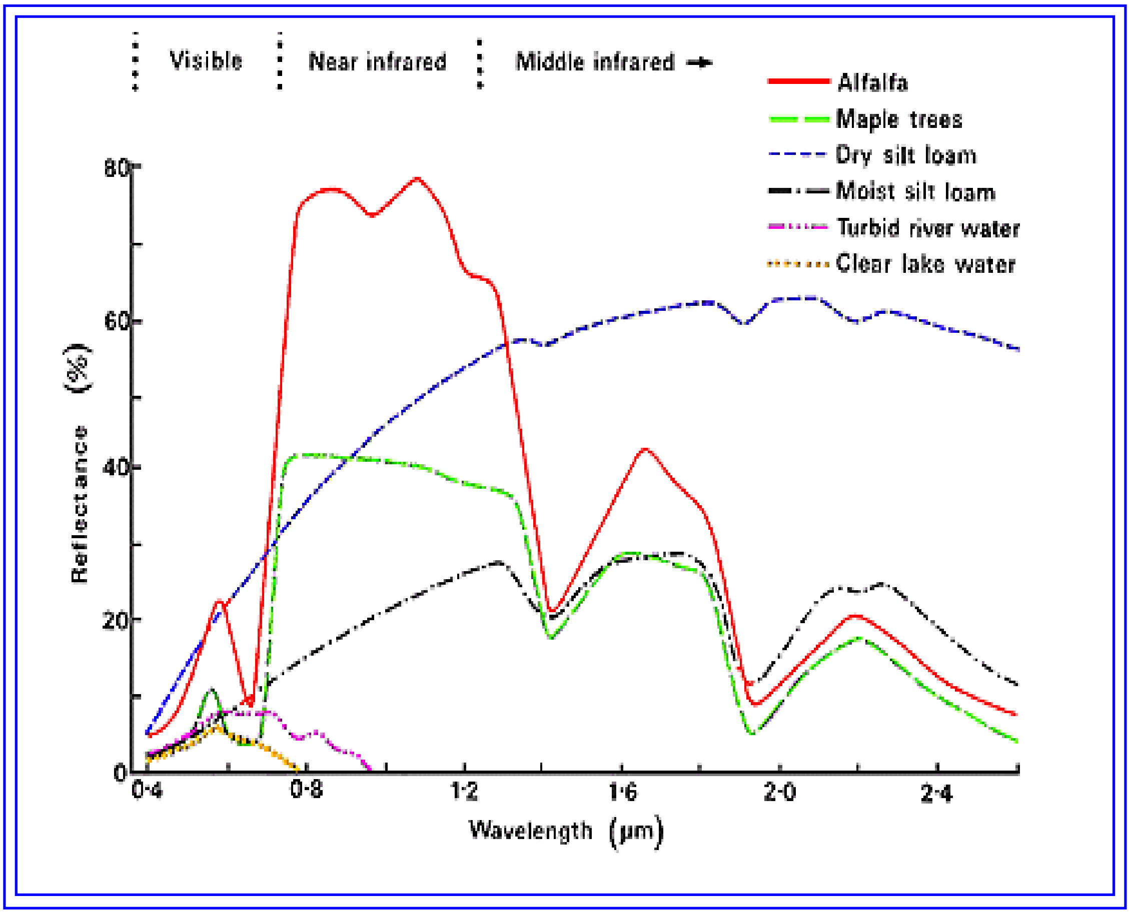

Fig 3.6: Typical spectral reflectance curves for vegetation (two different types), soil (two different types) and water (two different types)

(source: http://ceos.cnes.fr:8100/cdrom-00/ceosl/irsa/pages/intro2c.htm)

3.1.6.1: Spectral reflectance and signature of soil

The majority of the flux incident on a soil surface is reflected or absorbed and little is transmitted. The reflectance properties of the majority of soils are similar, with a positive relationship between reflectance and wavelength, as seen in fig: 3.7. Main factors influence the soil reflectance in remote sensing images are mineral composition, moisture content, organic matter content and soil texture (surface), soil structure and iron oxide content. Size and shape of the soil aggregate also influence the reflectance in the images.

3.1.6.1.1: Effect of mineral composition:

The mineral composition of soils affects the reflectance spectrum. Increasing reflectance of soils occurs from the visible to the shortwave infrared - with absorption bands around 1.4 µm and 1.9 µm related to the amount of moisture in the soil.

3.1.6.1.2: Effect of soil texture, structure and moisture:

The relationship between texture, structure and soil moisture can best be described with reference to two contrasting soil types. A clay soil tends to have strong structure, which leads to rough surface texture, and have high moisture content and as a result have a fairly low diffuse reflectance. In contrast, a sandy soil tends to have a weak structure, which leads to a smooth surface texture, and have low moisture content and as a result have fairly high and often specular reflectance properties. Soil texture (roughness) also affects soil optical properties. In visible wavelengths the presence of soil moisture considerably reduces the surface reflectance of soil, until the soil is saturated. Reflectance in near and middle infrared wavelengths is also negatively related to soil moisture. An increase in soil moisture will result in a rapid decrease in reflectance in water and hydroxyl absorbing wavebands. The effect of water and hydroxyl absorption is more noticeable in clay soil as it has much bound water and very strong hydroxyl absorption properties.

