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1.1 Introduction to GIS

The advent of cheap and powerful computers over the last few decades has allowed for the development of innovative software applications for the storage, analysis, and display of geographic data. Many of these applications belong to a group of software known as Geographic Information Systems (GIS). Many definitions have been proposed for what constitutes a GIS. Each of these definitions conforms to the particular task that is being performed. Instead of repeating each of these definitions, I would like to broadly define GIS according to what it does. Thus, the activities normally carried out on a GIS include:

1. *The measurement of natural and human made phenomena and processes from a spatial perspective. These measurements emphasize three types of properties commonly associated with these types of systems: elements, attributes, and relationships.*

2. *The storage of measurements in digital form in a computer database. These measurements are often linked to features on a digital map. The features can be of three types: points, lines, or areas (polygons).*

3. *The analysis of collected measurements to produce more data and to discover new relationships by numerically manipulating and modeling different pieces of data.*

4. *The depiction of the measured or analyzed data in some type of display - maps, graphs, lists, or summary statistics.*

The first computerized GIS began its life in 1964 as a project of the Rehabilitation and Development Agency Program within the government of Canada. The Canada Geographic Information System (CGIS) was designed to analyze Canada's national land inventory data to aid in the development of land for agriculture. The CGIS project was completed in 1971 and the software is still in use today. The CGIS project also involved a number of key innovations that have found their way into the feature set of many subsequent software developments.

From the mid-1960s to 1970s, developments in GIS were mainly occurring at government agencies and at universities. In 1964, Howard Fisher established the Harvard Lab for Computer Graphics where many of the industries early leaders studied. The Harvard Lab produced a number of mainframe GIS applications including: SYMAP (Synagraphic Mapping System), CALFORM, SYMVU, GRID, POLYVRT, and ODYSSEY. ODYSSEY was first modern vector GIS and many of its features would form the basis for future commercial applications. Automatic Mapping System was developed by the United States Central Intelligence Agency (CIA) in the late 1960s. This project then spawned the CIA's World Data Bank, a collection of coastlines, rivers, and political boundaries, and the CAM software package that created maps at different scales from this data. This development was one of the first systematic map databases. In 1969, Jack Dangermond, who studied at the Harvard Lab for Computer Graphics, co-founded Environmental Systems Research Institute (ESRI) with his wife Laura. ESRI would become in a few years the dominate force in the GIS marketplace and create ArcInfo and ArcView software. The first conference dealing with GIS took place in 1970 and was organized by Roger Tomlinson (key individual in the development of CGIS) and Duane Marble (professor at Northwestern University and early GIS innovator). Today, numerous conferences dealing with GIS run every year attracting thousands of attendants.

In the 1980s and 1990s, many GIS applications underwent substantial evolution in terms of features and analysis power. Many of these packages were being refined by private companies who could see the future commercial potential of this software. Some of the popular commercial applications launched during this period include: ArcInfo, ArcView, MapInfo, SPANS GIS, PAMAP GIS, INTERGRAPH, and SMALLWORLD. It was also during this period that many GIS applications moved from expensive minicomputer workstations to personal computer hardware.

1.1.1 Why document your data?

Working with your Geographic Information System on a regular basis as you do, you probably have a pretty good idea about what it contains, the area of the country it covers, and what its major strengths and weaknesses are likely to be. You know, for example, that your data cover the city of York, that period *information is only stored to the nearest century, and that the aerial photographic interpretation to the south–west of the city is a bit dubious.*

1.1.2 Documentation for others

Data offered to the ADS, however, may potentially be used by researchers from many different parts of the planet, and with widely varied levels of expertise. They have no way of knowing anything at all about your data unless you tell them.

In order to make sure that the maximum amount of information is delivered to the user whilst involving you, the depositor, in minimal effort, the Archaeology Data Service has developed a number of procedures to standardize and simplify the documentation process.

1.1.3 Documentation for you

Some form of record about your data — and about what you've done to it — is also, of course, undoubtedly useful within your own organization. Even using data every day, it is still possible to forget about where some of it came from, or how the data you currently used were originally compiled from various sources.

This guide introduces the issues relevant to both types of documentation, as well as discussing the detail relevant to one or the other.

1.2 Database & Scales

Quantitative and qualitative data are two types of data.

1.2.1 Qualitative data

Qualitative data is a categorical measurement expressed not in terms of numbers, but rather by means of a natural language description. In statistics, it is often used interchangeably with "categorical" data.

Although we may have categories, the categories may have a structure to them. When there is not a natural ordering of the categories, we call these nominal categories. Examples might be gender, race, religion, or sport.

When the categories may be ordered, these are called ordinal variables. Categorical variables that judge size (small, medium, large, etc.) are ordinal variables. Attitudes (strongly disagree, disagree, neutral, agree, strongly agree) are also ordinal variables, however we may not know which value is the best or worst of these issues. Note that the distance between these categories is not something we can measure.

1.2.2 Quantitative data

Quantitative data is a numerical measurement expressed not by means of a natural language description, but rather in terms of numbers. However, not all numbers are continuous and measurable. For example, the social security number is a number, but not something that one can add or subtract. Quantitative data always are associated with a scale measure.

Probably the most common scale type is the ratio-scale. Observations of this type are on a scale that has a meaningful zero value but also have an equidistant measure (i.e., the difference between 10 and 20 is the same as the difference between 100 and 110). For example, a 10 year-old girl is twice as old as a 5 year-old girl. Since you can measure zero years, time is a ratio-scale variable. Money is another common ratio-scale quantitative measure. Observations that you count are usually ratio-scale (e.g., number of widgets).

A more general quantitative measure is the interval scale. Interval scales also have a equidistant measure. However, the doubling principle breaks down in this scale. A temperature of 50 degrees Celsius is not "half as hot" as a temperature of 100, but a difference of 10 degrees indicates the same difference in temperature anywhere along the scale. The Kelvin temperature scale, however, constitutes a ratio scale because on the Kelvin scale zero indicates absolute zero in *temperature, the complete absence of heat. So one can say, for example, that 200 degrees Kelvin is twice as hot as 100 degrees Kelvin.*

1.2.3 Types of data

There are four types of data that may be gathered in social research, each one adding more to the next. Thus ordinal data is also nominal, and so on.

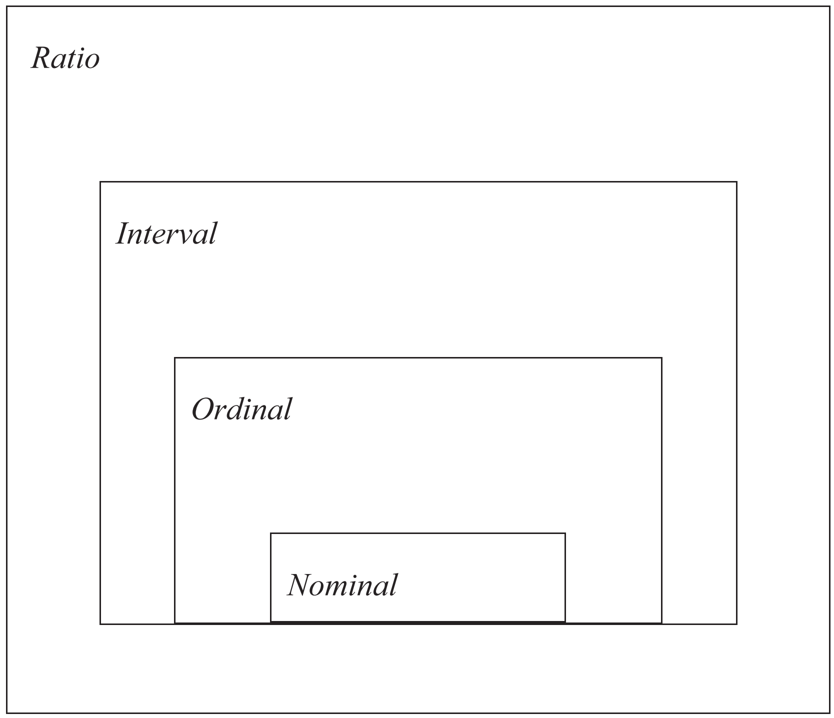

Fig. 1.1: Types of data

1.2.3.1 Nominal

The name 'Nominal' comes from the Latin nomen, meaning 'name' and nominal data are items which are differentiated by a simple naming system.

The only thing a nominal scale does is to say that items being measured have something in common, although this may not be described.

Nominal items may have numbers assigned to them. This may appear ordinal but is not -- these are used to simplify capture and referencing.

Nominal items are usually categorical, in that they belong to a definable category, such as 'employees'.

Example:

1. *The number pinned on a sports person.*
2. *A set of countries.*

1.2.3.2 Ordinal

Items on an ordinal scale are set into some kind of order by their position on the scale. This may indicate such as temporal position, superiority, etc.

The order of items is often defined by assigning numbers to them to show their relative position. Letters or other sequential symbols may also be used as appropriate.

Ordinal items are usually categorical, in that they belong to a definable category, such as '1956 marathon runners'.

You cannot do arithmetic with ordinal numbers -- they show sequence only.

Example:

1. *The first, third and fifth person in a race.*
2. *Pay bands in an organization, as denoted by A, B, C and D.*

1.2.3.3 Interval

Interval data (also sometimes called integer) is measured along a scale in which each position is equidistant from one another. This allows for the distance between two pairs to be equivalent in some way.

This is often used in psychological experiments that measure attributes along an arbitrary scale between two extremes.

Interval data cannot be multiplied or divided.

Example:

1. *My level of happiness, rated from 1 to 10.*
2. *Temperature, in degrees Fahrenheit.*

1.2.3.4 Ratio

In a ratio scale, numbers can be compared as multiples of one another. Thus one person can be twice as tall as another person. Important also, the number zero has meaning.

Thus the difference between a person of 35 and a person 38 is the same as the difference between people who are 12 and 15. A person can also have an age of zero.

Ratio data can be multiplied and divided because not only is the difference between 1 and 2 the same as between 3 and 4, but also that 4 is twice as much as 2.

Interval and ratio data measure quantities and hence are quantitative. Because they can be measured on a scale, they are also called scale data.

Example:

1. *A person's weight*
2. *The number of pizzas I can eat before fainting*

1.2.4 Parametric vs. Non-parametric

Interval and ratio data are parametric, and are used with parametric tools in which distributions are predictable (and often Normal).

Nominal and ordinal data are non-parametric, and do not assume any particular distribution. They are used with non-parametric tools such as the Histogram.

1.2.5 Continuous and Discrete

Continuous measures are measured along a continuous scale which can be divided into fractions, such as temperature. Continuous variables allow for infinitely fine sub-division, which means if you can measure sufficiently accurately, you can compare two items and determine the difference.

Discrete variables are measured across a set of fixed values, such as age in years (not microseconds). These are commonly used on arbitrary scales, such as scoring your level of happiness, although such scales can also be continuous.

1.2.6 Map Scale

Maps are rarely drawn at the same scale as the real world. Most maps are made at a scale that is much smaller than the area of the actual surface being depicted. The amount of reduction that has taken place is normally identified somewhere on the map. This measurement is commonly referred to as the map scale. Conceptually, we can think of map scale as the ratio between the distance between any two points on the map compared to the actual ground distance represented. This concept can also be expressed mathematically as:

$$\text{Map Scale} = \frac{\text{Map Distance}}{\text{Earth Distance}}$$

On most maps, the map scale is represented by a simple fraction or ratio. This type of description of a map's scale is called a representative fraction. For example, a map where one unit (centimeter, meter, inch, kilometer, etc.) on the illustration represents 1,000,000 of these same units on the actual surface of the Earth would have a representative fraction of 1/1,000,000 (fraction) or 1:1,000,000 (ratio). Of these mathematical representations of scale, the ratio form is most commonly found on maps.

Scale can also be described on a map by a verbal statement. For example, 1:1,000,000 could be verbally described as "1 centimeter on the map equals 10 kilometers on the Earth's surface" or "1 inch represents approximately 16 miles".

Most maps also use graphic scale to describe the distance relationships between the map and the real world. In a graphic scale, an illustration is used to depict distances on the map in common units of measurement. Graphic scales are quite useful because they can be used to measure distances on a map quickly.

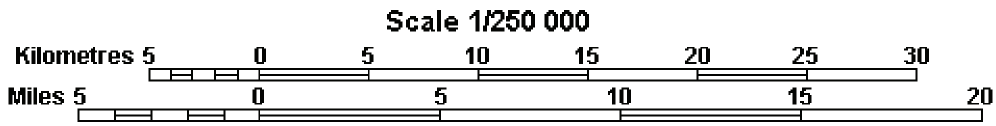

Fig. 1.2: Graphic scale

The following graphic scale was drawn for map with a scale of 1:250,000. In the illustration distances in miles and kilometers are graphically shown.

Maps are often described, in a relative sense, as being either small scale or large scale. Figure 2a-10 helps to explain this concept. In we have maps representing an area of the world at scales of 1:100,000, 1:50,000, and 1:25,000. Of this group, the map drawn at 1:100,000 has the smallest scale relative to the other two maps. The map with the largest scale is map C which is drawn at a scale of 1:25,000.

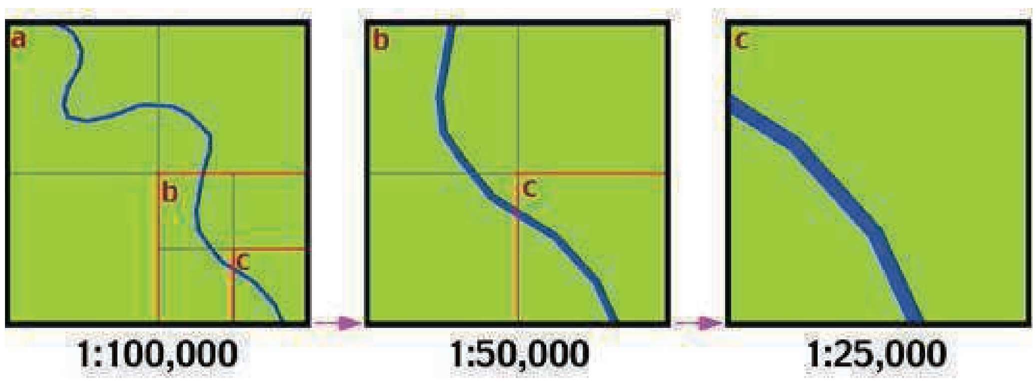

Fig. 1.3: Map scale

The following three illustrations describe the relationship between map scale and the size of the ground area shown at three different map scales. The map on the far left has the smallest scale, while the map on the far right has the largest scale. Note what happens to the amount of area represented on the maps when the scale *is changed. A doubling of the scale (1:100,000 to 1:50,000 and 1:50,000 to 1:25,000) causes the area shown on the map to be reduced to 25% or one-quarter.*

1.3 Concepts in GIS

A phrase many use in referring to GIS is "computer mapping." GIS is about creating maps on a computer for a variety of descriptive and analytical purposes. GIS can help planners and analysts "visualize" data to better understand patterns and concentrations of spatial phenomena. GIS also has the useful ability to portray layers of information, to help uncover spatial relationships among multiple sets of data. A typical GIS "session" involves bringing in various map layers for analysis.

Map layers can take the form of points, lines, or areas.

Points represent phenomena that have a specific location, such as homes, businesses, colleges, schools, and crime sites. Lines represent phenomena that are linear in nature, such as roads, rivers, and water lines. Areas represent phenomena that are bounded (states, counties, zip codes, school districts, census tracts). For example, a higher education institution may want to create a map illustrating the housing locations of off-campus students. A map would typically include (1) the layer of student housing locations represented by points; (2) a map layer portraying streets, represented as lines; and (3) some form of a bounded area layer such as villages or towns, and city wards. It is important to note that the extent to which one can match data to base maps goes well beyond the familiar examples of mapping state, county, and town data. For example, an excellent use of GIS is in the area of facilities management. Both MapInfo and ArcView have the ability to import AutoCAD drawing files, the most popular format for building and room drawings. Characteristics of each building and room can be associated to the drawings in a GIS. Many higher education institutions have already developed such applications.

Perhaps the most important concept involved in using a GIS is that of associating, or "attaching," attribute data to a spatially referenced base map. For example, picture a map of the United States with the state boundaries easily visible and distinguishable. This *common base map in a GIS would contain the name of each state and, importantly, the coordinates (latitude and longitude) of each state boundary. With this information, a GIS can display a simple base map of the United States by state. A database of socioeconomic data such as population, median income, and racial distribution for each state in the country can then be associated or attached to the state boundary map layer. In social sciences research, a GIS may associate the demographic information in the database to the base map by matching the name of each state in the base map to the name of each state in the database. It is this capability of matching up or "merging" data in a database to a base map that is at the foundation of nearly every analysis employing GIS technology.*

It is therefore extremely important that the data contain a locational identifier in order to be mapped in a GIS. Typical examples of locational identifiers are street address, zip code, county, state, and census tract. If this information is in the data, then the data can be associated to a base map and portrayed and analyzed in a GIS. The term used to describe the associating of attribute data to a base map in a GIS is geocoding, or geographically encoding the data to allow it to be mapped. Address-level data are typically geocoded to a street-level base map, county statistics are geocoded against a county-level base map, and so forth.

Another key concept associated with GIS is that it can be a tremendous reporting tool. One way to think about GIS is that it is a "visual communication tool." Think of a standard data report that lists the number of students by county who attend a particular higher education institution. The counties would be listed in one column and the number of students in a County Boundary and Census Tracts (Polygon or Area Layers), High School Locations (Point Layer), Interstate Highways (Line Layer) and the information or labels (Annotation Layer).

Fig. 1.4: Points, Lines, and Areas

The table could be sorted alphabetically by county or by number of students. This type of report does not have a "spatial" dimension illustrating the location of each respective county. Once these data are geocoded and mapped, one can add a powerful dimension to the communication and "absorption" of the information on the reader's part. Concentrations and patterns immediately come alive. At many institutions in upstate New York, for example, there is a clear upstate-downstate distinction among the student body. A map can illustrate this distinction much more powerfully than a table of county names and numbers.