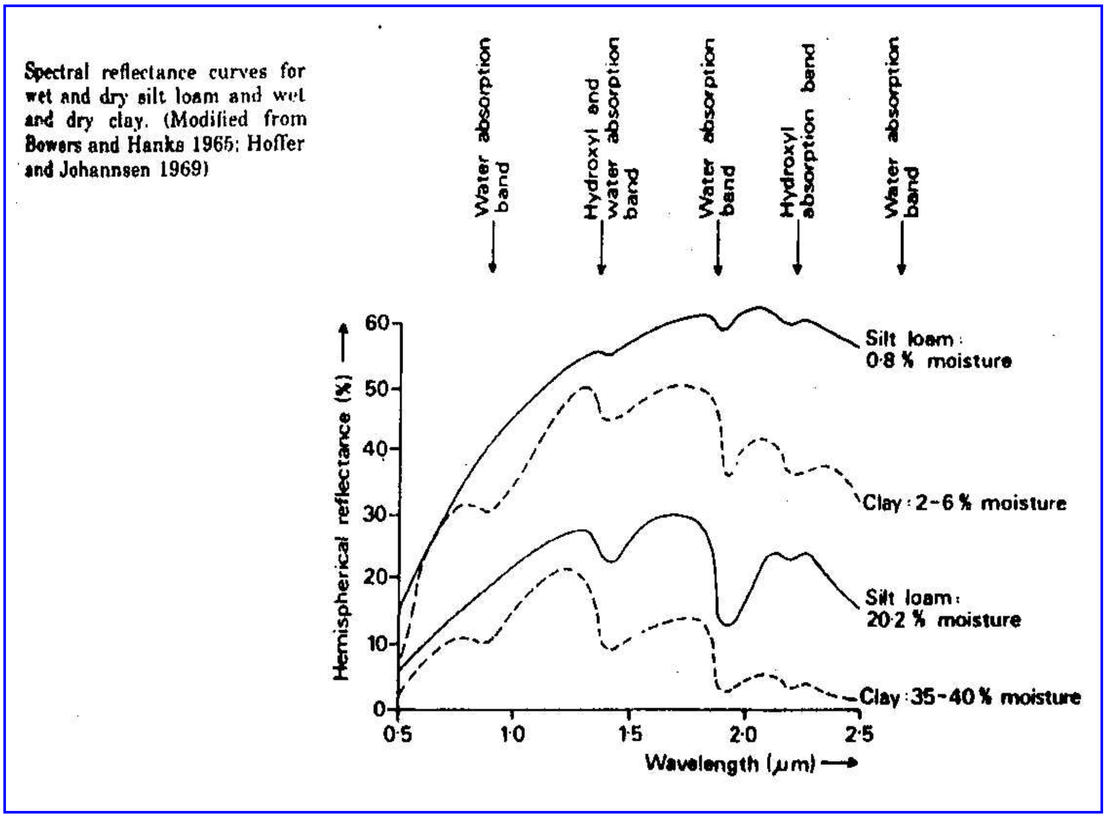

Fig 3.7: effect of soil moisture on soil spectral reflectance

(Source: Tutorials from Indian Institute of Remote Sensing, Dehradun, India)

3.1.6.1.3: Effect of organic matter:

Organic matter may indirectly affect the spectral influence, based on the soil structure and water retention capacity. It is dark and its presence decreases the reflectance from the soil up to an organic matter content of around 4-5% but beyond it hardly effects.

3.1.6.1.4: Effect of iron oxide:

Iron oxide gives many soils their rusty red coloration. Iron oxide selectively reflects red light.

3.1.6.1.5: Effect of size and shape:

Soil aggregate size and shape influence the reflectance properties. If the size of a soil aggregate large in diameter, a decrease in reflection will result.

3.1.6.2: Spectral reflectance and signature of vegetation

Components that are involved in classifying vegetation from remote sensing images received from satellites include chemical properties and physical properties recorded for the vegetation (including surface texture, roughness and local slope properties).

There are several factors that influence the reflectance quality of vegetation on satellite and remote sensing images. These include brightness, greenness and moisture. Brightness is calculated as a weighted sum of all the bands and is defined in the direction of principal variation in soil reflectance. Greenness is orthogonal to brightness and is a contrast between the near-infrared and visible bands. It is related to the amount of green vegetation in the scene. Moisture in vegetation will reflect more energy than dry vegetation.

Leaf properties that influence the leaf optical properties are the internal or external structure, age, water status, mineral stresses, and the health of the leaf (figure 3.8). It is important to note that the reflectances of the optical properties of leaves are the same, regardless of the species. What may differ for each leaf, is the typical spectral features recorded for the three main optical spectral domains; leaf pigments, cell structure and water content.