1.4 Components in GIS

A Geographic Information System combines computer cartography with a database management system. The figure below describes some of the major components common to a GIS. This diagram suggests that a GIS consists of three subsystems: (1) an input system that allows for the collection of data to be used and analyzed for some purpose; (2) computer hardware and software systems that store the data, allow for data management and analysis, and can be used to display data manipulations on a computer monitor; (3) an output system that generates hard copy maps, images, and other types of output.

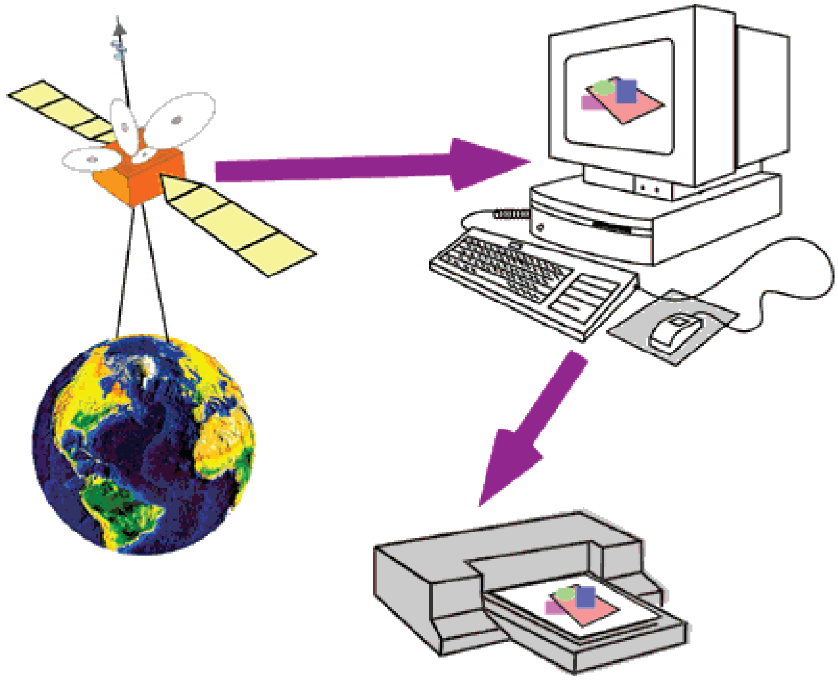

Fig.1.5: Components of a Geographic Information System

Three major components of a Geographic Information System. These components consist of input, computer hardware and software, and output subsystems.

Two basic types of data are normally entered into a GIS. The first type of data consists of real world phenomena and features that have some kind of spatial dimension. Usually, these data elements are depicted mathematically in the GIS as either points, lines, or polygons that are referenced geographically (or geocoded) to some type of coordinate system. This type data is entered into the GIS by devices like scanners, digitizers, GPS, air photos, and satellite imagery. The other type of data is sometimes referred to as an attribute. Attributes are pieces of data that are connected or related to the points, lines, or polygons mapped in the GIS. This attribute data can be analyzed to determine patterns of importance. Attribute data is entered directly into a database where it is associated with element data.

1.5 Application of GIS

Fig. 1.6: The tools and applications of GIS has increased

1.5.1 Application of GIS in energy exploration

GIS applications in energy exploration are the primary way in which oil potentiality in suitable locations is evaluated. This service has become indispensable for the petroleum industries to stay ahead in the competition regarding the discovery of new sources of petroleum.

It is with the help of GIS applications in energy exploration that large petroleum companies select the most suitable sites for their retail outlets by evaluating the information on demography and transportation, which can optimize the customers satisfaction.

GIS applications in energy exploration helps to analyze and integrate a lot of different types of data to the specified location and then by overlaying, viewing, and manipulating the data in the form of a map, it discovers the new or extension of the potent oil source. The data required for exploration are:

- *Satellite imagery*
- *Digital aerial photo mosaics*
- *Seismic surveys*
- *Surface geology studies*
- *Sub-surface and cross section interpretations and images*
- *Good locations*
- *Existing infrastructure information*

GIS applications in energy exploration manage the spatial distribution of components of the daily petroleum based business items like leases, pipelines, wells, environmental concerns, facilities, and retail outlets, within the corporate database. The digital mapping of the web enabled GIS applications apply appropriate geographic analysis efficiently.

The exploration of the oil reserves is associated with the production process of the petroleum resources. GIS technology is ideally suited for aiding the respective petroleum company to understand certain geographic, infrastructural, logistical, and environmental factors related to that specific site. The GIS applications in energy exploration can also be integrated with other economic business planning engines to provide a focused business solution. They help the petroleum industry by providing relevant information regarding drilling platforms, oil refineries, and pipeline networks. These infrastructural requirements for energy production exist in difficult commercial, operational, and environmental conditions. Therefore, it is essential that they should be planned, maintained, and operated effectively.

In a nutshell, GIS applications in energy exploration integrate the exploration and production of energy reserves with the infrastructure management systems of the oil plants.

1.5.2 Vehicle tracking systems

Vehicle tracking systems are usually used for managing a fleet of vehicles. The vehicles of a fleet are fitted with GPS, which usually transmit the positional data of the vehicles to a central station. The central station is a monitoring station, where the position of vehicles is displayed on a GIS map. Vehicle tracking systems will be useful for the police and emergency response services. The central station usually diverts the vehicle nearest to the site, where the vehicles are required. By using a wireless phone service or cellular phone network, real time corrections can be sent to the receivers fitted on the vehicles and better results can be obtained.

1.5.3 Application in Forestry

GIS applications in forestry in India is the indispensable method by means of which the total forest area in India is measured.

Digital mapping has brought about a revolutionary change in the entire Geographical Information System (GIS). The rudimentary method of depending on paper maps has been changed and at present, one depends on digital maps, which in fact have been playing a significant role in the monitoring and management of the forests.

The Geographical Information System, Global Positioning System, and Remote Sensing are important technological applications used in various areas of life in today's era of modern communication.

The GIS Applications in forestry has come up with excellent results in the decision making in the field level. There are different types of GIS Applications in forestry, such as -

- *Supervising of afforestation plans*
- *Monitoring of plantation schemes*
- *Corridor mapping for animal migration*
- *Habitat mapping*

- *Land capability mapping*

GIS applications in forestry are also used for the prevention of trespassers in the forests. This is done with the help of satellite imageries. The total forest area in India is under danger from various quarters today. GIS applications in forestry are also very useful in the protection of forests. With the help of such applications in the GIS system, accurate information can be remotely and easily obtained. The geo-spatial data is organized to make important decisions. The data should be accurate as any type of error within the GIS calculations would misguide the users.

Some other useful purposes for which GIS applications in forestry can be used are the selection of locations for plantation or for supervising the ongoing danger of encroachments. Moreover, issues like burning of forests and 'jhum' cultivation can be regulated. The expansion of infrastructure and communication networks are also taken care of by GIS applications. Managing the forests and village are also aided by these applications.

Forest Fire Monitoring in Uttaranchal State Forest Department

Synergy of Indian Remote sensing Satellite (IRS) systems covering IRS-P6, IRS-1D, and data given by TERRA/AQUA Moderate resolution Imaging Spectroradiometer (MODIS), National Oceanic and Aeronautic Administration - Advanced Very High Resolution Radiometer (NOAA-AVHRR), Defense Meteorological Satellite Program-Operational Line scan System (DMSP-OLS), Environment Satellite (ENVISAT) are useful in forest fire detection, active fire progression monitoring, near real time damage assessment, and mitigation planning.
The Decision Support Center (DSC) is established at National Remote Sensing Centre (NRSC) as part of Disaster Management Support Programme of Department of Space (DOS), for working towards effective management of disasters in India. Considering the importance of forest fire management in India, a comprehensive Indian Forest Fire Response and Assessment System (INFFRAS) is invoked under DSC activities of NRSC, which integrates multi-sensor satellite data and ground data through spatially and temporally explicit GIS analysis frame work. The INFFRAS is designed to provide services on:

1. *Fire alerts :Value-added daily daytime TERRA/AQUA MODIS fire locations and DMSP-OLS derived daily nighttime fire locations*

2. *Fire progression: Progression of fires using daily day and night fire location information given by MODIS/DMSP-OLS and burnt area expansion derived from temporal high resolution data sets*

3. *Burnt area assessment: Mapping episodic fire events using moderate and high resolution optical data sets*

4. *Forest fire mitigation plans.*

1.5.4 Vehicle navigation systems

Vehicle navigation systems are used for guiding vehicles to their destination. These systems usually use GPS or inertial navigation systems or a combination of both for positioning the vehicle. The advantage of using both inertial navigation systems and GPS is that navigation can be continued even when the GPS cannot receive the signals form the satellites due to obstruction. In countries like the US, vehicle navigation systems are used for guiding tourists to different tourist spots. The vehicle navigation systems use a computer, which determines the position of the vehicle, plans the route and gives the directions to the driver. The driver gives the location of his/her destination while starting his journey and the computer guides the driver by giving either audio or and visual instructions. The route the computer plans is usually optimized route; the route is the route optimized for distance or the route can be the most or the least used route (Jurgen, 1998). GPS receivers, which have the capability of displaying the speed, will be useful for determining the speed of the vehicle, even though the display might show a non-zero value of speed sometimes, when the speed of the vehicle is zero.

1.5.5 Property Tax Assessment System using GIS

Municipal authorities all over India understand the importance of bringing IT into their infrastructure and setup. This has led to opening and the consolidation of IT departments in the municipal corporations in the country. Property tax assessment is one of the areas of Kanpur Municipal Corporation where we can use the technology to meet the *challenges of storing huge amount of data, and updating it on a continuous basis in an effective manner. For example, a revenue inspector who has to collect property tax from a number of households, would like to know the defaulters in his assigned area, and an IT system would give him a document or spreadsheet listing the names and addresses of the same. However, if the inspector could be shown visualization on the map about where those properties are corresponding to the defaulters, it would give him much more information than a spreadsheet. Similarly, an administrative officer for a ward or zone could login to the GIS system and visualize the properties under his jurisdiction, and see the properties corresponding to defaulters in different colors, depending on the amount to be paid by the defaulters. The Property Tax Assessment System (PTAS) GIS is one such system which attempts to benefit the municipal authorities for all queries related to property tax. Similar kind of systems can exist for water tax management, and any other tax related information system. The functionalities are described comprehensively in this project report document. This project report document will attempt to describe and consolidate the requirements of GIS application designed for the municipal authority. It gives the detailed information of the developed functionalities and the dependencies on GIS.*

The PTIS is developed using Development environment shown in the figure.

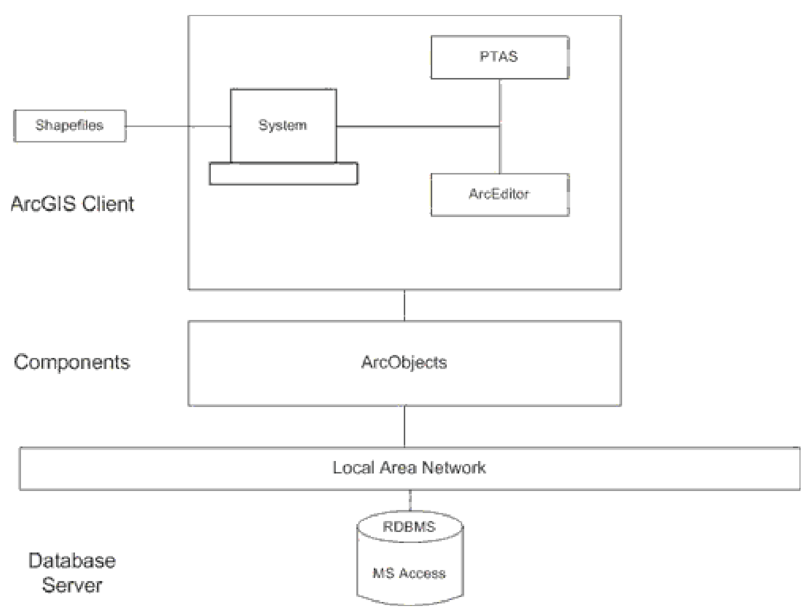

Fig. 1.7: PTIS

1.5.6 Emergency response planning

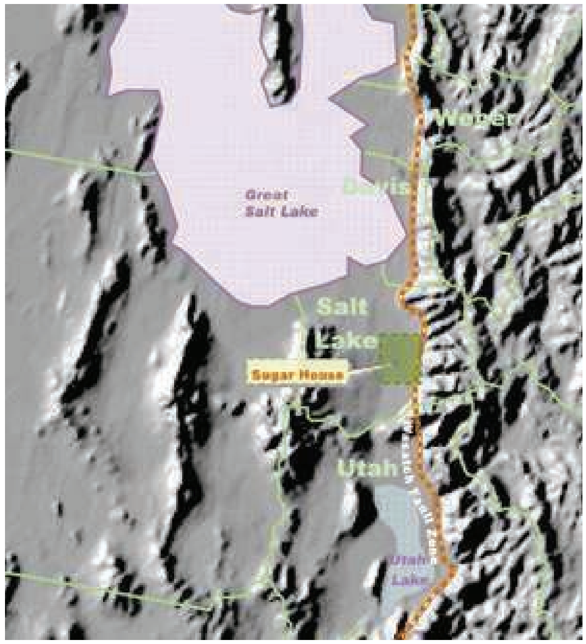

Fig. 1.8: The Wasatch Fault zone runs through Salt Lake City along the foot of the Wasatch Mountains in north-central Utah.

Map of the area surrounding the USGS Sugar House 7.5-minute quadrangle, Salt lake City, Utah, showing the location of the Wasatch Fault zone.

A GIS was used to combine road network and earth science information to analyze the effect of an earthquake on the response time of fire and rescue squads. The area covered by the USGS Sugar House 7.5-minute topographic quadrangle map was selected for the study because it includes both undeveloped areas in the mountains and a part of Salt Lake City. Detailed earth science information was available for the entire region.

The road network from a USGS digital line graph includes information on the types of roads, which range from rough trails to divided highways. The locations of fire stations were plotted on the road network. A GIS function called network analysis was used to calculate the time necessary for emergency vehicles to travel from the fire stations to different areas of the city. The network analysis function considers two elements: (1) distance from the fire station, and (2) speed of travel based on the type of road. The analysis shows that under normal conditions, most of the area within the city will be *served in less than 7 minutes and 30 seconds because of the distribution and density of fire stations and the continuous network of roads.*

The accompanying illustration depicts the blockage of the road network that would result from an earthquake, assuming that any road crossing the fault trace would become impassable. The primary effect on emergency response time would occur in neighborhoods west of the fault trace, where travel times from the fire stations would be noticeably lengthened.

Fig. 1.9: Blocking of road network

After faulting, initial model. Network analysis in a GIS produces a map of travel times from the stations after faulting. The fault is in red. Emergency response times have increased for areas west of the fault.

1.5.7 Three-dimensional GIS

To more realistically analyze the effect of the Earth's terrain, we use three-dimensional models within a GIS. A GIS can display the Earth in realistic, three-dimensional perspective views and animations that convey information more effectively and to wider audiences than traditional, two-dimensional, static maps. The U.S. Forest Service was offered a land swap by a mining company seeking development rights to a mineral deposit in Arizona's Prescott National Forest. Using a GIS, the USGS and the U.S. Forest Service created perspective views of the area to depict the terrain as it would appear after mining.

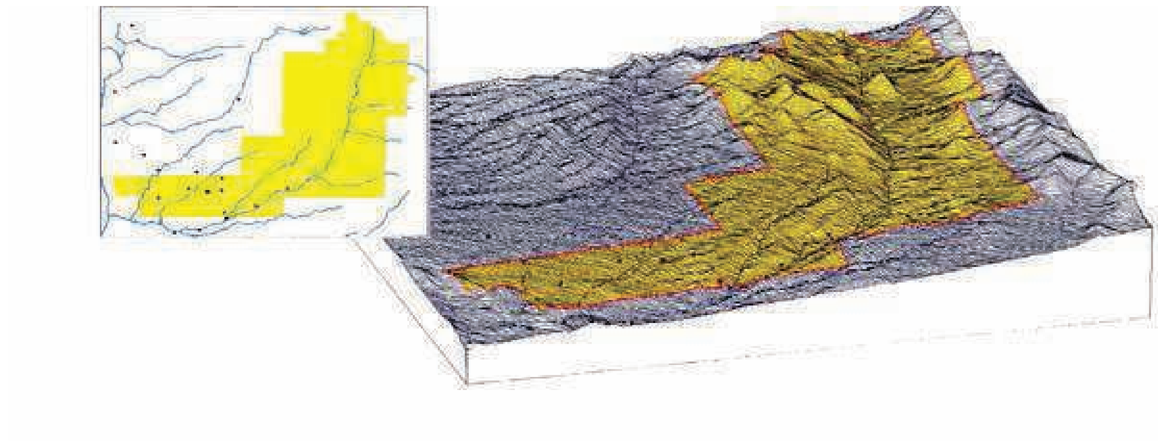

Fig. 1.10: Prescott National Forest, showing altered topography due to mine development.

To assess the potential hazard of landslides both on land and underwater, the USGS generated a three-dimensional image of the San Francisco Bay area. It created the image by mosaicing eight scenes of natural color composite Landsat 7 Enhanced Thematic Mapper imagery on California fault data using approximately 700 digital elevation models at 1:24,000 scale.

Fig 1.11: Three-dimensional image of the San Francisco Bay created to assess the potential of land and underwater avalanches.

1.6 Summary

In this unit we have discussed about geographical information systems, its components and its applications. Database types and scales have been introduced and discuss, such that designing and building a database in GIS can be understood. The basic format of

Geographical data representation along with the computer, software and user requirements has also been highlighted. At the end we have discussed about varied and intensive application of GIS.

1.7 Glossary

Area- *A closed, two-dimensional shape defined by its boundary. A calculation of the size of a two-dimensional feature, measured in square units.*

Digitize- *To encode map features as x,y coordinates in digital form. Lines are traced to define their shapes. This can be accomplished either manually or by use of a scanner.*

Digitizer- *A device connected to a computer, consisting of a tablet and a handheld puck, that converts positions on the tablet surface as they are traced by an operator to digital x,y coordinates, yielding vector data consisting of points, lines, and polygons.*

Database- *A logical collection of interrelated information, managed and stored as a unit. A GIS database includes data about the spatial location and shape of geographic features recorded as points, lines, and polygons as well as their attributes.*

Geocoded- *Translating geographic coordinates of map units (e.g. lines and points), into X, Y digits or grid cells*

Line- *A shape defined by a connected series of unique x,y coordinate pairs. A line may be straight or curved.*

Point- *A level of spatial measurement referring to an object which has no dimension at a specified scale. Examples include wells, weather stations, and navigational lights.*

1.8 References

1. *Burrough, Peter A. and Rachael A. McDonnell. 1998. Principles of Geographical Information Systems. Published by Oxford University Press, Toronto. ISBN13: 9780198233657 ISBN10: 0198233655*

2. *http://teams.gemstone.umd.edu/classof2009/fastr/Jardine%20Article.pdf*

3. *http://www.gdmc.nl/oosterom/PoGISHyperlinked.pdf*

4. *http://ads.ahds.ac.uk/project/goodguides/gis/sect35.html*

5. *http://giswin.geo.tsukuba.ac.jp/sis/tutorial/Fundamentals_of_GIS_Estoque.pdf*

6. *http://geografi.ums.ac.id/ebook/Spatial_Data_Modelling_for_3D_GIS.pdf*

7. *http://www.trfic.msu.edu/products/profcorner_products/Intro_to_GIS.pdf*

8. *http://www.gpsworld.com/transportation/rail/news/antenna-based-control-system-can-stop-a-train-8802*

9. *http://egsc.usgs.gov/isb/pubs/gis_poster/*

10. *http://business.mapsofindia.com/gis-india/application/*

11. *http://www.gisdevelopment.net/technology/lbs/techlbs008.htm*

12. *http://www.gisdevelopment.net/application/urban/overview/urban_p005.htm*

1.9 Suggested Readings

1. *Burrough, Peter A. and Rachael A. McDonnell. 1998. Principles of Geographical Information Systems. Published by Oxford University Press, Toronto. ISBN13: 9780198233657 ISBN10: 0198233655*

2. *Clarke, Keith C. 2002. Getting Started with Geographic Information Systems, 4th ed., Prentice Hall Series in Geographic Information Science, Prentice-Hall Inc., Upper Saddle River, New Jersey. ISBN NO: 0130460273*

1.10 Terminal Questions

1. *What is the full form of GIS?*

2. *What are the different data types? Explain each in 1 or 2 sentences.*

3. *What do you understand by 1: 50000? Explain.*

4. *Which feature type will you choose to draw the following features: Rail, road, plantation area, agriculture area, rivers, spot heights, single house, village, contours, forest.*

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UNIT 2: READING A TOPOSHEET

2.1 Components of a Toposheet

2.1.1 Latitude & Longitude

2.1.2 Scale: Distance on Maps

2.1.3 North: Direction on Maps

2.1.4 Legend

2.2 Features in a Toposheet

2.2.1 Landform Features

2.2.2 Slopes

2.2.3 Drainage Pattern

2.2.4 Settlements

2.2.5 Significance of colours in a Toposheet

2.2.6 Map Interpretation Procedure

2.3 Toposheet Scale and Numbering System

2.3.1 India and Adjacent Countries Series

2.3.2 Reading of Topographical Maps

2.4 Summary

2.5 Glossary

2.6 References

2.7 Suggested Readings

2.8 Terminal Questions

2.1 Components of a Toposheet

A map can be simply defined as a graphic representation of the real world. This representation is always an abstraction of reality. Because of the infinite nature of our Universe it is impossible to capture all of the complexity found in the real world. For example, topographic maps abstract the three-dimensional real world at a reduced scale on a two-dimensional plane of paper.

The art of map construction is called cartography. People who work in this field of knowledge are called cartographers. The construction and use of maps has a long history. Some academics believe that the earliest maps date back to the fifth or sixth century BC. Even in these early maps, the main goal of this tool was to communicate information. Early maps were quite subjective in their presentation of spatial information. Maps became more objective with the dawn of Western science. The application of scientific method into cartography made maps more ordered and accurate. Today, the art of map making is quite a sophisticated science employing methods from cartography, engineering, computer science, mathematics, and psychology.

Cartographers classify maps into two broad categories: reference maps and thematic maps. Reference maps normally show natural and human-made objects from the geographical environment with an emphasis on location. Examples of general reference maps include maps found in atlases and topographic maps. Thematic maps are used to display the geographical distribution of one phenomenon or the spatial associations that occur between a numbers of phenomena.

2.1.1 Latitude & Longitude

Most maps allow us to specify the location of points on the Earth's surface using a coordinate system. For a two-dimensional map, this coordinate system can use simple geometric relationships between the perpendicular axes on a grid system to define spatial location. The figure illustrates how the location of a point can be defined on a coordinate system.

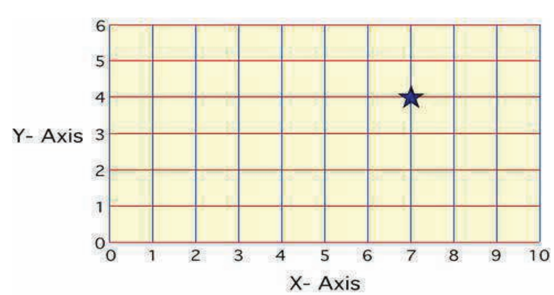


Fig. 2.1: Latitude & Longitude

A grid coordinate system defines the location of points from the distance traveled along two perpendicular axes from some stated origin. In the example above, the two axes are labeled X and Y. The origin is located in the lower left hand corner. Unit distance traveled along each axis from the origin is shown. In this coordinate system, the value associated with the X-axis is given first, following by the value assigned from the Y-axis. The location represented by the star has the coordinates 7 (X-axis), 4 (Y-axis).

Two types of coordinate systems are currently in general use in geography: the geographical coordinate system and the rectangular (also called Cartesian) coordinate system.

The geographical coordinate system measures location from only two values, despite the fact that the locations are described for a three-dimensional surface. The two values used to define location are both measured relative to the polar axis of the Earth. The two measures used in the geographic coordinate system are called latitude and longitude.

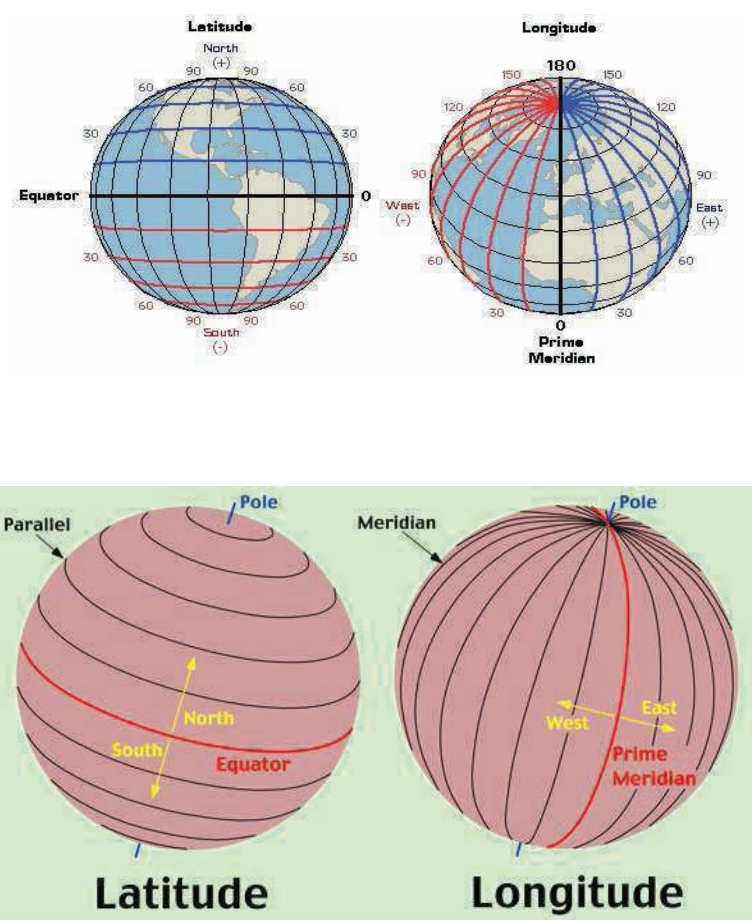


Fig 2.2: Latitude and Longitude

Lines of latitude or parallels are drawn parallel to the equator (shown in red) as circles that span the Earth's surface. These parallels are measure in degrees (°). There are 90 angular degrees of latitude from the equator to each of the poles. The equator has an assigned value of 0°. Measurements of latitude are also defined as being either north or south of equator to distinguish the hemisphere of their location. Lines of longitude or meridians are circular arcs that meet at the poles. There are 180° of longitude either side of a starting meridian which is known the Prime Meridian. The Prime Meridian has a designated value of 0°. Measurements of longitude are also defined as being either west or east of the Prime Meridian.

Latitude measures the north-south position of locations on the Earth's surface relative to a point found at the center of the Earth. This central point is also located on the Earth's rotational or polar axis. The equator is the starting point for the measurement of latitude. The equator has a value of zero degrees. A line of latitude or parallel of 30° North has an angle that is 30° north of the plane represented by the equator. The maximum value that latitude can attain is either 90° North or South. These lines of latitude run parallel to the rotational axis of the Earth.

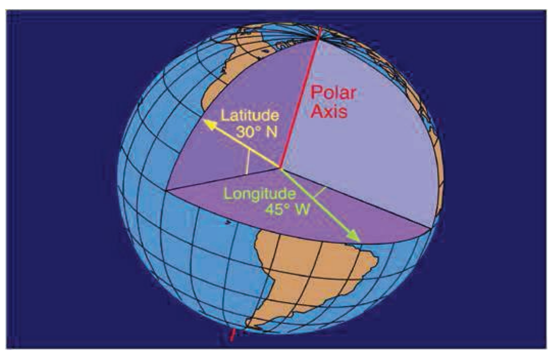


Fig. 2.3: Measurement of latitude and longitude

Measurement of latitude and longitude relative to the equator and the Prime Meridian and the Earth's rotational or polar axis.

Longitude measures the west-east position of locations on the Earth's surface relative to a circular arc called the Prime Meridian. The position of the Prime Meridian was determined by international agreement to be in-line with the location of the former astronomical observatory at Greenwich, England. Because the Earth's circumference is similar to circle, it was decided to measure longitude in degrees. The number of degrees found in a circle is 360. The Prime Meridian has a value of zero degrees. A line of longitude or meridian of 45° West has an angle that is 45° west of the plane represented by the Prime Meridian. The *maximum value that a meridian of longitude can have is 180° which is the distance halfway around a circle. This meridian is called the International Date Line. Designations of west and east are used to distinguish where a location is found relative to the Prime Meridian. For example, all of the locations in North America have a longitude that is designated west.*

2.1.2 Scale: Distance on Maps

We have learned that depicting the Earth's three-dimensional surface on a two-dimensional map creates a number of distortions that involve distance, area, and direction. It is possible to create maps that are somewhat equidistance. However, even these types of maps have some form of distance distortion. Equidistance maps can only control distortion along either lines of latitude or lines of longitude. Distance is often correct on equidistance maps only in the direction of latitude.

On a map that has a large scale, 1:125,000 or larger, distance distortion is usually insignificant. An example of a large-scale map is a standard topographic map. On these maps measuring straight line distance is simple. Distance is first measured on the map using a ruler. This measurement is then converted into a real world distance using the map's scale. For example, if we measured a distance of 10 centimeters on a map that had a scale of 1:10,000, we would multiply 10 (distance) by 10,000 (scale). Thus, the actual distance in the real world would be 100,000 centimeters.

Measuring distance along map features that are not straight is a little more difficult. One technique that can be employed for this task is to use a number of straight-line segments. The accuracy of this method is dependent on the number of straight-line segments used. Another method for measuring curvilinear map distances is to use a mechanical device called an opisometer. This device uses a small rotating wheel that records the distance traveled. The recorded distance is measured by this device either in centimeters or inches.

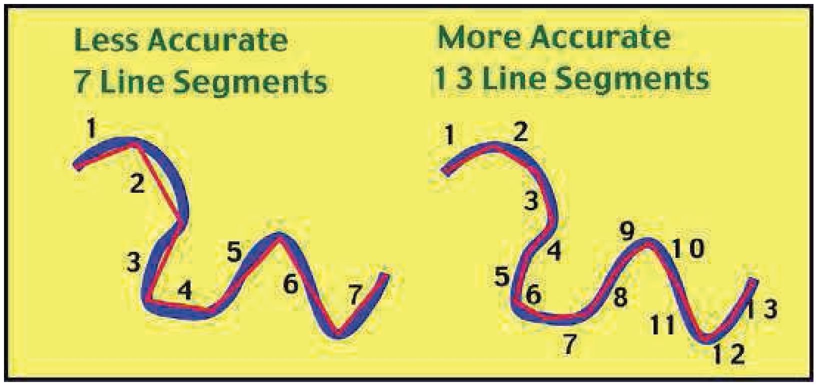


Fig 2.4: Measurement of distance on a map feature using straight-line segments.

2.1.3 North: Direction on Maps

Like distance, direction is difficult to measure on maps because of the distortion produced by projection systems. However, this distortion is quite small on maps with scales larger than 1:125,000. Direction is usually measured relative to the location of North or South Pole. Directions determined from these locations are said to be relative to True North or True South. The magnetic poles can also be used to measure direction. However, these points on the Earth are located in spatially different spots from the geographic North and South Pole. The North Magnetic Pole is located at 78.3° North, 104.0° West near EllefRingnes Island, Canada. In the Southern Hemisphere, the South Magnetic Pole is located in Commonwealth Day, Antarctica and has a geographical location of 65° South, 139° East. The magnetic poles are also not fixed overtime and shift their spatial position overtime.

Topographic maps normally have a declination diagram drawn on them. On Northern Hemisphere maps, declination diagrams describe the angular difference between Magnetic North and True North. On the map, the angle of True North is parallel to the depicted lines of longitude. Declination diagrams also show the direction of Grid North. Grid North is an angle that is parallel to the easting lines found on the Universal Transverse Mercator (UTM) grid system.

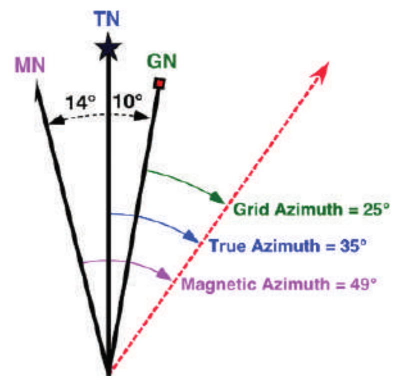


Fig. 2.5: Direction on map

This declination diagram describes the angular difference between Grid, True, and Magnetic North. This illustration also shows how angles are measured relative grid, true, and magnetic azimuth.

In the field, the direction of features is often determined by a magnetic compass which measures angles relative to Magnetic North. Using the declination diagram found on a map, individuals can convert their field measures of magnetic direction into directions that are relative to either Grid or True North. Compass directions can be described by using either the azimuth system or the bearing system. The azimuth system calculates direction in degrees of a full circle. A full circle has 360 degrees. In the azimuth system, north has a direction of either the 0 or 360°. East and west have an azimuth of 90° and 270°, respectively. Due south has an azimuth of 180°.

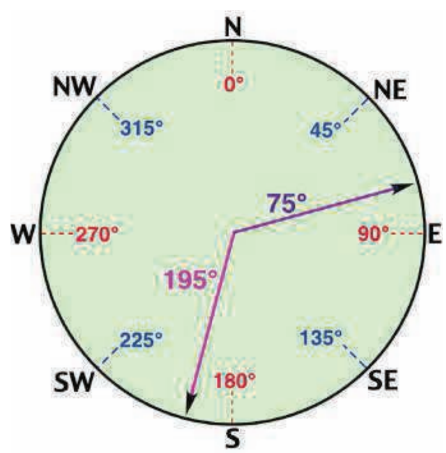


Fig. 2.6: Direction

Azimuth system for measuring direction is based on the 360 degrees found in a full circle. The illustration shows the angles associated with the major cardinal points of the compass. Note that angles are determined clockwise from north.

The bearing system divides direction into four quadrants of 90 degrees. In this system, north and south are the dominant directions. Measurements are determined in degrees from one of these directions. The measurement of two angles based on this system are described below.

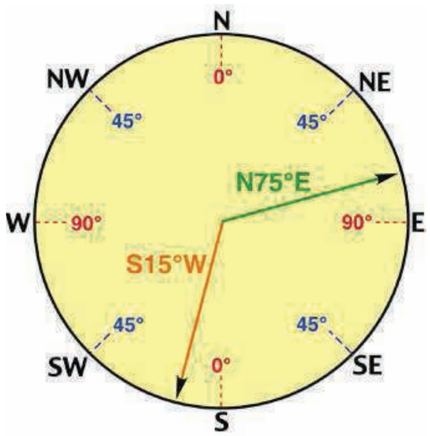


Fig. 2.7: Measurement of two angles

The bearing system uses four quadrants of 90 degrees to measure direction. The illustration shows two direction measurements. These measurements are made relative to either north or south. North and south are given the measurement 0 degrees. East and west have a value of 90 degrees. The first measurement (green) is found in the north - east quadrant. As a result, its measurement is north 75 degrees to the east or N75°E. The first measurement (orange) is found in the south - west quadrant. Its measurement is south 15 degrees to the west or S15°W.