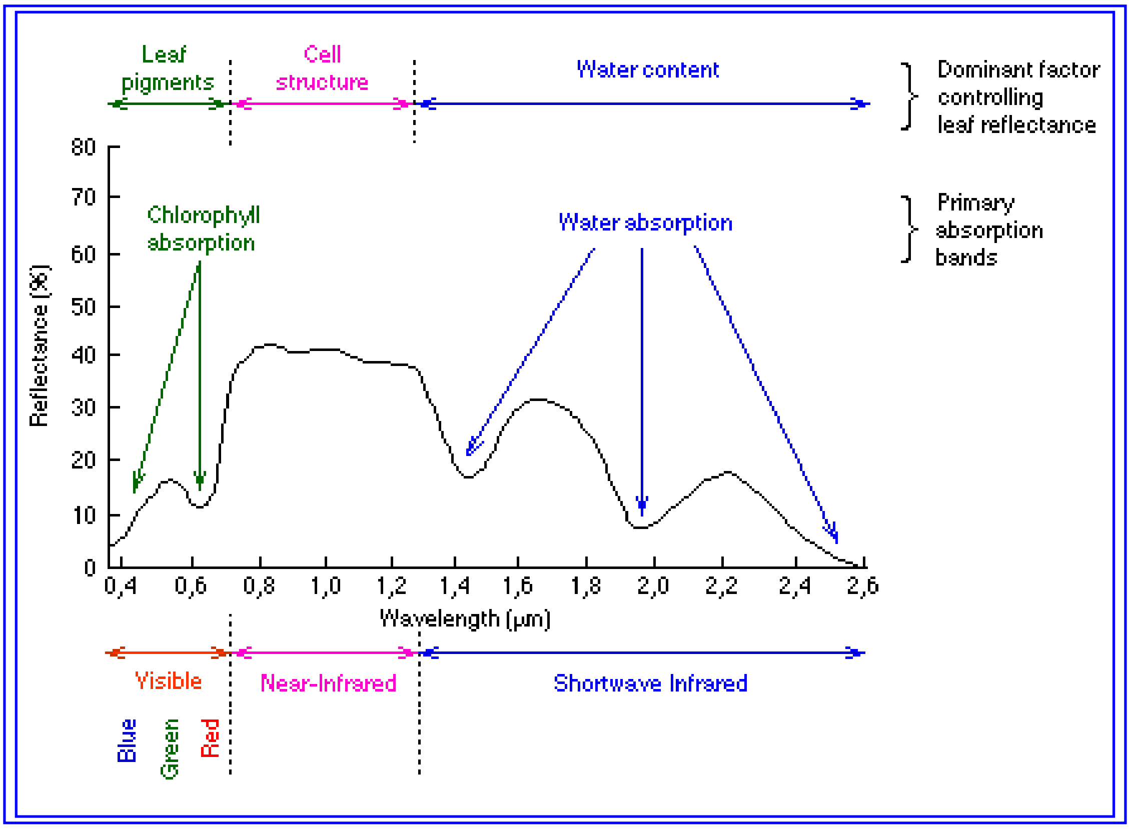

Fig 3.8: Typical spectral response characteristics of green vegetation

(Source: http://www.rsunt.geo.ucsb.edu/rscc/vol2/lec2/2_2.html#21)

Electromagnetic wavelengths affect different parts of plant and trees. These parts include leaves, stems, stalks and limbs of the plants and trees. The length of the wavelengths also plays a role in the amount of reflection that occurs. Tree leaves and crop canopies reflect more in the shorter radar wavelengths, while tree trunks and limbs reflect more in the longer wavelengths. The density of the tree or plant canopy will affect the scattering of the wavelengths.

Within the electromagnetic spectrum, bands will produce different levels of reflectance rates. For example, in the visible bands (400 - 700 nm), a lower reflectance will occur as more light will be absorbed by the leaf pigments than reflected. The blue (450 nm) and red (670 nm) wavelengths include two main absorption bands that absorb two main leaf pigments.

The images created by remote sensing will be influenced by these factors: quality, scale and season of photography, film type and background. Other factors that influence vegetation classification are time of day, sun angle, atmospheric haze, clouds, processing errors of transparencies/prints and errors in interpretating the images.

Photographic texture (smoothness and coarseness of images), total contrast or colour, relative sizes of crown images at a given photo scale and topographic location helps to determine the cover types of vegetation.

Different types of images will display diverse characteristics of vegetation. Satellite images can be combined with topographic data (ancillary data) for better interpretation.

3.1.6.3: Spectral reflectance and signature of water

The majority of radiation flux incident upon water is not reflected but is either absorbed or transmitted. In visible wavelengths of EMR, little light is absorbed, a small amount, usually below 5% is reflected and the rest is transmitted. Wavelengths in the blue-green portion of the spectrum will have a high transmittance rate. The most distinctive characteristic of water, with reference to spectral reflectance, is the energy absorption at the near-infrared wavelengths (figure 3.9). Water absorbs Infrared strongly, leaving little radiation to be either reflected or transmitted. This results in sharp contrast between any water and land boundaries. The factors, which govern the variability in reflectance of a water body, are the depth of the water, suspended material within the water and surface roughness of the water.

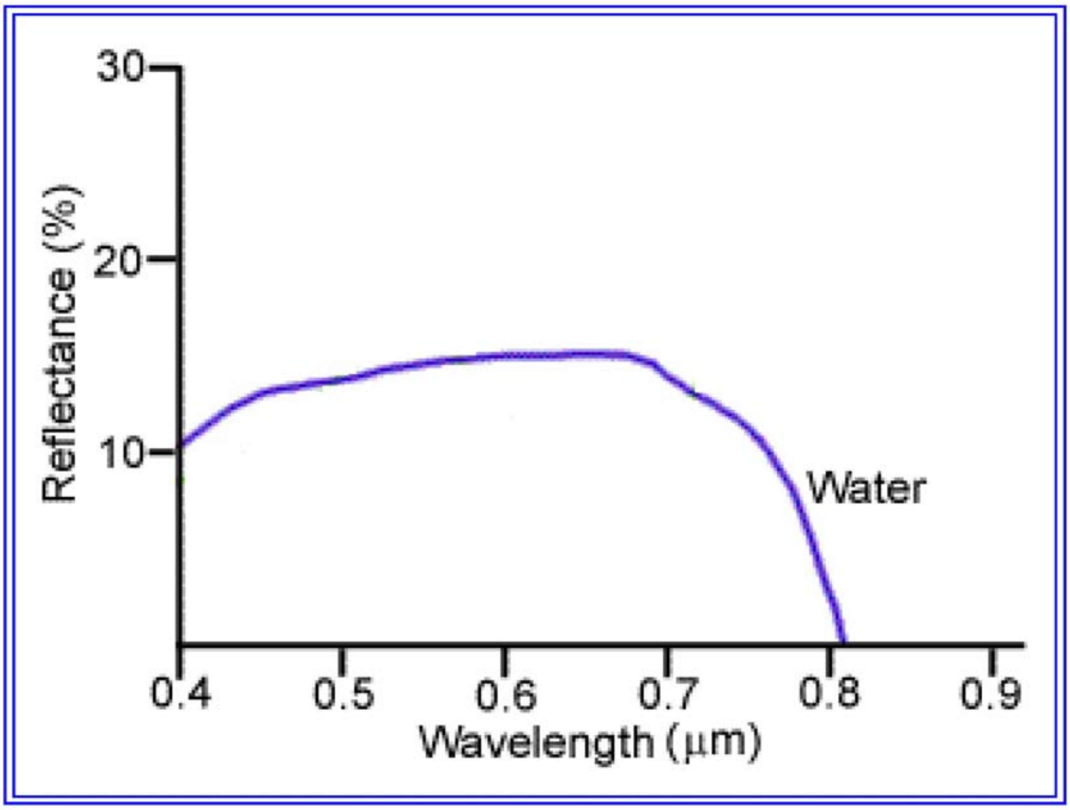

Fig 3.9: Typical spectral reflectance of water

(source: http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php)

Energy is absorbed by water in wavelengths. The wavelengths will interact in a complex manner with the water and matter (figure 3.10). The reflectance properties of water are a function of the water and the material in the water (organic and/or inorganic material). In shallow water some of the radiation is reflected not by the water itself but from the bottom of the water body. Therefore, in shallow streams it is often the underlying material that determines the water body’s reflectance properties and colour in the FCC. If the water has a large amount of suspended sediment present, than a higher visible reflectance will result compared to clearer waters. Turbulent water will also affect the amount of energy absorbed and transmitted. The amount of chlorophyll will also affect the amount of water reflectance. An increase in chlorophyll will result in a decrease of blue wavelengths and increase in green wavelengths. Water bodies that contain very high amount of chlorophyll have reflectance properties that resemble, at least in part, those of vegetation with increased green and decreased blue and decreased red reflectance. Temperature variations also affect the reflectance of water throughout the day.

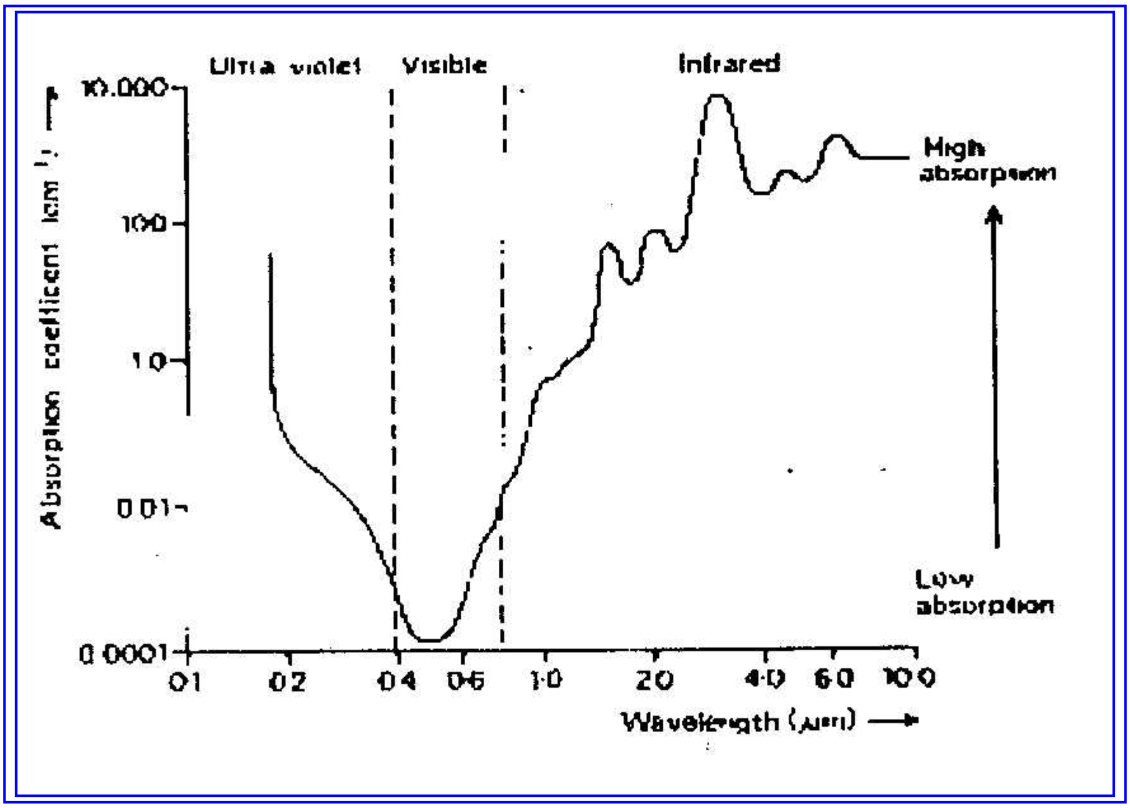

Fig 3.10: Absorption of electromagnetic radiation by sea water

(source: Tutorials from Indian Institute of Remote Sensing, Dehradun, India)

The roughness of water surface can also affect its reflectance properties. If the surface is smooth then light is reflected, giving very high or very low reflectance, dependent upon the location of the sensor. If the surface is very rough then there will be increased scattering at the surface, which in turn will increase the reflectance.