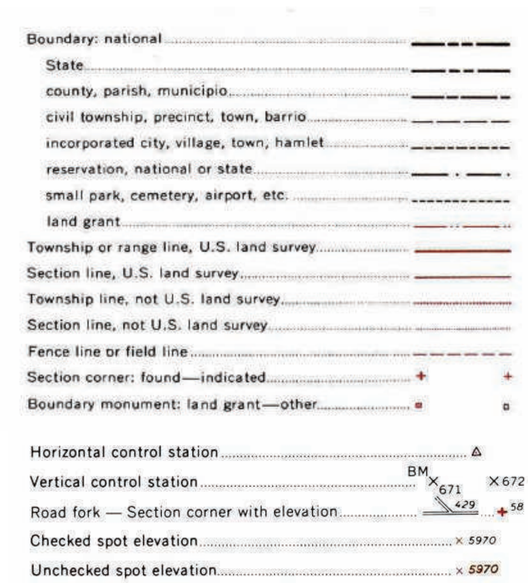
Topographic Maps

A topographic map is a detailed and accurate two-dimensional representation of natural and human-made features on the Earth's surface. These maps are used for a number of applications, from camping, hunting, fishing, and hiking to urban planning, resource management, and surveying. The most distinctive characteristic of a topographic map is that the three-dimensional shape of the Earth's surface is modeled by the use of contour lines. Contours are imaginary lines that connect locations of similar elevation. Contours make it possible to represent the height of mountains and steepness of slopes on a two-dimensional map surface. Topographic maps also use a variety of symbols to describe both *natural and human made features such as roads, buildings, quarries, lakes, streams, and vegetation.*

Topographical maps, also known as general purpose maps, are drawn at relatively large scales. These maps show important natural and cultural features such as relief, vegetation, water bodies, cultivated land, settlements, and transportation networks, etc. These maps are prepared and published by the National Mapping Organisation of each country. For example, the Survey of India prepares the topographical maps in India for the entire country. The topographical maps are drawn in the form of series of maps at different scales. Hence, in the given series, all maps employ the same reference point, scale, projection, conventional signs, symbols and colours. The topographical maps in India are prepared in two series, i.e. India and Adjacent Countries Series and The International Map Series of the World.

2.1.4 Legend

Topographic maps use symbols to represent natural and human constructed features found in the environment. The symbols used to represent features can be of three types: points, lines, and polygons. Points are used to depict features like bridges and buildings. Lines are used to graphically illustrate features that are linear. Some common linear features include roads, railways, and rivers. However, we also need to include representations of area, in the case of forested land or cleared land; this is done through the use of color.



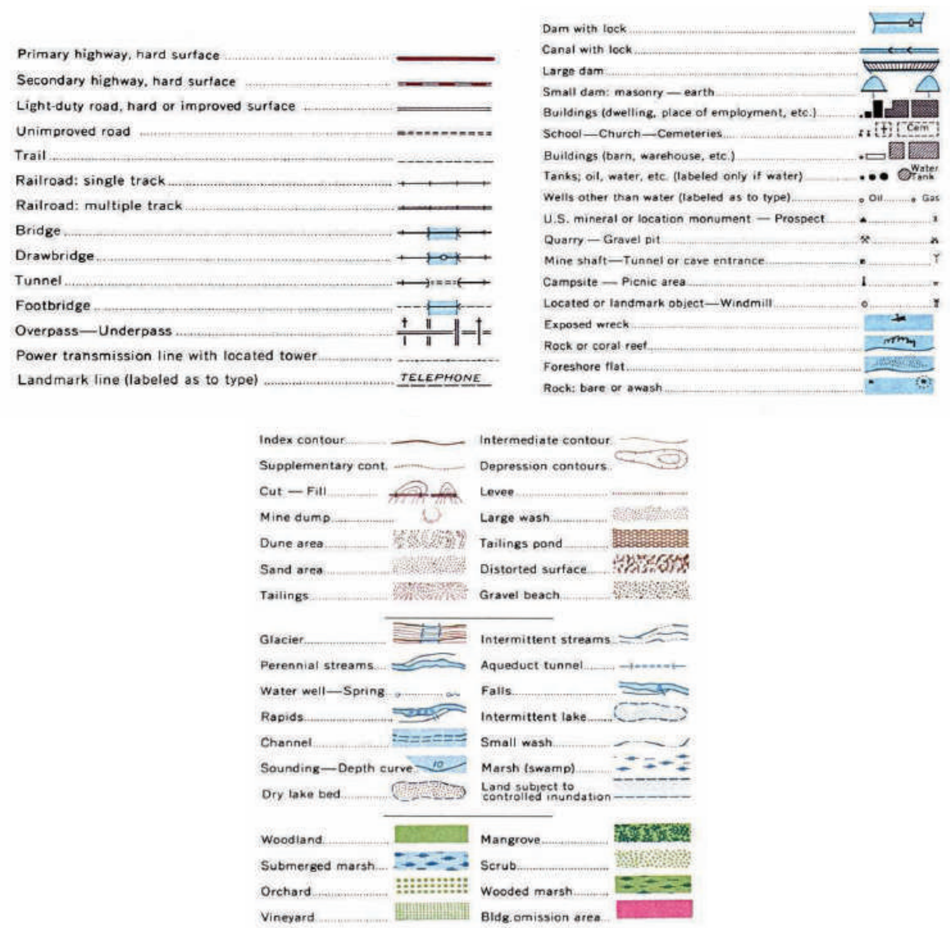


Fig. 2.8: Legend

2.2 Features in a Toposheet

2.2.1 Landform Features

Topographic maps can describe vertical information through the use of contour lines (contours). A contour line is an isoline that connects points on a map that have the same elevation. Contours are often drawn on a map at a uniform vertical distance. This distance is called the contour interval. The map in the Figure 2d-1 shows contour lines with an interval of 100 feet. Note that every fifth brown contour lines is drawn bold and has the appropriate elevation labeled on it. These contours are called index contours. On Figure 2.9 they represent elevations of 500, 1000, 1500, 2000 feet and so on. The interval at which contours are drawn on a map depends on the amount of the relief depicted and the scale of the map.

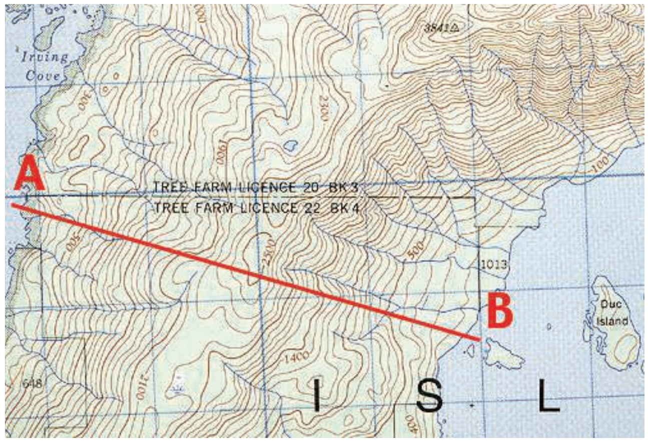


Fig. 2.9: elevations of 500, 1000, 1500, 2000 feet

Portion of the "Tofino" 1:50,000 National Topographic Series of Canada map. The brown lines drawn on this map are contour lines. Each line represents a vertical increase in elevation of 100 feet. The bold brown contour lines are called index contours. The index contours are labeled with their appropriate elevation which increases at a rate of 500 feet. Note the blue line drawn to separate water from land represents an elevation of 0 feet or sea-level. Contour lines provide us with a simple effective system for describing landscape configuration on a two-dimensional map. The arrangement, spacing, and shape of the contours provide the user of the map with some idea of what the actual topographic configuration of the land surface looks like. Contour intervals the are spaced closely together describe a steep slope. Gentle slopes are indicated by widely spaced contours. Contour lines that V upwards indicate the presence of a river valley. Ridges are shown by contours that V downwards.

Some basic features of contour lines are

- *A contour line is drawn to show places of equal heights.*
- *Contour lines and their shapes represent the height and slope or gradient of the landform.*
- *Closely spaced contours represent steep slopes while widely spaced contours represent gentle slope.*
- *When two or more contour lines merge with each other, they represent features of vertical slopes such as cliffs or waterfalls.*
- *Two contours of different elevation usually do not cross each other.*

A topographic profile is a two-dimensional diagram that describes the landscape in vertical cross-section. Topographic profiles are often created from the contour information found on topographic maps. The simplest way to construct a topographic profile is to place a sheet of blank paper along a horizontal transect of interest. From the map, the elevation of the various contours is transferred on to the edge of the paper from one end of the transect to the other. Now on a sheet of graph paper use the x-axis to represent the horizontal distance covered by the transect. The y-axis is used to represent the vertical dimension and measures the change in elevation along the transect. Most people exaggerate the measure of elevation on the y-axis to make changes in relief stand out. Place the beginning of the transect as copied on the piece of paper at the intersect of the x and y-axis on the graph paper. The contour information on the paper's edge is now copied onto the piece of graph paper. Figure 2.10 shows a topographic profile drawn from the information found on the transect A-B above.

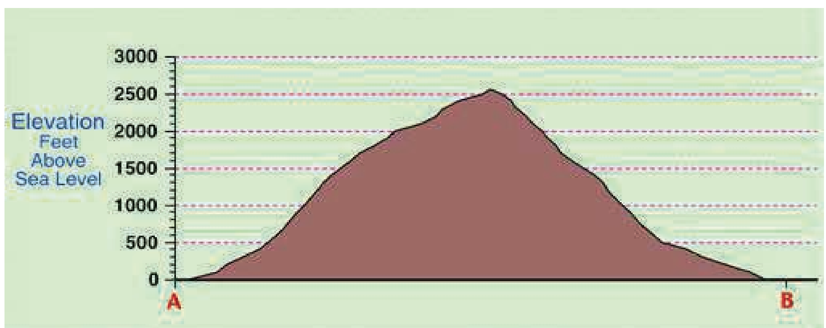


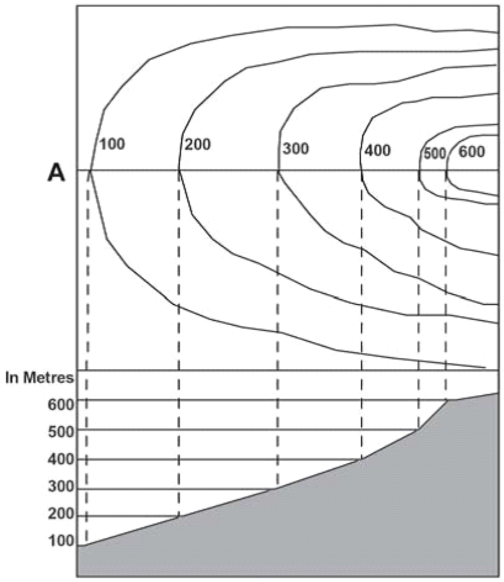
Fig. 2.10: Topographic profile

The following topographic profile shows the vertical change in surface elevation along the transect AB from Figure 2.10. A vertical exaggeration of about 4.2 times was used in the profile (horizontal scale = 1:50,000, vertical scale = 1:12,000 and vertical exaggeration = horizontal scale/vertical scale).

2.2.2 Slopes

We know that all the topographical features show varying degrees of slopes. For example, a flat plain exhibits gentler slopes and the cliffs and gorges are associated with the steep slopes. Similarly, valleys and mountain ranges are also characterised by the varying degree of slopes, i.e. steep to gentle. Hence, the spacing of contours is significant since it indicates the slope.

The slopes can broadly be classified into gentle, steep, concave, convex and irregular or undulating. The contours of different types of slopes show a distinct spacing pattern.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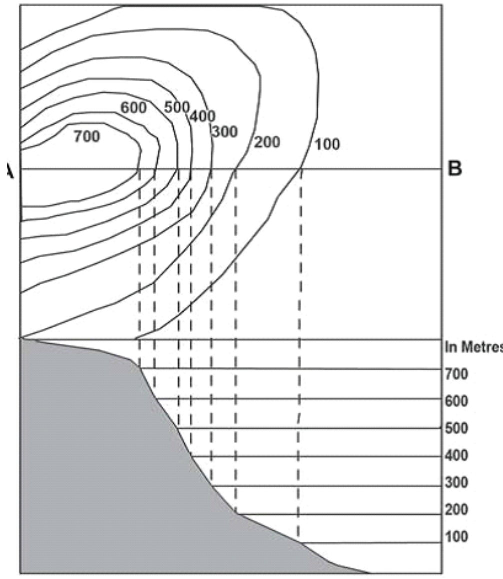
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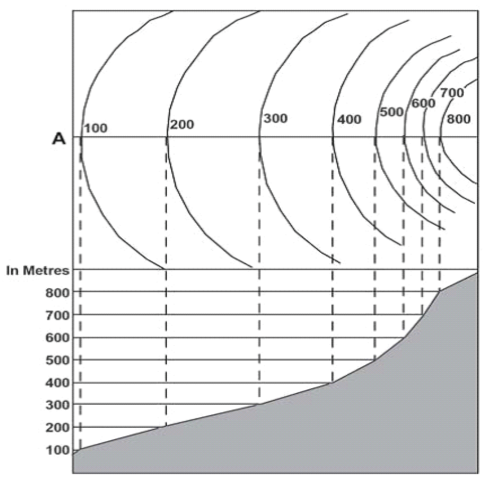
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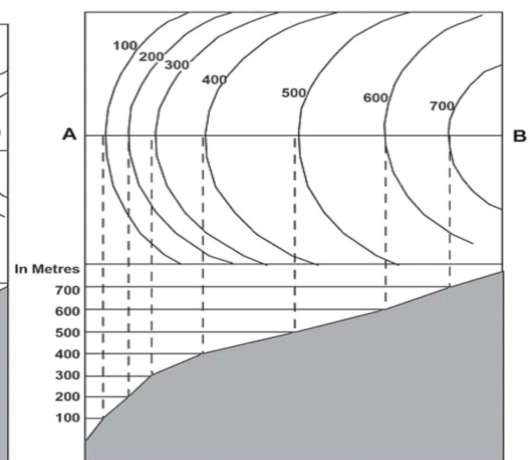
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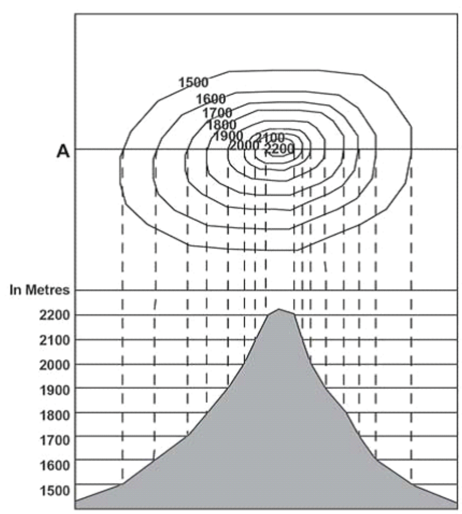
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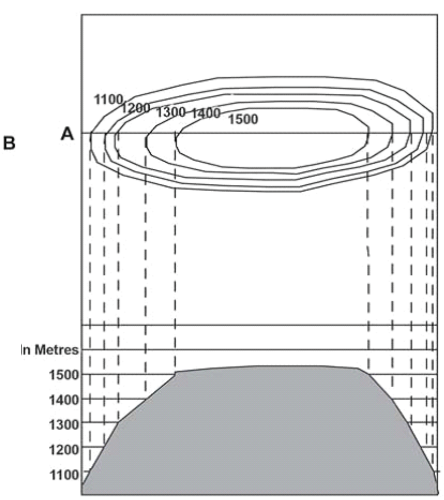
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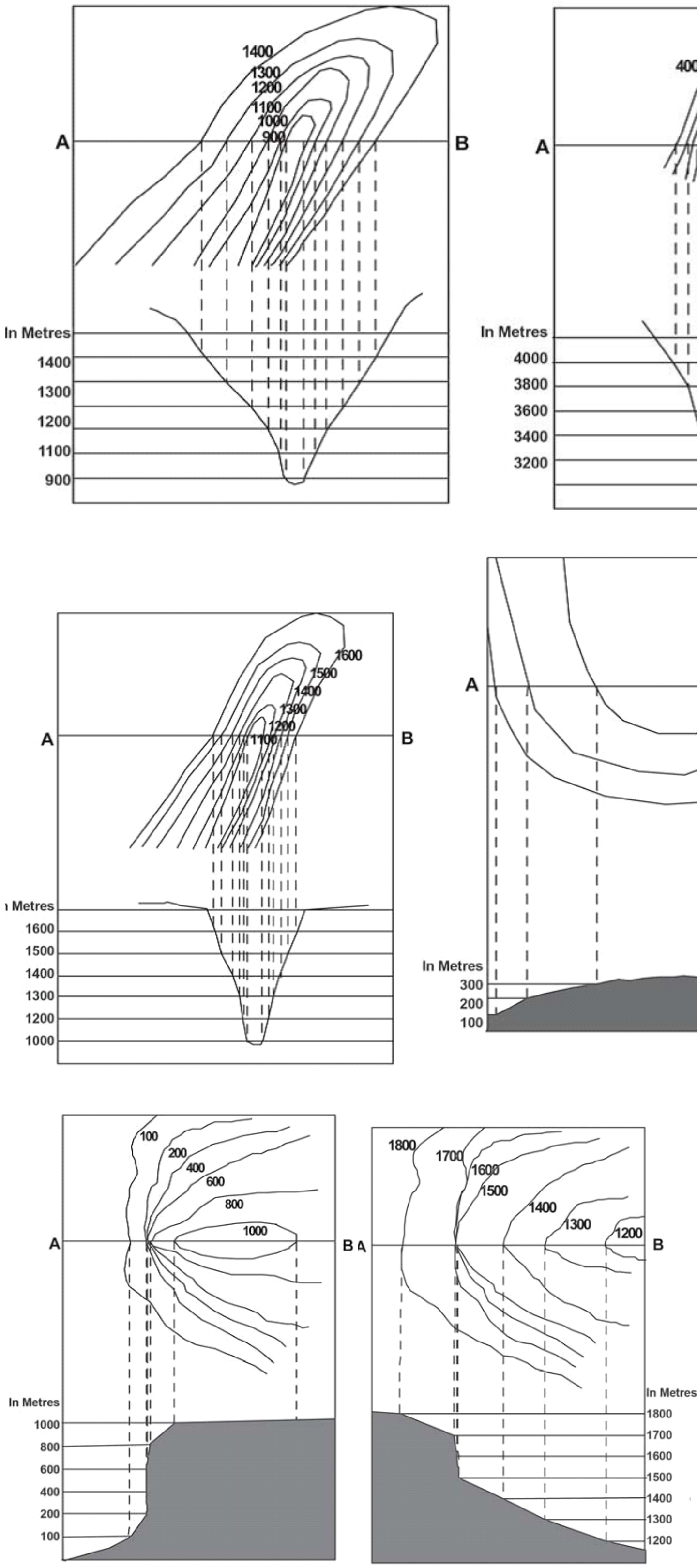


Fig. 2.11 Slopes

2.2.3 Drainage Pattern

The term drainage basin describes an area drained collectively by the network of a river along with its tributaries and sub-tributaries of various dimensions.