3.2: Geographical Information System (GIS):

Fast growing trends in computer technology, information systems and virtual world enables to obtain data about physical and cultural worlds and to use it for research or to solve practical problems. The introduction of modern technologies has led to an increased use of computers and information technology instead of manual methods in all aspects of spatial data handling. These Information Systems contains data in analog or digital form about the phenomena in the real world and are able to create, manipulate, store and use spatial data much faster and at rapid rate as compared to conventional methods. Data is very important and added value as we progress from data to information to knowledge. The software technology used in this domain is geographic information systems (GIS). With the help of a GIS, different types of data can be stored in digital form. The spatial analysis functions of the GIS are then applied to perform the planning tasks (figure 3.11). This can speed up the process and allows for easy modifications to the analysis approach.

GIS can be defined as "An integrated system of computer hardware and software coupled with procedures and a human analyst which together support the capture, storage, management, manipulation, analysis, modeling and display of spatially referenced data "

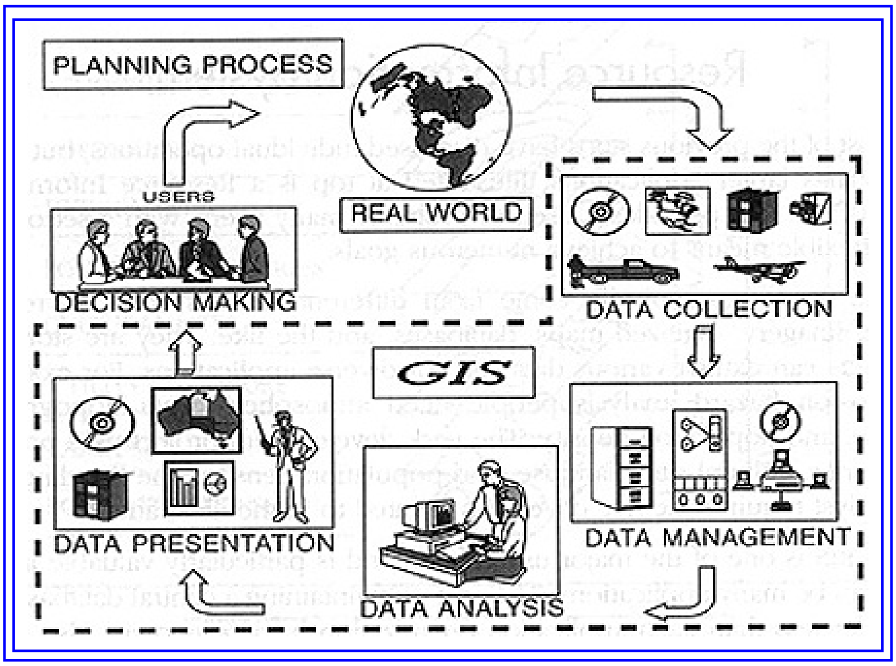

Fig 3.11: GIS in planning process

(Source: http://rst.gsfc.nasa.gov/Front/tofc.html)

In short geographical information system gives power to create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas and develop effective solutions like never before. It can be said as supporting tool for decision making process. Mapmaking and geographic analysis are not new, but a GIS performs these tasks better and faster than do the old manual methods.

3.2.1: Data Models:

Conversion of real world geographical variation into discrete objects is done through data models. It represents the linkage between the real world domain of geographic data and computer representation of these features. Data models are of two types: Raster and Vector. There are three different geometric classes of data in both the models, viz. the point representing the position, line giving the length and polygon giving information about the perimeter or area.

3.2.1.1: Raster model: In raster type of representation of the geographic data, a set of cells located by coordinate is used; each cell is independently addressed with the value of an attribute. Each cell contains a single value and every location corresponds to a cell. One set of cell and associated value is a layer (figure 3.12).

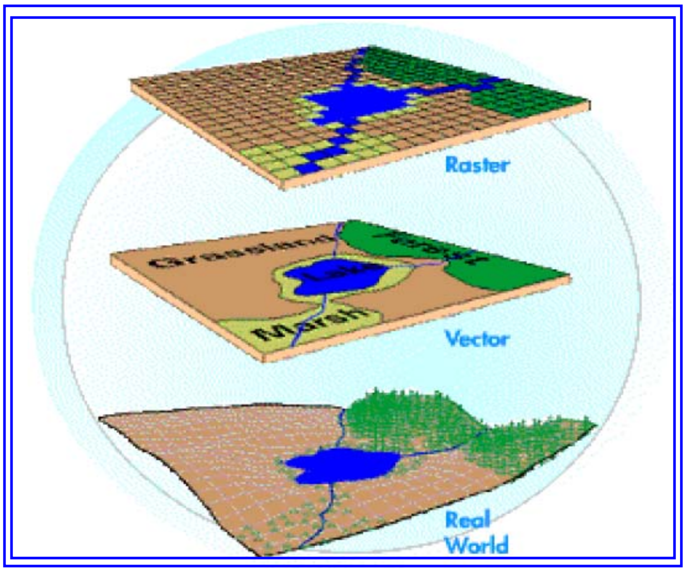

Fig 3.12: Data models generated in GIS domain

(Source: Lecture note, EDUSAT program 2007, Department Of Space, Govt. of India)

3.2.1.2: Vector model: Vector data model uses line segments or points represented by their explicit 'x', 'y' coordinates to identify locations. Discrete objects are formed by connecting line segments which area is defined by set of line segments. Vector data models require less storage space, outputs are appreciable, estimation of are/perimeters is accurate and editing is faster and convenient as compared to raster model (figure 3.12).