An area drained by a single river is called its Catchment Area.

A drainage system as seen in the topographical sheets usually develops a pattern which is related to the general structure of its basin.

Fig. 2.12: Drainage system

3 distinct patterns can be recognized

1. DENDRITIC

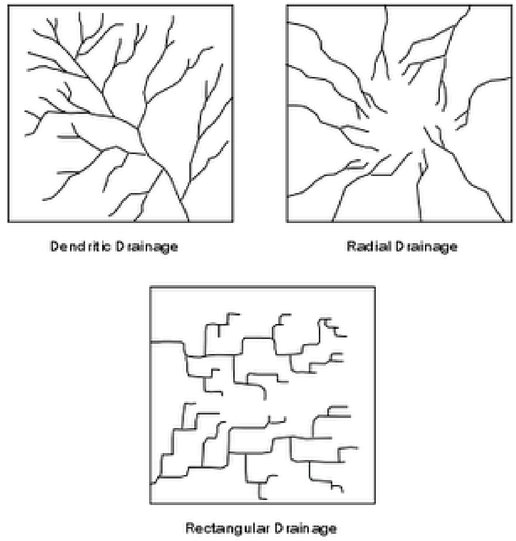


Fig 2.13: Dendritic drainage

Dendritic drainage patterns are most common. They develop on a land surface where the underlying rock is of uniform resistance to erosion.

Dendritic drainage systems are the most common form of drainage system. The term dendritic comes from the Greekword "dendron", meaning tree, due to the resemblance of the system to a tree.

In a dendritic system there is one main river (like the trunk of a tree), which was joined and formed by many smallertributary rivers. They develop where the river channel follows the slope of the terrain. Dendritic systems form in V-shaped valleys; as a result, the rock types must be impervious and non-porous

2. TRELLIS

Rectangular drainage patterns develop where linear zones of weakness, such as joints or faults cause the streams to cut down along the weak areas in the rock.

Trellis systems form in areas of alternating geology, particularly chalk and clay. The main river (the consequent) flows straight down hill.

Subsequent streams develop perpendicular to the consequent along softer rock and erode it away, forming vales.

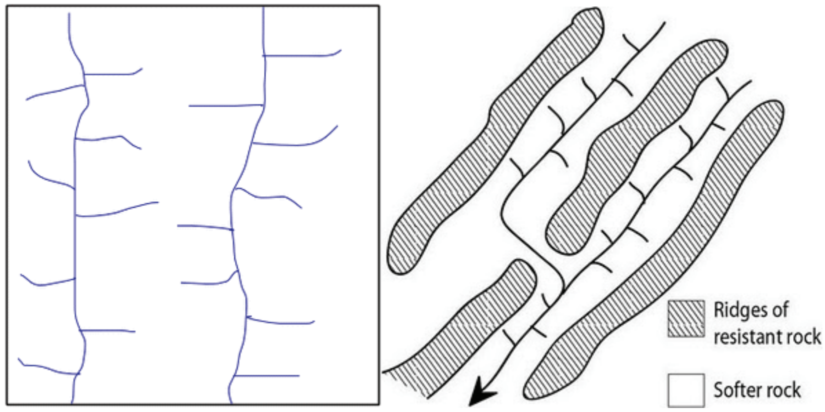


Fig 2.14: Trellis systems

The consequent river then cuts through the escarpments of harder rock.

Obsequent streams flow down thedip slope of the escarpments to join the subsequent streams.

3. RADIAL

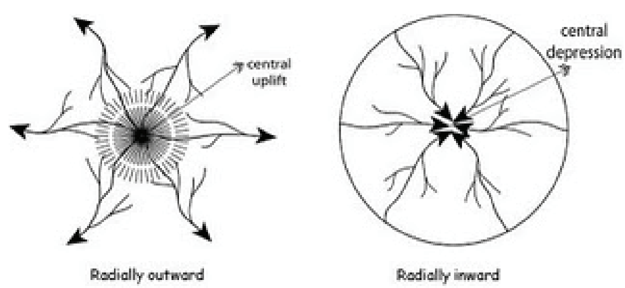


Fig 2.15: Radial drainage patterns

Radial drainage patterns develop surrounding areas of high topography where elevation drops from a central high area to surrounding low areas.

2.2.4 Settlements

Distribution of settlements can be seen in the map through its site, location pattern, alignment and density. The nature and causes of various settlement patterns may be clearly understood by comparing the settlement map with the contour map.

Four types of rural settlements may be identified on the map *(a) Compact*

(b) Scattered

(c) Linear

(d) Circular

Similarly, urban centers may also be distinguished as

(a) Cross-road town

(b) Nodal point

(c) Market centre

(d) Hill station

(e) Coastal resort centre

(f) Port

(g) Manufacturing centre with suburban villages or satellite towns

(h) Capital town

(i) Religious centre

Various factors determine the site of settlements like

(a) Source of water

(b) Provision of food

(c) Nature of relief

(d) Nature and character of occupation

(e) Defence

Site of settlements should be closely examined with reference to the contour and drainage map. Density of settlement is directly related to food supply. Sometimes, village settlements form alignments, i.e. they are spread along a river valley, road, embankment, coastline – these are called linear settlements. In the case of an urban settlement, a cross-road town assumes a fan-shaped pattern, the houses *being arranged along the roadside and the crossing being at the heart of the town and the main market place. In a nodal town, the roads radiate in all directions.*

2.2.5 Significance of colours in a Toposheet

On toposheets colours are used to show certain features. Each colour used on a map has significance.

1. *BLACK – All names, river banks, broken ground, dry streams, surveyed trees, heights and their numbering, railway lines, telephone and telegraph lines, lines of latitude and longitude.*

2. *BLUE – Water features or water bodies that contain water.*

3. *GREEN – All wooded and forested areas, orchards, scattered trees and scrubs.*

   Note: Prominent surveyed trees are shown in black. Surveyed trees have numbers on their trunks. They serve as landmarks and are not allowed to be cut.

4. *YELLOW – All cultivated areas are shown with a yellow wash.*

5. *WHITE PATCHES – Uncultivable land*

6. *BROWN – Contour lines, their numbering, form lines, and sand features such as sand hills and dunes.*

7. *RED – Grid lines (eastings and northings) and their numbering, roads, cart tracks, settlements, huts and buildings.*

SETTLEMENTS

1. *On a topo map, all settlements are shown by symbols in RED colour.*

2. *The size of the symbol and size and style of letters used give an idea of the size of the settlement.*

3. *In the case of large cities, major roads are marked and named.*

4. *Deserted village cities, temporarily occupied huts are also shown.*

5. *Places of worship, forts, water towers, burial grounds, police stations, post office, dak bungalow, circuit houses, etc. are indicated by suitable symbols.*
6. *Dense settlements are mainly found in fertile plains and wide river valleys.*
7. *Sparse Settlements are mainly observed in areas like forests, deserts, mountain slopes, plateaus and hill tops with poor vegetation•*
8. *Absence of Settlements near swamps, marsh land, sandy deserts, thick impenetrable forests, flood-prone areas, steep mountain slopes.*

OCCUPATION AND MAP FEATURES

AGRICULTURE – Level land with yellow wash; many wells

LUMBERING: Forests

CATTLE REARING – Pastures, meadows, grasslands, presence of road in highland region (sheep)

FISHING – Plenty of rivers

MINING –Stony wastes, quaries, limestone beds

TRADE – Dense settlements near road

INDUSTRY – Large settlements near roads and railways, presence of raw materials, (like making, cement industry near limestone beds)

TOURISM – hotels and inns

APPROXIMATE OR RELATIVE HEIGHT-is height is not taken from sea level but with respect to the surrounding area. It may be the height of a dam, bridge, sand dune or it can be the depth of a well, tank, hill or river canal, for example , 3r, 5r, 8r, etc.

Example:

3r - the relative depth of perennial lined well in 3 metres

5r – the relative height of dry tank is 5 metres

2.2.6 Map Interpretation Procedure

Map interpretation involves the study of factors that explain the causal relationship among several features shown on the map. For example, the distribution of natural vegetation and cultivated land can be better understood against the background of landform and drainage. Likewise, the distribution of settlements can be examined in association with the levels of transport network system and the nature of topography.

The following steps will help in map interpretation:

Find out from the index number of the topographical sheet, the location of the area in India. This would give an idea of the general characteristics of the major and minor physiographic divisions of the area. Note the scale of the map and the contour interval, which will give the extent and general landform of the area. Trace out the following features on tracing sheets.

(a) Major landforms – as shown by contours and other graphical features.

(b) Drainage and water features – the main river and its important tributaries.

(c) Land use – i.e. forest, agricultural land, wastes, sanctuary, park, school, etc.

(d) Settlement and Transport pattern.

Describe the distributional pattern of each of the features separately drawing attention to the most important aspect.

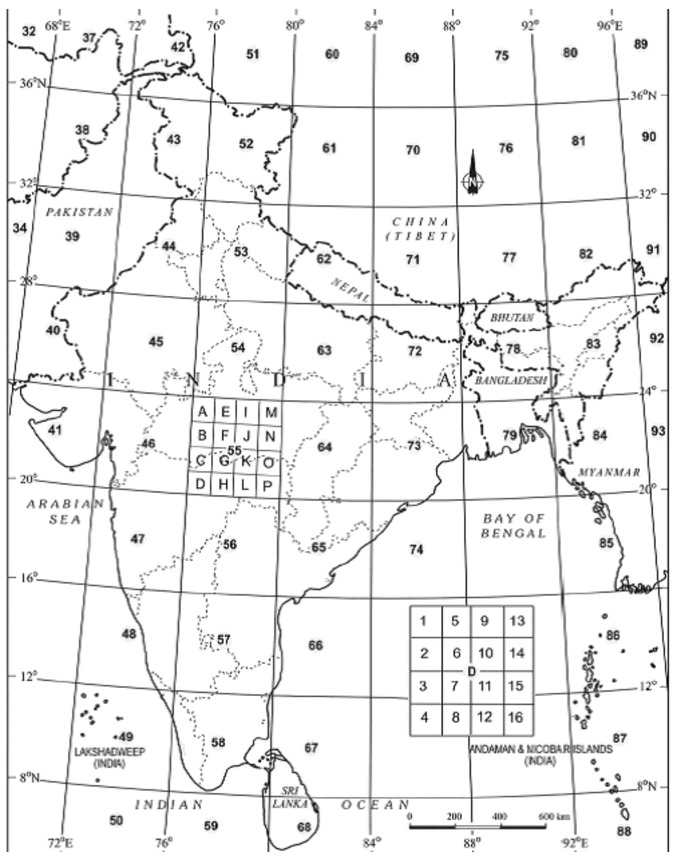
Superimpose pairs of these maps and note down the relationship, if any, between the two patterns. For example, if a contour map is superimposed over a land use map, it provides the relationship between the degree of slope and the type of the land used.

Aerial photographs and satellite imageries of the same area and of the same scale can also be compared with the topographical map to update the information.

2.3 Toposheet Scale and Numbering System

Topographic maps provides the graphical portrayal of objects present on the surface of the earth. These maps provide the preliminary information about a terrain and thus very useful for engineering works. For most part of India, topographic maps are available which are prepared by the Survey of India. To identify a map of a particular area, a map *numbering system has been adopted by Survey of India. The system of identification is as follows:*

An International Series (within 4° N to 40° N Latitude and 44° E to 124° E Longitude) at the scale of 1: 1,000,000 is being considered as base map. The base map is divided into sections of 4° latitude x 4° longitude and designated from 1 (at the extreme north-west) to 136, covering only land areas and leaving any 4° square if it falls completely in the sea



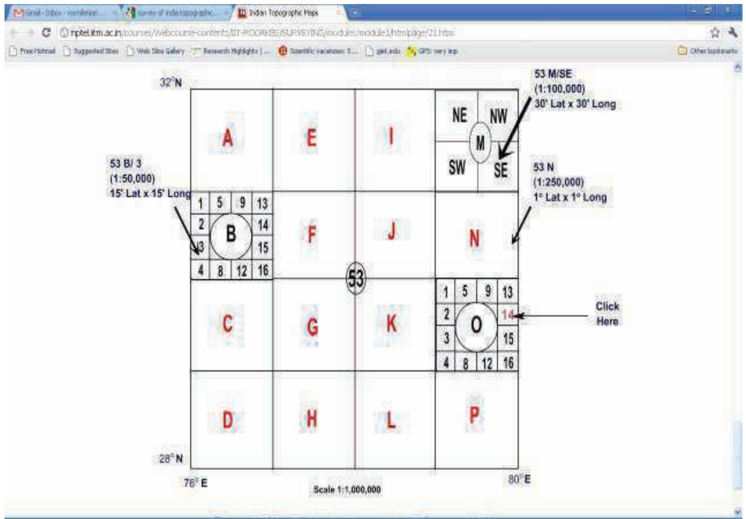


Fig. 2.16: Toposheet

2.3.1 India and Adjacent Countries Series

Topographical maps under India and Adjacent Countries Series were prepared by the Survey of India till the coming into existence of Delhi Survey Conference in 1937. Henceforth, the preparation of maps for the adjoining countries was abandoned and the Survey of India confined itself to prepare and publish the topographical maps for India as per the specifications laid down for the International Map Series of the World. However, the Survey of India for the topographical maps under the new series retained the numbering system and the layout plan of the abandoned India and Adjacent Countries Series. The topographical maps of India are prepared on 1 : 10,00,000, 1 : 250,000, 1 : 1,25,000, 1 : 50,000 and 1: 25,000 scale providing a latitudinal and longitudinal coverage of 4° x 4°, 1° x 1°, 30′ x 30′, 15′ x 15′ and 5′ x 7′ 30″, respectively. The numbering system of each one of these topographical maps is shown below.

International Map Series of the World: Topographical Maps under International Map Series of the World are designed to produce standardized maps for the entire World on a scale of 1: 10,00,000 and 1:250,000.

2.3.2 Reading of Topographical Maps

The study of topographical maps is simple. It requires the reader to get acquainted with the legend, conventional sign and the colours shown on the sheets. The conventional sign and symbols depicted on the topographical sheets are shown in the following figures.

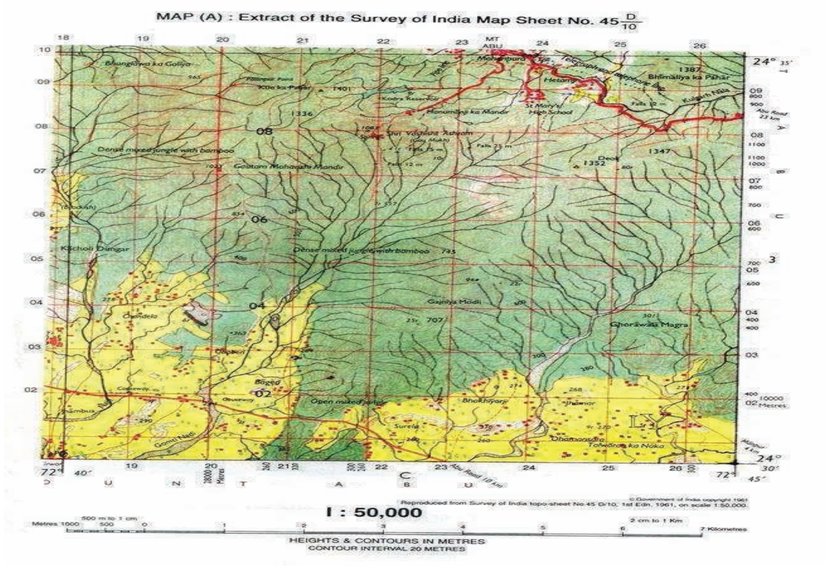


Fig. 2.17: Conventional sign and symbols on the topographical maps

2.4 Summary

In this unit we have learnt about the toposheet. The components of a toposheet, apart from the area described, namely latitude and longitude, legend and scale have been well illustrated. The following sections are about the derived information from a toposheet, like landforms, slope, drainage pattern, etc. The various scales at which toposheets are available along with the numbering system, and how the numbering system and scales are correlated have also been included.