3.2.2: Layers and Coverages:

The common requirement to access data on the basis of one or more classes has resulted in employing several schemes in which all data of a particular level of classification, such as roads, rivers or vegetation types are grouped into so called layers and more than one layer together form coverage. The concept of layers is to be found in both vector and raster models. The layers can be combined with each other in various ways to create new layers that are a function of the individual ones. The characteristic of each layer with in layer-based GIS is that all locations with each layer may be said to belong to a single arial region or cell, whether it be a polygon bounded by lines in vector system, or a grid cell in a raster system. But it is possible for each region to have multiple attributes. The following figure shows layers and coverage concept in GIS (figure 3.13).

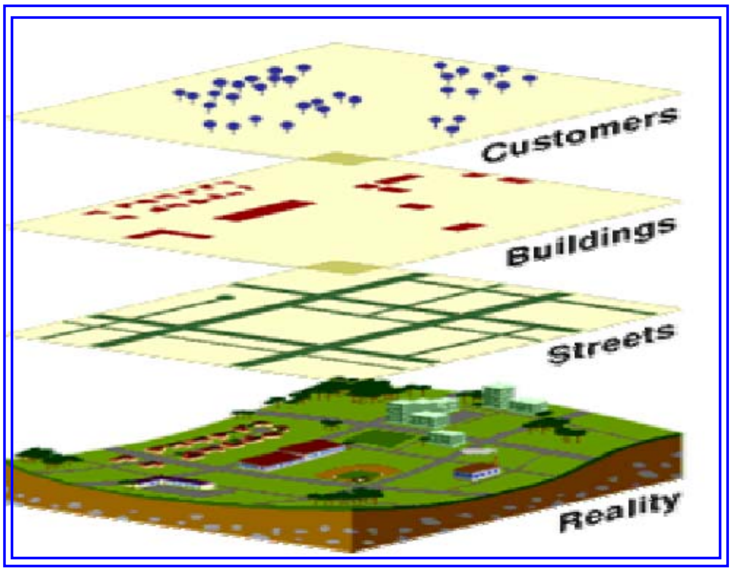

Fig 3.13: Different layers and coverages generated in GIS domain

(Source: Lecture note, EDUSAT program 2007, Department Of Space, Govt. of India)

3.3: Global Positioning System (GPS):

The Global Positioning System (GPS) is a burgeoning technology, which provides unequalled accuracy and flexibility of positioning for navigation, surveying and GIS data capture. The GPS provides continuous three-dimensional positioning 24 h/day throughout the world. The three dimentional nature of GPS measurements also allows us to determine horizontal as well as vertical displacement at the same time and place (Kalpan, 1996; Segall and Davis, 1997). The technology seems to be beneficiary to the GPS user community in terms of obtaining accurate data upto about100 meters for navigation, metre-level for mapping, and down to millimetre level for geodetic positioning. The GPS technology has tremendous amount of applications in GIS data collection, surveying, and mapping.

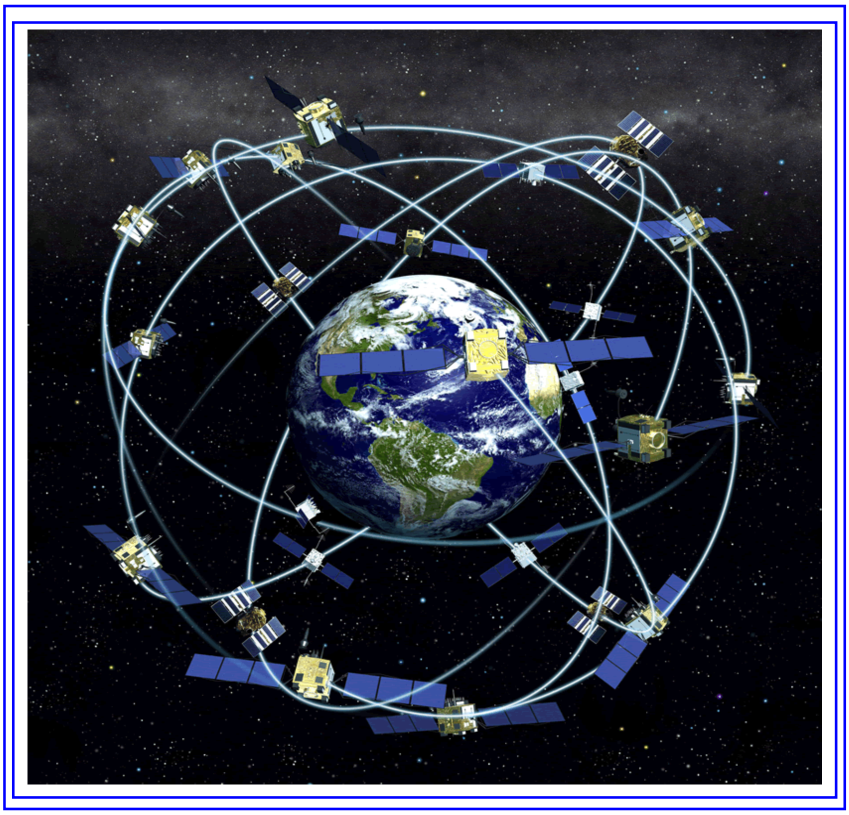

Fig 3.14: Constellation of NAVSTAR satellites orbiting earth

(Source: www.linuxjournal.com)