2.5 Glossary

Azimuth- *The horizontal angle, measured in degrees, between a baseline drawn from a center point and another line drawn from the same point. Normally, the baseline points true north and the angle is measured clockwise from the baseline.*

Coordinate- *any of the magnitudes that serve to define the position of a point, line, or the like, by reference to a fixed figure, system of lines*

Isoline - *A line connecting points of equal value on a map. Isolines fall into two classes: those in which the values actually exist at points, such as temperature or elevation values, and those in which the values are ratios that exist over areas, such as population per square kilometer or crop yield per acre. The first type of isoline is specifically called an isometric line or isarithm; the second type is called an isopleth.*

Grid- *In cartography, any network of parallel and perpendicular lines superimposed on a map and used for reference. These grids are usually referred to by the map projection or coordinate system they represent*

Landform- *A specific geomorphic feature on the surface of the earth, ranging from large-scale features such as plains, plateaus, and mountains to minor features such as hills, valleys, and alluvial fans.*

Map- *A map is a detailed and accurate two-dimensional representation of natural and human-made features on the real world.*

Pattern- *A distinctive style, model, or form*

Relief- *Elevations and depressions of the earth's surface, including those of the ocean floor. Relief can be represented on maps by contours, shading, hypsometric tints, digital terrain modeling, or spot elevations.*

Slope - *The incline, or steepness, of a surface. Slope can be measured in degrees from horizontal (0–90), or percent slope (which is the rise divided by the run, multiplied by 100). A slope of 45 degrees equals 100 percent slope. As slope angle approaches vertical (90 degrees), the percent slope approaches infinity.*

2.6 References

1. *http://brhectorsgeoworld.blogspot.com/2009/02/topographical-survey-maps.html*
2. *https://sites.google.com/a/tges.org/geo-jaydeep/std-10-geography/topographical-maps*
3. *http://www.iasexams.com/NCERT-Books/NCERTBooksforClass11/FreedownloadClass11Geography3PracticalGeographyNCERTBook/Class11_Geography3_PracticalGeography_Unit05_NCERT_TextBook_EnglishEdition.pdf*
4. *http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT-ROORKEE/SURVEYING/modules/module1/htmlpage/21.htm*

2.7 Suggested Readings

1. *Misra, R.P. and A. Ramesh. 1989. Fundamentals of Cartography (Revised and Enlarged). Published by Concept Publishing Company, Mohan Garden, New Delhi, India. ISBN (Paperback): ISBN NO: 9788170222224*

2.8 Terminal Questions

1. *Explain with diagram latitude/longitude and north arrow of a toposheet.*
2. *Draw diagram and briefly describe any 2 different types of features represented with contour lines.*
3. *Name 2 different type of drainage patterns with 2 characteristics each.*
4. *What do you understand by 45 D/10? Give any 2 numbers of its adjoining toposheets.*

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UNIT 3: DATA: SPATIAL AND NON-SPATIAL I

3.1. Introduction to Spatial Data

3.1.1 Spatial representation of Data in GIS

3.2. Concepts of Geoid, Datum, Spheroid

3.3. Types of Projection Systems

3.3.1 Class (cylindrical, conical or azimuthal)

3.3.2 Point of secancy (tangent or secant)

3.3.3 Aspect (normal, transverse or oblique)

3.3.4 Distortion property (equivalent, equidistant or conformal)

3.3.5 Map projections in common use

3.3.5.1 Cylindrical projections

3.3.5.2 Mercator projection

3.3.5.3 Tranverse Mercator projectio

3.3.5.4 Universal Tranverse Mercator (UTM) projection

3.3.5.5 Conic projections

3.3.5.6 Lambert conformal conic projection

3.3.5.7 Polyconic projection

3.3.5.8 Azimuthal projections

3.3.5.9 Stereographic projection

3.3.5.10 Orthographic projection

3.4. Choice of a Projection System

3.5. Introduction to Non spatial data

3.6. Linking spatial and non spatial data

3.6.1 Introduction

3.6.2 Advantages and Disadvantages of GIS database

3.6.3 Sources of data for GIS

3.6.3.1 Direct Data Entry

3.6.3.2 Global positioning systems (GPS)

3.6.3.3 Satellite Data

3.7. Summary

3.8. Glossary

3.9. References

3.10. Suggested Readings

3.11. Terminal Questions

3.1 ***Introduction to Spatial Data***

"Everything is related to everything else, but near things are more related than distant things." Tobler's first law of geography

Since the advent of GIS in the 1980s, many government agencies have invested heavily in GIS installations, including the purchase of hardware and software and the construction of mammoth databases. Two fundamental functions of GIS have been widely realized: generation of maps and generation of tabular reports.

Indeed, GIS provides a very effective tool for generating maps and statistical reports from a database. However, GIS functionality far exceeds the purposes of mapping and report compilation. In addition to the basic functions related to automated cartography and data base management systems, the most important uses of GIS are spatial analysis capabilities. As spatial information is organized in a GIS, it should be able to answer complex questions regarding space. Making maps alone does not justify the high cost of building a GIS. The same maps may be produced using a simpler cartographic package. Likewise, if the purpose is to generate tabular output, then a simpler database management system or a statistical package may be a more efficient solution.

It is spatial analysis that requires the logical connections between attribute data and map features, and the operational procedures built on the spatial relationships among map features. These capabilities make GIS a much more powerful and cost-effective tool than automated cartographic packages, statistical packages, or data base management systems. Indeed, functions required for performing spatial analyses that are not available in either cartographic packages or data base management systems are commonly implemented in GIS.

Principally, there are three spatial data components that need to be stored for GIS data: geometric data, thematic data, and a link identification (ID) for the geometric and the thematic component. The illustration in Figure 4.1 shows the link between the geometric component (which deals with the location of the data by means, for example, of a reference coordinate system) and the thematic component (it provides the attribute values *of the data, e.g. names, and other identifiers (IDs) of the data). Object or feature needs to be geometrically and thematically described (Longley et al., 1999; Laurini and Thompson, 1991). The basic components of spatial data (TINs) can be used to describe real world terrain objects, whether natural or man-made; thus we have TIN-based spatial objects.*

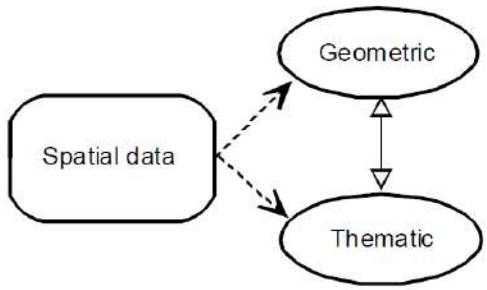


Fig. 3.1: Spatial data components

3.1.1 Spatial representation of Data in GIS

The type of analysis one wants to conduct with GIS depends largely on how data are measured. The data that are usually mapped in a GIS can be categories, counts or amounts, ratios, or ranks. A category is a group with similar characteristics. For example, an admission office producing a map of areas of recruitment could categorize high schools by type of control, public or private. Counts and amounts can be used to map discrete features (number of students at each high school within the state) or continuous phenomena (household income by census block). A ratio is used to allow comparison of data between small and large areas and between areas with many features versus those with few. When using counts or amounts to summarize data by area, analysts should be aware that such data types can skew the patterns if the areas vary by size. To avoid false interpretation, GIS analysts can use average, proportion, and density to summarize indicators by area. One might be interested, for instance, in mapping the average number of people per household, or the proportion of high school students in total population by census block. Mapping density allows the analyst *to see where features are concentrated; it is particularly useful in displaying distributions when the size of the areas summarized varies greatly. Mapping the population per square mile by census tract is an essential analysis when deciding on the location, for instance, of a future campus.*

Rank shows relative value rather than measured value. Rank can be expressed either as text (very satisfied, satisfied, neutral, dissatisfied, very dissatisfied) or numbers (one through five). For example, senior survey data could be mapped to examine whether satisfaction with the college experience is higher for in-state students than for out-of-state students.

After determining the type of data to map, the next decision a GIS analyst has to make is whether to map individual values (by assigning a unique symbol) or to group the values into classes. This decision always involves a tradeoff between presenting the data values accurately and generalizing the values to uncover patterns on the map.

3.2 Concepts of Geoid, Datum, Spheroid

The Earth as a Sphere. In this calculation the Earth is viewed as being an evenly round 'ball'. This is called a Sphere. From an imaginary centre of the Earth, calculations are made from the centre of the Earth to the surface of the Earth.

In this diagram the distances from the centre of the Earth to the Equator and the Geographic/True North Pole (indicated by 'a' and 'b') are the same value.

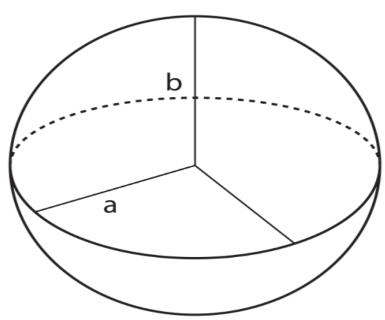


Fig. 3.2(a): Distances from the centre of the Earth

The Earth as an Ellipsoid (or Spheroid). However, the Earth is not evenly round - it is in fact wider around the Equator than it is between the North and South Poles. This is called an Ellipsoid (or a Spheroid).. All Ellipsoids/Spheroids are 'wider' than they are 'tall'.

In this diagram the length of 'a' is greater than the length of 'b'.

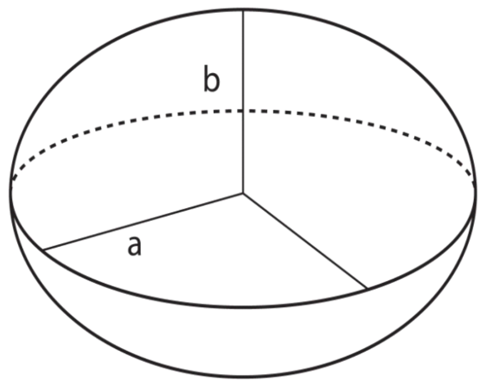


Fig. 3.2(b): Distances from the centre of the Earth

The use of the terms Ellipsoid and Spheroid can be very confusing as they are used interchangeably within the geodetic community

A Spheroid is simply an Ellipsoid which is as wide as it is long (ie evenly round and close in shape to that of a sphere). All other Ellipsoids are longer than they are wide (ie shaped more like an Australian Rules football).

In Australia, most datums refer to the Australian National Spheroid.

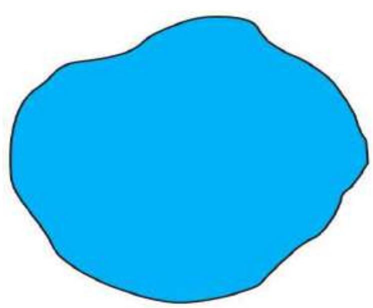


Fig. 3.3(a): The Earth as a Geoid

However, this is also a very simplistic concept. The Earth in reality is a very misshapen object. This is called a Geoid. The Earth's Geoid is a surface which is complex to accurately describe mathematically. But it can be identified by measuring gravity.

The Earth's Geoid is regarded as being equal to Mean Sea Level. Over open oceans the Geoid and Mean Sea Level are approximately the same, but in continental areas they can differ significantly. However, it must be noted that this difference it is not of any practical consequence for most people and and it is considered reasonable that they are regarded as the same.

Because of the Earth's Geoid's irregularity Geodesists have chosen to use Ellipsoids (or Spheroids) to calculate the location of latitude and longitude.

Fig. 3.3(b): Earth's Shape

The Earth's True Shape - Its Terrain of course the Earth isn't just ocean (Mean Sea Level). Much of the land masses are well above the sea level (eg Mount Everest is over 8,000 metres above Mean Sea Level), while in the ocean it is well below sea level (eg the Mariana Trench is over 10,000 metres below Mean Sea Level.

In summary - there are four surfaces that geodesists study:

1 *Ellipsoid/Spheroid*

2 Geoid

3 Mean Sea Level

4 Terrain

It is important to recognise that the relationship between these four surfaces is not always the same. Rather, as this diagram indicates, they 'wobble' around each other.

(Please note that for this diagram the relationship between these four has been exaggerated so that you may better understand the nature of this 'wobbling'.)

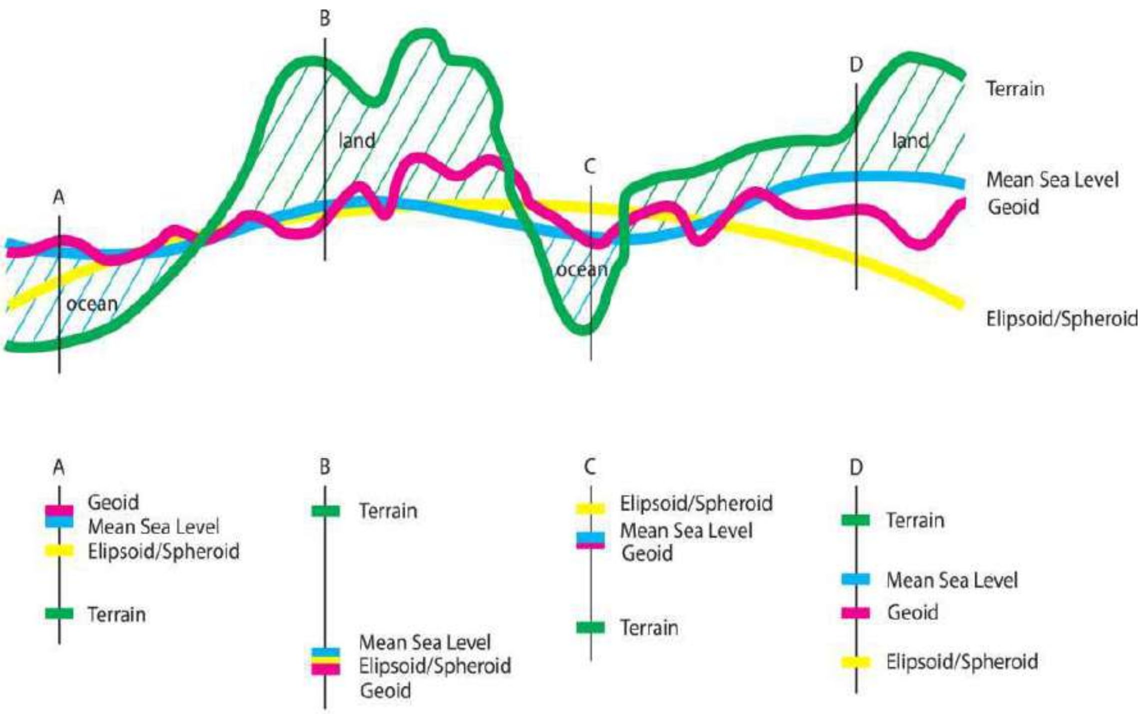


Fig. 3.4: Four examples (A, B, C and D) have been chosen to decribe how these relationships may change.

A and C show the Earths' terrain as being below Mean Sea Level - this is equivalent to an area of ocean. Note how the Geoid and Mean Seal Level are very close to the same value, but their relationship to the Ellipsoid/Spheroid varies.

B and D show the Earths' terrain as being above Mean Sea Level - this is equivalent to an area of land. It is worth noting that the differeces between the Geoid and Mean Seal Level is much greater than in the ocean examples. And, similarly, their relationship to the Ellipsoid/Spheroid varies.

With an understanding of these four geometric shapes and their relationships to each other it is possible to better understand Datums.

While a spheroid approximates the shape of the earth, a datum defines the position of the spheroid relative to the center of the earth. A datum provides a frame of reference for measuring locations on the surface of the earth. It defines the origin and orientation of latitude and longitude lines.

These two diagrams illustrate these two situations:

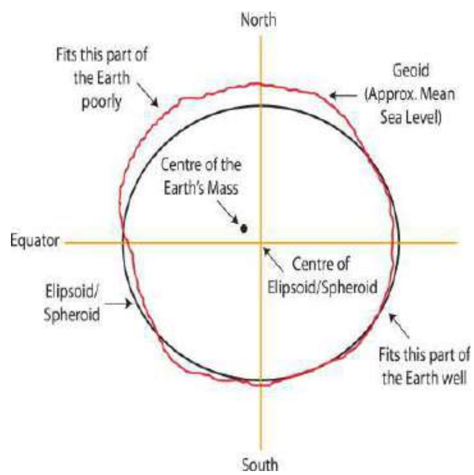


Fig 3.5: Origin and orientation of latitude and longitude lines

Local or Regional Datums

A local datum aligns its spheroid to closely fit the earth's surface in a particular area. A point on the surface of the spheroid is matched to a particular position on the surface of the earth. This point is known as the origin point of the datum. The coordinates of the origin point are fixed, and all other points are calculated from it.

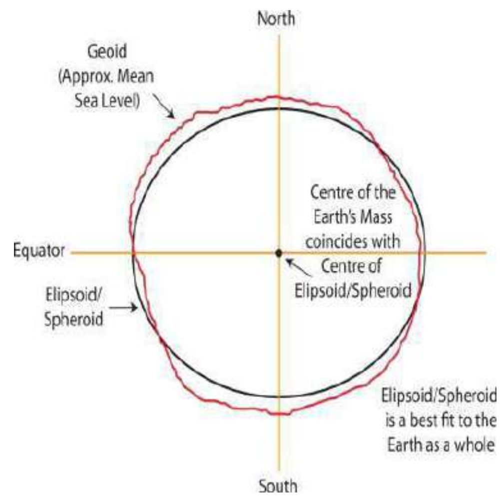


Fig. 3.6: Local or Regional Datums

Geocentric Datums

In the last 15 years, satellite data has provided geodesists with new measurements to define the best earth-fitting spheroid, which relates coordinates to the earth's center of mass. An earth-centered, or geocentric, datum uses the earth's center of mass as the origin. The most recently developed and widely used datum is WGS 1984. It serves as the framework for locational measurement worldwide.

3.3 Types of Projection Systems

A map projection is a mathematically described technique of how to represent the Earth's curved surface on a flat map. To represent parts of the surface of the Earth on a flat paper map or on a computer screen, the curved horizontal reference surface must be mapped onto the 2D mapping plane. The reference surface for large-scale mapping is usually an oblate ellipsoid, and for small-scale mapping, a sphere.

Map projections can be described in terms of their:

- *class (cylindrical, conical or azimuthal)*
- *point of secancy (tangent or secant)*
- *aspect (normal, transverse or oblique), and*

- *distortion property (equivalent, equidistant or conformal).*

3.3.1 Class (cylindrical, conical or azimuthal)

i. The three classes of map projections are cylindrical, conical and azimuthal. The Earth's reference surface projected on a map wrapped around the globe as a cylinder produces a cylindrical map projection. Projected on a map formed into a cone gives a conical map projection. When projected directly onto the mapping plane it produces an azimuthal (or zenithal or planar) map projection. The figure below shows the surfaces involved in these three classes of projections.

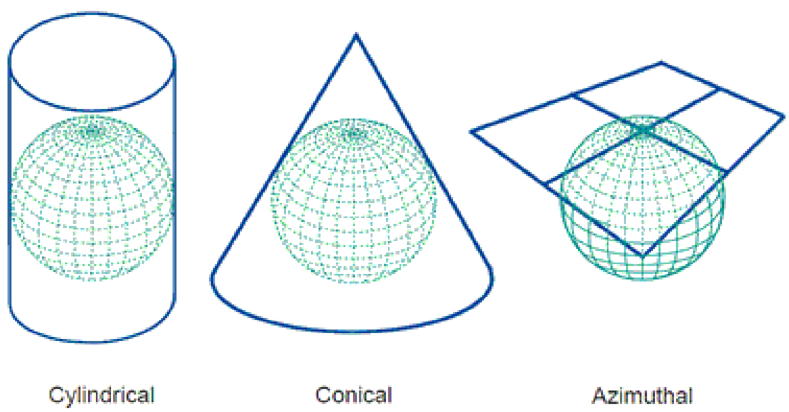


Fig. 3.7: The three classes of map projections: cylindrical, conical and azimuthal. The projection planes are respectively a cylinder, cone and plane.

3.3.2 Point of secancy (tangent or secant)

ii. The planar, conical, and cylindrical surfaces in the figure above are all tangent surfaces; they touch the horizontal reference surface in one point (plane) or along a closed line (cone and cylinder) only. Another class of projections is obtained if the surfaces are chosen to be secant to (to intersect with) the horizontal reference surface; illustrations are in the figure below. Then, the reference surface is intersected along one closed line (plane) or two closed lines (cone and cylinder). Secant map surfaces are used to reduce or average scale errors because the line(s) of intersection are not distorted on the map (section 4.3 scale distortions on a map).

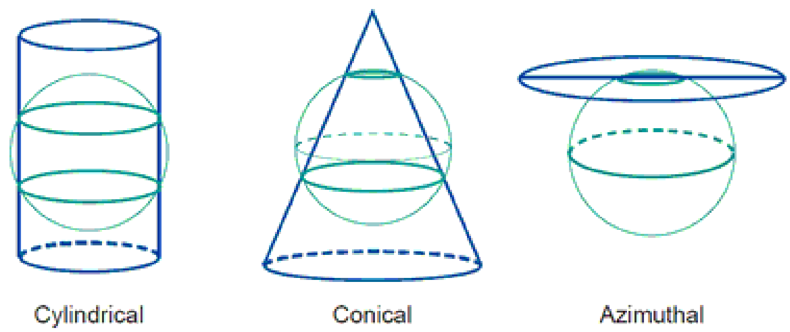


Fig. 3.8: Three secant projection classes

A method to calculate the lines of intersection in a normal conical or cylindrical projection (i.e. standard parallels) could be by determining the range in latitude in degrees north to south and dividing this range by six. The "one-sixth rule" places the first standard parallel at one-sixth the range above the southern boundary and the second standard parallel minus one-sixth the range below the northern limit (figure below). There are other possible approaches.

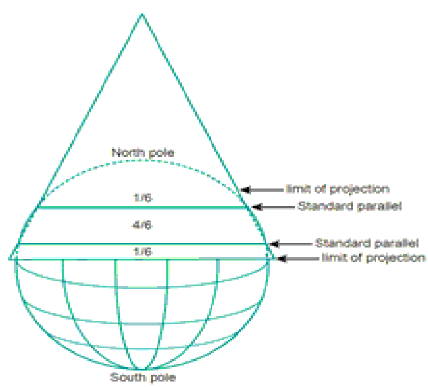


Fig. 3.9: A conical projection with a secant projection plane. The lines of intersection (standard parallels) are selected at one-sixth below and above the limit of the mapping area.

3.3.3 Aspect (normal, transverse or oblique)

iii. Projections can also be described in terms of the direction of the projection plane's orientation (whether cylinder, plane or cone) with respect to the globe. This is called the aspect of a map projection. The three possible aspects *are normal, transverse and oblique. In a normal projection, the main orientation of the projection surface is parallel to the Earth's axis (as in the figures above for the cylinder and the cone). A transverse projection has its main orientation perpendicular to the Earth's axis. Oblique projections are all other, non-parallel and non-perpendicular, cases. The figure below provides two examples.*

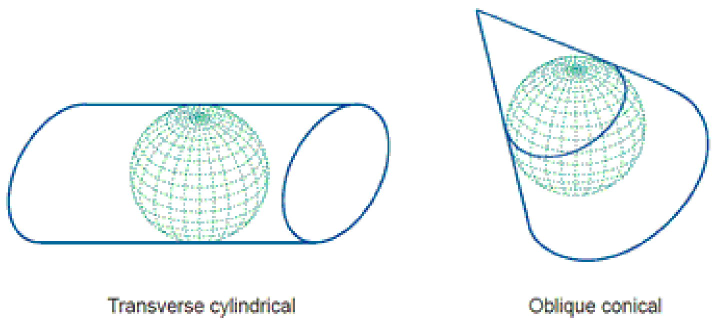


Fig. 3.10: A transverse and an oblique map projection

The terms polar and equatorial are also used. In a polar azimuthal projection the projection surface is tangent or secant at the pole. In an equatorial azimuthal or equatorial cylindrical projection, the projection surface is tangent or secant at the equator.

3.3.4 Distortion property (equivalent, equidistant or conformal)

iv. So far, we have not specified how the Earth's reference surface is projected onto the plane, cone or cylinder. How this is done determines which kind of distortion properties the map will have compared to the original curved reference surface. The distortion properties of map are typically classified according to what is not distorted on the map:

- *In a conformal (orthomorphic) map projection the angles between lines in the map are indentical to the angles between the original lines on the curved reference surface. This means that angles (with short sides) and shapes (of small areas) are shown correctly on the map.*

- *In an equal-area (equivalent) map projection the areas in the map are identical to the areas on the curved reference surface (taking into account the map scale), which means that areas are represented correctly on the map.*

- *In an equidistant map projection the length of particular lines in the map are the same as the length of the original lines on the curved reference surface (taking into account the map scale).*

A particular map projection can have any one of these three properties. No map projection can be both conformal and equal-area. A projection can only be equidistant (true to scale) at certain places or in certain directions.

Another descriptor of a map projection might be the name of the inventor (or first publisher) of the projection, such as Mercator, Lambert, Robinson, Cassini etc., but these names are not very helpful because sometimes one person developed several projections, or several people have developed similar projections. For example J.H.Lambert described half a dozen projections. Any of these might be called 'Lambert's projection', but each need additional description to be recognized.

Based on these discussions, a particular map projection can be classified. An example would be the classification 'conformal conic projection with two standard parallels' having the meaning that the projection is a conformal map projection, that the intermediate surface is a cone, and that the cone intersects the ellipsoid (or sphere) along two parallels; i.e. the cone is secant and the cone's symmetry axis is parallel to the rotation axis. This would amount to the projection of the figure above(conical projection with a secant projection plane). Other examples are:

- *Polar stereographic azimuthal projection with secant projection plane;*

- *Lambert conformal conic projection with two standard parallels;*

- *Lambert cylindrical equal-area projection with equidistant equator;*

- *Transverse Mercator projection with secant projection plane.*

3.3.5 Map projections in common use

A variety of map projections have been developed, each with its own specfic qualities. Only a limited amount are frequently used. Here are some well-known projections described and illustrated. They are grouped into cylindrical, conical and azimuthal projections.

3.3.5.1 Cylindrical projections

Probably one of the best known cylindrical projection is Mercator's cylindrical projection. The transverse case and occasionally the oblique case of the Mercator projection are used in several countries for topographic mapping purposes. The Transverse Mercator and Univeral Transverse Mercator (UTM) projection are the best known examples. Two other well-known normal cylindrical projections are the equidistant cylindrical (or Plate Carrée) projection and Lambert's cylindrical equal-area projection. Normal cylindrical projections are typically used to map the world in its entirety (in particular areas near the equator are shown well).

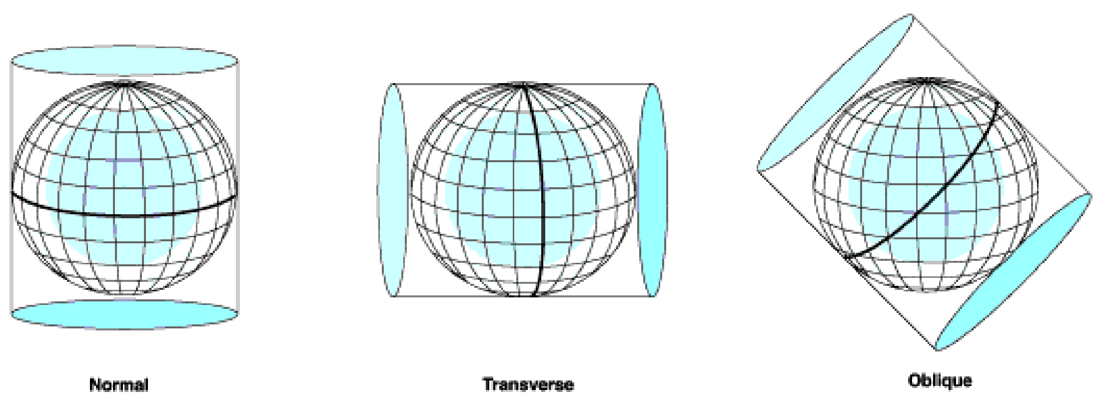


Fig. 3.11: Cylindrical projections

3.3.5.2 Mercator projection

The Mercator projection is a normal cylindrical projection. The property of the projection is conformal. Parallels and meridians are straight lines intersecting at *right angles, a requirement for conformality. Meridians are equally spaced. The parallel spacing increases with distance from the equator (figure below).*

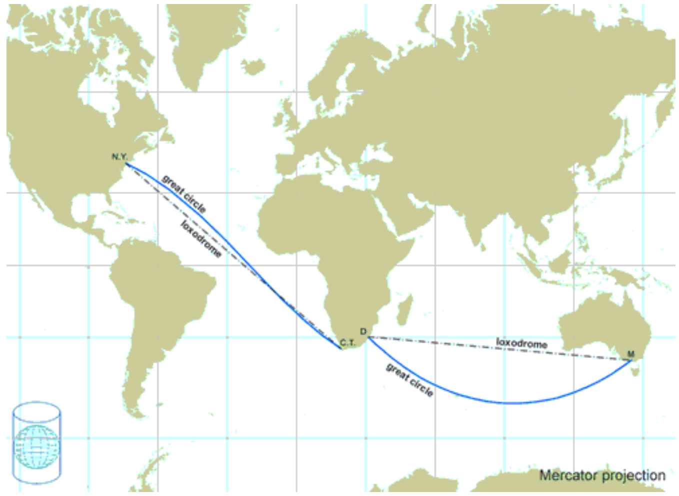


Fig. 3.12: Mercator projection is a cylindrical map projection with a conformal property. The loxodromes in black are straight lines. The great circle lines (orthodromes) in blue are curved.

The projection was originally designed to display accurate compass bearings for sea travel. Any straight line drawn on this projection represents a constant compass bearing or a true direction line (loxodrome or rhumb line). Sailing the shortest distance course along the great circle means that the direction changes every moment. These changes in course direction can be deternined by plotting the great circle onto the Mercator projection (figure above).

The Mercator projection is sometimes inappropriately used in atlases for maps of the world, and for wall-maps as area distortions are significant towards the polar regions. The ellipses of distortion appear as circles (indicating conformality) but increase in size away from the equator (indicating area distortion). This exaggeration of area as latitude increases makes Greenland appear to be as large as South America when, in fact, it is only one eight of the size.

3.3.5.3 Tranverse Mercator projection

The Transverse Mercator projection is a transverse cylindrical conformal projection. The projection is also known as the Gauss-Krüger or Gauss conformal. Angles and shapes (of small areas) are shown correctly, as a result of conformality. The figure below shows a part of the world mapped on the Transverse Mercator projection.

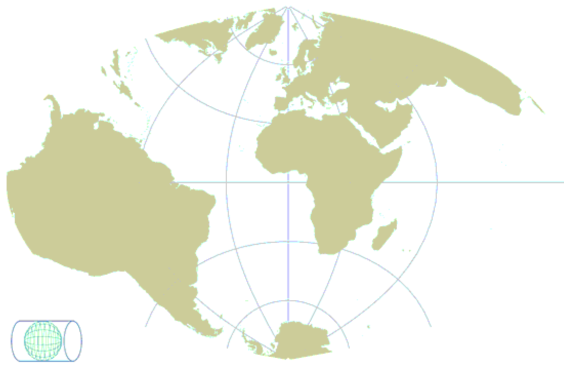


Fig. 3.13: A part of the world mapped on a transverse cylinder in the Transverse Mercator projection.

Versions of the Transverse Mercator (TM) projection are used in many countries as the local map coordinate system on which the topographic mapping is based. Ghana uses TM projection with the central meridian located at 1°W of Greenwich. The projection is also used for aeronautical charts and recommended to the European Commission for conformal pan-European mapping at scales larger than 1:500,000.

3.3.5.4 Universal Tranverse Mercator (UTM) projection

The Universal Transverse Mercator (UTM) projection uses a transverse cylinder, secant to the reference surface (figure below). It is recommended for topographic mapping by the United Nations Cartography Committee in 1952. The UTM divides the world into 60 narrow longitudinal zones of 6 degrees, numbered from 1 to 60. The narrow zones of 6 degrees (and the secant map surface) make the *distortions so small that they can be ignored when constructing a map for a scale of 1:10,000 or smaller.*

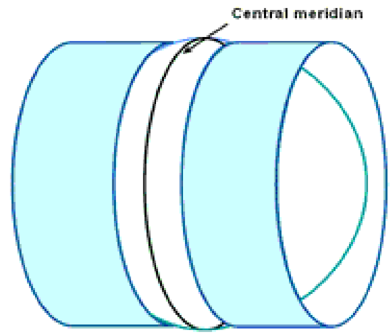


Fig. 3.14: The projection plane of the UTM projection is a secant cylinder in a transverse position.

The UTM projection is designed to cover the world, excluding the Arctic and Antarctic regions. The areas not included in the UTM system, regions north of 84°N and south of 80°S, are mapped with the Universal Polar Stereographic (UPS) projection. The figure below shows the UTM zone numbering system. Shaded in the figure is UTM grid zone 3N which covers the area 168° - 162°W (zone number 3), and 0° - 8°N (letter N of the latitudinal belt).

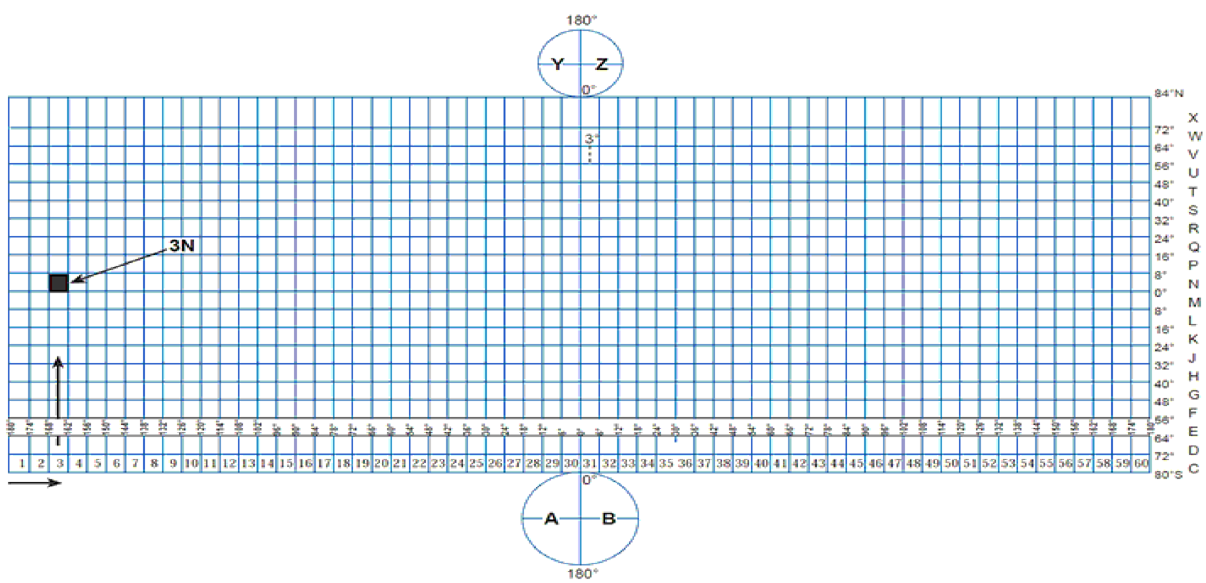


Fig. 3.15: UTM zone numbering system

Each zone has its own central meridian. E.g. zone 11 extends from 120°W to 114°W, therefore the central meridian has a longitude value of 117°W (figure below).

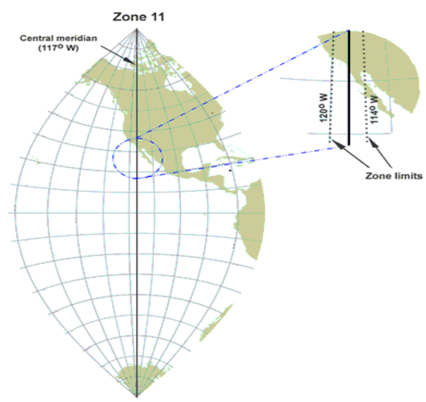


Fig. 3.16: Part of the world mapped in UTM Zone 11.The central meridian is located at 117 degrees west of Greenwich. The zone extends from 120°W to 114°W.

If a map series covers more than one UTM zone it is inconvenient to have the Eastings changing suddenly at a zone junction. For this reason a 40 kilometer overlap into an adjacent zone is allowed (figure below). Mapping beyond this area will result in distortions at the edges of a UTM zone which may not be acceptable for the larger map scales.