3.3.1: GPS –Basics:

The GPS uses constellation of 24 satellites, continuously orbiting earth and computers to compute positions anywhere on earth (figure 3.14). The GPS is based on satellite ranging. That means the position on the earth is determined by measuring the distance from a group of satellites in space. In order to understand GPS basics, the system can be categorized into five logical steps: (1) Triangulation from the satellite is the basis of the system, (2) To triangulate, the GPS measures the distance using the travel time of the radio message, (3) To measure travel time, the GPS need a very accurate clock, (4) Once the distance to a satellite is known, then we need to know where the satellite is in space and (5) As the GPS signal travels through the ionosphere and the earth's atmosphere, the signal is delayed. To compute a position in three dimensions we need to have four satellite measurements. The GPS uses a trigonometric approach to calculate the positions, The GPS satellites are so high up that their orbits are very predictable and each of the satellites is equipped with a very accurate atomic clock.

3.3.2: GPS – Components:

The GPS is divided into three major components as listed below:
(1) The Control Segment
(2) The Space Segments
(3) The User Segment

3.3.2.1: The Control Segment:

The Control Segment consists of five monitoring stations (Colorado Springs, Ascesion Island, Diego Garcia, Hawaii, and Kwajalein Island). Three of the stations (Ascension, Diego Garcia, and Kwajalein) serve as uplink installations, capable of transmitting data to the satellites, including new ephemerides (satellite positions as a function of time), clock corrections, and other broadcast message data, while Colorado Springs serves as the master control station (figure 3.15). The monitoring stations track all GPS signals for use in controlling the satellites and predicting their orbits. Meteorological data also are collected at the monitoring stations, permitting the most accurate evaluation of tropospheric delays of GPS signals. Satellite tracking data from the monitoring stations are transmitted to the master control station for processing. This processing involves the computation of satellite ephemerides and satellite clock corrections. The master station controls orbital corrections, when any satellite strays too far from its assigned position, and necessary repositioning to compensate for unhealthy (not fully functioning) satellites.

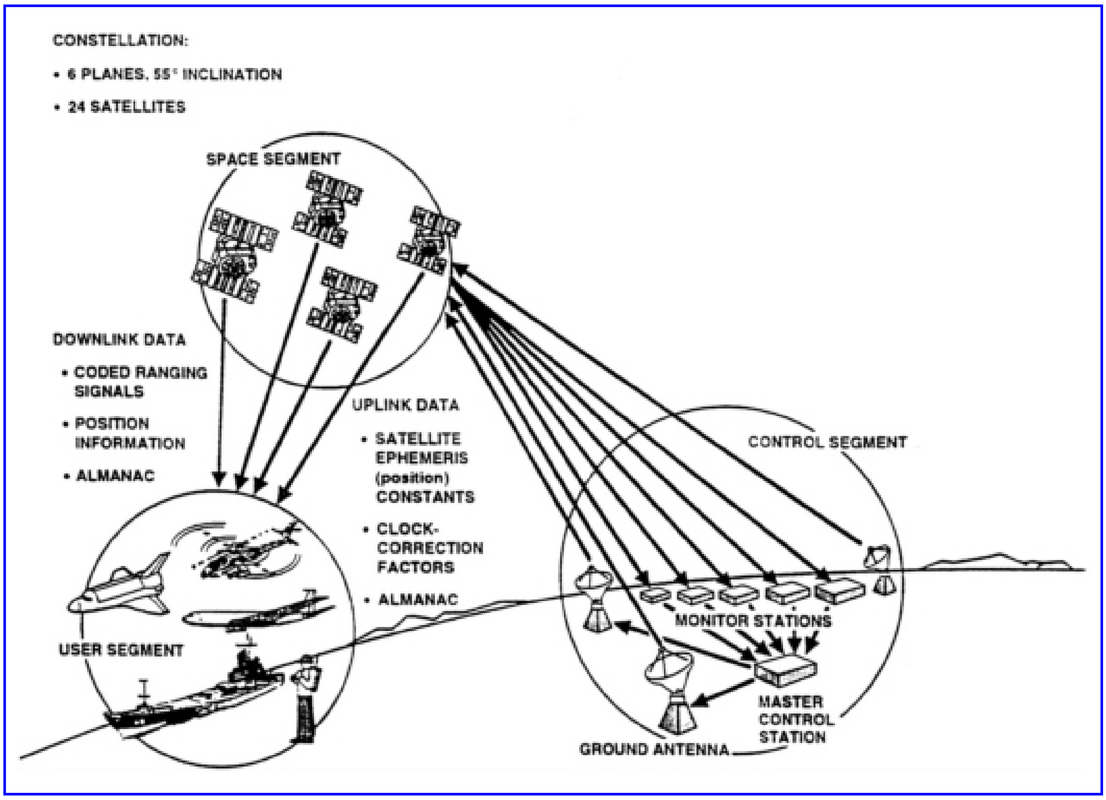

Fig 3.15: Different components of GPS

(Source: http://books.nap.edu/openbook.php?recprds_id=9254&page=6)

3.3.2.2: The Space Segment:

The Space Segment consists of the constellation of 24 earth orbiting NAVASTAR satellites. The satellites are arrayed in 6 orbital planes with 4 satellites per plane, equally spaced 60° apart along the equator and inclined at 55° from the equatorial plane. They orbit at altitudes of about 12000, miles each, with orbital periods of 12 sidereal hours (i.e., determined by or from the stars), or approximately one half of the earth's periods, approximately 12 hours of 3-D position fixes. The next block of satellites is called Block IIR, and they will provide improved reliability and have a capacity of ranging between satellites, which will increase the orbital accuracy. Each satellite contains four precise atomic clocks (Rubidium and Cesium standards) and has a microprocessor on board for limited self-monitoring and data processing. The satellites are equipped with thrusters which can be used to maintain or modify their orbits.

3.3.2.3: The User Segment:

The user segment is a total user and supplier community, both civilian and military. The User Segment consists of all earth-based GPS receivers. Receivers vary greatly in size and complexity, though the basic design is rather simple. The typical receiver is composed of an antenna and preamplifier, radio signal microprocessor, control and display device, data recording unit, and power supply. The GPS receiver decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation, and time. This is a continuous process and generally the position is updated on a second-by-second basis, output to the receiver display device and, if the receiver display device provides data capture capabilities, stored by the receiver-logging unit.

3.3.3: GPS Positioning Types:

There are basically two different types of global positioning as described below:

3.3.3.1: Absolute Positioning:

The mode of positioning relies upon a single receiver station. It is also referred to as 'stand-alone' GPS, because, unlike differential positioning, ranging is carried out strictly between the satellite and the receiver station, not on a ground-based reference station that assists with the computation of error corrections. As a result, the positions derived in absolute mode are subject to the unmitigated errors inherent in satellite positioning.

3.3.3.2: Differential Positioning:

Relative or Differential GPS carries the triangulation principles one step further, with a second receiver at a known reference point. To further facilitate determination of a point's position, relative to the known earth surface point, this configuration demands collection of an error-correcting message from the reference receiver. Differential-mode positioning relies upon an established control point. The reference station is placed on the control point, a triangulated position, the control point coordinate. This allows for a correction factor to be calculated and applied to other roving GPS units used in the same area and in the same time series.

3.3.4: Inherent sources of errors:

GPS errors sources from random noise, bias to large scale blunders.

- **Noise** errors usually amount to location inaccuracies of up to a few meters and are caused by receiver noise and pseudo random noise.

- **Bias** errors result primarily from the addition of the selective availability signals. The intentional degradation of the signal by S/A amounts to approximately two standard deviations of the potential C/A code resolution (i.e., from under 30 meters to about 100 meters). All NAVSTAR satellites generate different S/A codes; hence this is a changing and low frequency bias. Other bias errors include clock inaccuracies, which, if left uncorrected by ground control, may result in minor (up to one-meter) errors. Atmospheric dynamics can account for errors of over 10 meters, with tropospheric factors such as changes in air temperature, barometric pressure and humidity accounting for only one meter or less. Ionospheric delays of up to 10 meters are possible due to upper atmospheric aberrations. Multipath bias errors, generally sub-meter in range, are frequently unavoidable, caused by interference of signals by near-receiver reflectance of waves, or other physical obstacles in the line-of-sight between the receiver and SVs.

- **Blunders** are systematic errors that may result from user mistakes (including incorrect geodetic datum selection), software problems, receiver failures or control segment mistakes. Computer or human error can cause position solution inaccuracies from one meter to over two orders of magnitude greater.

3.3.5: GPS Applications:

One of the most significant and unique features of the Global Positioning Systems is the fact that the positioning signal is available to users in any position worldwide at any time. With a fully operational GPS system, it can be generated to a large community of likely to grow as there are multiple applications, ranging from surveying, mapping, and navigation to GIS data capture. The GPS will soon be a part of the overall utility of technology.

3.3.5.1 Surveying and Mapping:

The high precision of GPS carrier phase measurements, together with appropriate adjustment algorithms, provides an adequate tool for a variety of tasks for surveying and mapping. Using Differential Global Positioning System methods, accurate and timely can be carried out. Continuous kinematic techniques can be used for topographic surveys and accurate linear mapping.

3.3.5.2 Navigation:

Navigation using GPS can save countless hours in the field. Any feature, even if it is under water, can be located up to one hundred meters simply by scaling coordinates from a map, entering waypoints, and going directly to the site.

3.3.5.3 Remote Sensing and GIS:

It is also possible to integrate GPS positioning into remote-sensing. Using DGPS or kinematic techniques, depending upon the accuracy required, real time or post-processing will provide positions for the sensor which can be projected to the ground, instead of having ground control projected to an image. GPS are becoming very effective tools for GIS data capture. The GIS user community benefits from the use of GPS for locational data capture in various GIS applications. The GPS can easily be linked to a laptop computer in the field, and, with appropriate software, users can also have all their data on a common base with every little distortion. Thus GPS can help in several aspects of construction of accurate and timely GIS databases.