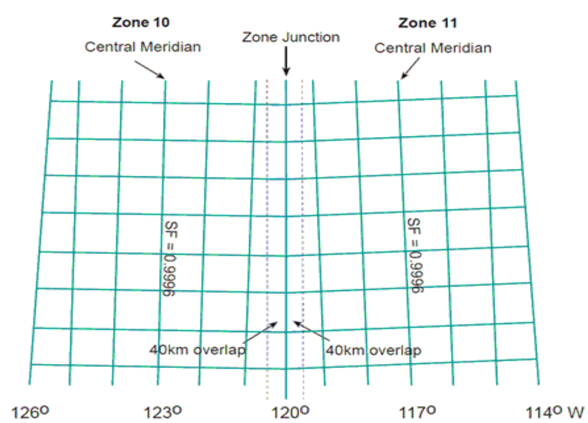


Fig. 3.17: 2 adjacent UTM-zones of 6 degrees longitude with a 40km overlap into the adjacent zone.

UTM zones can be calculated with the help of this formula:

(180 + Longitude) / 6

(Longitude of east of greenwich meridian is +ve and that of west is -ve)

3.3.5.5 Conic projections

Four well-known normal conical projections are the Lambert conformal conic projection, the simple conic projection, the Albers equal-area projection and the Polyconic projection. They give useful maps of mid-latitudes for countries which have no great extent in latitude.

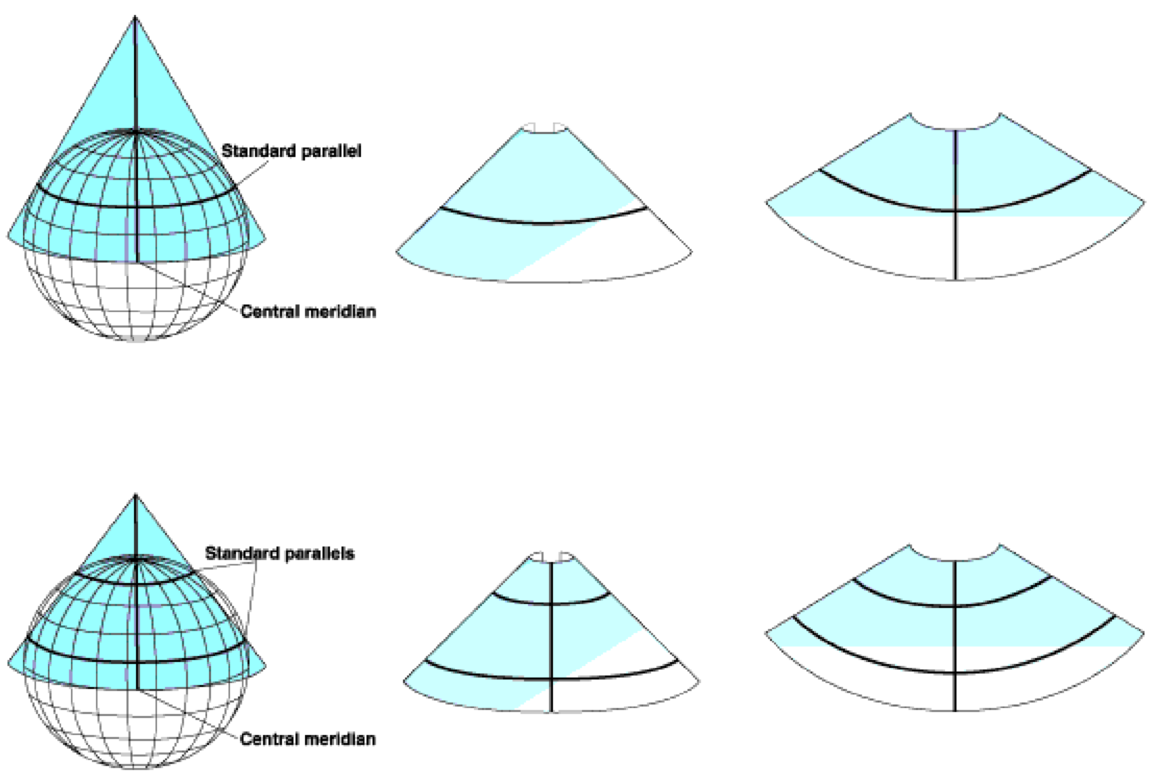


Fig. 3.18: Conic (secant)

3.3.5.6 Lambert conformal conic projection

The Lambert conformal conic projection is confomal. The parallels and meridians intersect at right angles (as in any conformal projection). Areas are, of course, inaccurate in conformal projections. Like with other conformal projections, Lambert's conical is also widely used for topographic maps. It is adapted in France and recommended to the European Commission for conformal pan-European mapping at scales smaller or equal to 1:500,000.

Fig. 3.19: Lambert Conformal Conic projection (standard parallels 10 and 30 degrees North).

3.3.5.7 Polyconic projection:

The polyconic projection is neither conformal nor equal-area. The projection is a derivation from the simple conic projection, but with every parallel true to scale (similar to the Bonne's equal-area projection). The polyconic projection is projected onto cones tangent to each parallel, so the meridians are curved, not straight (figure below). The scale is true along the central meridian and along each parallel. The distortion increase rapidly away from the central meridian. This disadvantage makes the projection unsuitable for large areas on a single sheet. It is adaptable for topographic maps, and is earlier used for the

International Map of the World, a map series at 1:1,000,000 scale published by a number of countries to common internationally agreed specifications, and also for large-scale mapping of the United States until the 1950's and coastal charts by the U.S. Coast and Geodetic Survey.

Fig. 3.20: Polyconic projection, with true scale along each parallel.

3.3.5.8 Azimuthal projections

Azimuthal (or zenithal or planar) projections are made upon a plane tangent (or secant) to the reference surface. All azimuthal projections possess the property of maintaining correct azimuths, or true directions from the centre of the map. In the polar cases, the meridians all radiate out from the pole at their correct angular distance apart. A subdivision may be made into perspective and non-perspective azimuthal projections. In the perspective projections, the actual mapping can be visualized as a true geometric projection, directly onto the mapping plane; illustrations are in the figure below. For the gnomonic projection, the perspective point (like a source of light rays), is the centre of the Earth. For the stereographic this point is the opposite pole to the point of tangency, and for the orthographic the perspective point is an infinite point in space on the opposite side of the Earth. Two well known non-perspective azimuthal projections are the azimuthal equidistantprojection (also called Postel projection) and the Lambert azimuthal equal-area projection.

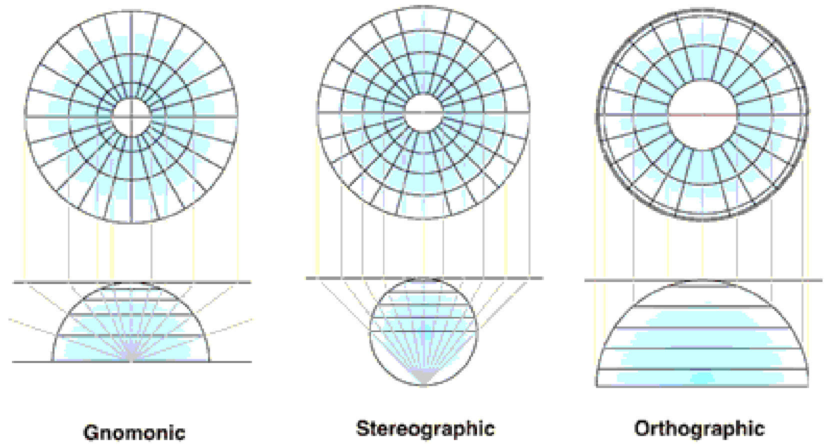


Fig. 3.21: Three perspective azimuthal projections: Gnomonic, stereographic and orthographic (source: ESRI).

3.3.5.9 Stereographic projection

The azimuthal stereographic projection is a conformal projection. Since the projection is conformal, parallels and meridians intersect at right angles. In the polar aspect the meridians are equally spaced straight lines, the parallels are unequally spaced circles centered at the pole (figure below). Spacing gradually increases away from the pole. The scale is constant along any circle having its centre at the projection centre, but increases moderately with distance from the centre. The ellipses of distortion remain circles (indicating conformality). Areas increase with distance from the projection center. The polar stereographic projection is used in combination with the UTM coordinate system as Universal Polar Stereographic (UPS) for mapping regions north of 84°N and south of 80°S. Recommended for conformal mapping of regions approximately circular in shape; the Netherlands uses a modified version of the stereographic projection (Dutch double stereographic) known as RijksDriehoekstelsel (RD).

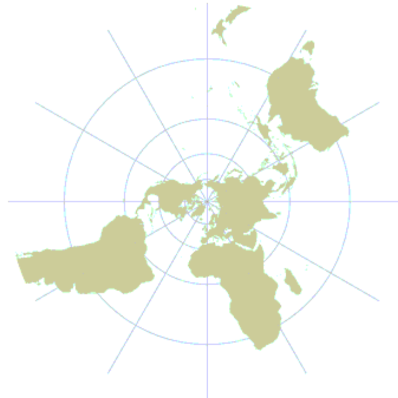


Fig. 3.22: Polar azimuthal stereographic projection is a planar projection with a conformal property.

3.3.5.10 Orthographic projection

The orthographic projection is a perspective projection that views the globe from an infinite distance. Distortion in size and area near the projection limit appears more realistic than almost any other projection. In the polar aspect, meridians are straight lines radiating from the center, and the lines of latitude are projected as concentric circles that become closer toward the edge of the globe. Only one hemisphere can be shown.

Google Earth shows the Earth as it looks from an elevated platform such as an airplane or orbiting satellite. The projection used to achieve this effect is called the general perspective. This is similar to the orthographic projection, except that the point of perspective is a finite (near earth) distance rather than an infinite (deep space) distance.

Fig. 3.23: Polar azimuthal orthographic projection.

3.4 Choice of a Projection System

When choosing a projection in which to store your database, consider the database's primary use.

1 *Databases created under contract or to be used by a government organization are often in a projection determined by the governing body, such as State Plane in the United States or Great Britain National Grid in the United Kingdom.*

2 *Use equal area projections for thematic or distribution maps.*

3 *Presentation maps are usually conformal projections, although compromise and equal area projections can also be used.*

4 *Navigational maps are usually Mercator, true direction, and/or equidistant.*

If every place we wanted to map lined up nicely into these areas of minimal distortion we would be home-free, jumping to the next step of choosing "special properties". A little experience shows that geographic space is not so fine and regular and many places will always fall outside the good areas on the basic projections. One easy way to adjust for this is to change the aspect of the projection. This translates the distortion pattern in the projection space so the areas of least distortion are moved to another geographic area. Even with this added flexibility the choices are sill pretty limiting. Malling suggests that various modifications are possible to make a projection work better:

1. *Redistribution of scales and using more than one line of zero distortion, such as in a secant case.*

2. *Imposition of special boundary conditions.*

3. *Using the projection more than once to get recentred or interrrupted maps.*

4. *Combining projections. (Mechanically or mathematically)*

Although we may have succeeded in minimizing distortion in general, we still need to consider the special properties of a projection. For a particular map-use the map may need to be conformal, equal area, or some compromise of these. In some cases, such as navigation, conformality is absolutely necessary. In statistical mapping, equivalence is necessary.

The final projection choice would seem to be a fairly straightforward function of minimized distortion and special properties. In the end though, there are several other factors that will influence choices.Sometimes it is not necessary to consider special properties. At large scales the differences introduced by distortion cannot be measured on many maps.

3.5 Introduction to Non spatial data

The data that are usually mapped in a GIS can be categories, counts or amounts, ratios, or ranks.

A category is a group with similar characteristics. For example, an admission office producing a map of areas of recruitment could categorize high schools by type of control, public or private. Counts and amounts can be used to map discrete features (number of students at each high school within the state) or continuous phenomena (household income by census block).

A ratio is used to allow comparison of data between small and large areas and between areas with many features versus those with few. When using counts or amounts to *summarize data by area, analysts should be aware that such data types can skew the patterns if the areas vary by size.*

To avoid false interpretation, GIS analysts can use average, proportion, and density to summarize indicators by area. One might be interested, for instance, in mapping the average number of people per household, or the proportion of high school students in total population by census block.

Mapping density allows the analyst to see where features are concentrated; it is particularly useful in displaying distributions when the size of the areas summarized varies greatly. Mapping the population per square mile by census tract is an essential analysis when deciding on the location, for instance, of a future campus. Rank shows relative value rather than measured value. Rank can be expressed either as text (very satisfied, satisfied, neutral, dissatisfied, very dissatisfied) or numbers (one through five). For example, senior survey data could be mapped to examine whether satisfaction with the college experience is higher for in-state students than for out-of-state students. It is important to note that to understand the data, GIS analysts often create multiple maps using each of the variable types discussed here. For example, to understand the distribution of Hispanic high school students in a state, one might want to create maps showing total Hispanic population by county, the percentage of Hispanics in the total population, and the density of the Hispanic population. After determining the type of data to map, the next decision a GIS analyst has to make is whether to map individual values (by assigning a unique symbol) or to group the values into classes. This decision always involves a tradeoff between presenting the data values accurately and generalizing the values to uncover patterns on the map.

As with statistical analysis, it is important to remember that in deciding how to present the information on a map, one should always first consider the purpose of the map and the intended audience. If, for instance, one wants to explore the data to see what patterns and relationships exist in them, the analyst would probably want to display more detail and use various map types. A good start is mapping individual values if one is unfamiliar with the data or area being mapped. The simple display of individual values might also *help in deciding later how to group the values into classes. If one wants to present the map to academic decision makers, however, using classes to group individual values becomes a necessary exercise. Finding patterns and being able to compare areas quickly is especially difficult when the range of values is large. Rank often lends itself to being mapped as individual values; since most Likert scales used in higher education research often involve a maximum of five values, the other numeric data types usually require some kind of aggregation. When mapping ranks with more than eight or nine values, most GIS analysts would recommend grouping them into classes since too many different symbols on a map can make it difficult to distinguish the ranks. Such grouping can be done by simply assigning the same symbol or color to adjacent ranks.*

For count, amount, and ratio, grouping individual values in classes is usually recommended for more than twelve unique values. The upper and lower limits for each class can be specified manually or derived by the GIS tool, depending on how the data values are distributed. The grouping schemes most frequently used by GIS software are the equal interval, quartile, and standard deviation. Usually four or five classes are enough to reveal patterns in the data without confusing the reader. However, if one uses fewer than three or four classes, there might not be much variation between features and therefore no clear patterns will emerge.

Linking spatial and non spatial data

3.6.1 Introduction

A phrase many use in referring to GIS is "computer mapping." GIS can help planners and analysts "visualize" data to better understand patterns and concentrations of spatial phenomena. GIS also has the useful ability to portray layers of information, to help uncover spatial relationships among multiple sets of data. A typical GIS "session" involves bringing in various map layers for analysis. Map layers can take the form of points, lines, or areas.

Points represent phenomena that have a specific location, such as homes, businesses, colleges, schools, and crime sites. Lines represent phenomena that are linear in *nature, such as roads, rivers, and water lines. Areas represent phenomena that are bounded (states, counties, zip codes, school districts, census tracts).*

It is important that the data contain a locational identifier in order to be mapped in a GIS. Typical examples of locational identifiers are street address, zip code, county, state, and census tract. The term used to describe the associating of attribute data to a base map in a GIS is geocoding, or geographically encoding the data to allow it to be mapped. Address-level data are typically geocoded to a street-level base map; county statistics are geocoded against a county-level base map, and so forth.

3.6.2 Advantages and Disadvantages of GIS database

Data collection, and the maintenance of databases, remains the most expensive and time consuming aspect of setting up a major GIS facility. This typically costs 60-80% of the overall costs of a GIS project.

There are a lot considerations to be made before designing a GIS database:

1. *the nature of the source data e.g. it is already in raster form*
2. *the predominant use to which it will be put*
3. *the potential losses that may occur in transition*
4. *storage space (increasingly less important)*
5. *requirements for data sharing with other systems/software*

The issue of scale is often raised in relation to GIS data base development. It is important to remember that data stored in a GIS does not have a scale. Sometime people refer to a 1:25000 scale data base. What they mean is that the data has been taken from 1:25000 maps or that it has a level of accuracy which is roughly equivalent to that found on 1:25000 scale maps.

3.6.3 Sources of data for GIS

Problems can arise when some of the data is drawn from large scale mapping and other data is drawn from much smaller scale mapping. In this case great care has to be taken that conclusions are not drawn on the basis of the less reliable data.

There are several methods used for entering spatial data into a GIS, including:

1. *manual digitising and scanning of analogue maps*
2. *image data input and conversion to a GIS*
3. *direct data entry including global positioning systems (GPS)*
4. *transfer of data from existing digital sources*

At each stage of data input there should be data verification should occur to ensure that the resulting database is as error free as possible.

3.6.3.1 Direct Data Entry

Surveying and manual coordinate entry

1. *In surveying, measured angles and distances from known points are used to determine the position of other points*
2. *Surveying field data are almost always recorded as polar coordinates and transformed into rectangular coordinates*

Surveying field data are almost always recorded as polar coordinates and transformed into rectangular coordinates. Polar coordinates are composed of: a measured distance and an angle measured clockwise from North.

3.6.3.2 Global positioning systems (GPS)

A Global Positioning System (GPS) is a set of hardware and software designed to determine accurate locations on the earth using signals received from selected satellites. Location data and associated attribute data can be transferred to mapping and Geographical Information Systems (GIS). GPS will collect individual points, lines and areas in any combination necessary for a mapping or GIS project. More importantly, with GPS you can create complex data dictionaries to accurately and efficiently collect attribute data. This makes GPS is a very effective tool for simultaneously collecting spatial and attribute data for use with GIS. GPS is also an effective tool for collecting control points for use in registering base maps when known points are not available.

GPS operate by measuring the distances from multiple satellites orbiting the Earth to compute the x, y and z coordinates of the location of a GPS receiver.

3.6.3.3 Satellite Data

Image data includes satellite images, aerial photographs and other remotely sensed or scanned data. For example, if the image is a remotely sensed satellite image, each pixel represents light energy reflected from a portion of the Earth's surface.

Satellite remote sensing has the ability to provide complete, cost-effective, repetitive spatial and temporal data coverage, which means that various phenomena can be analysed synoptically, and such tasks as the assessment and monitoring of land condition can be carried out over large regions.

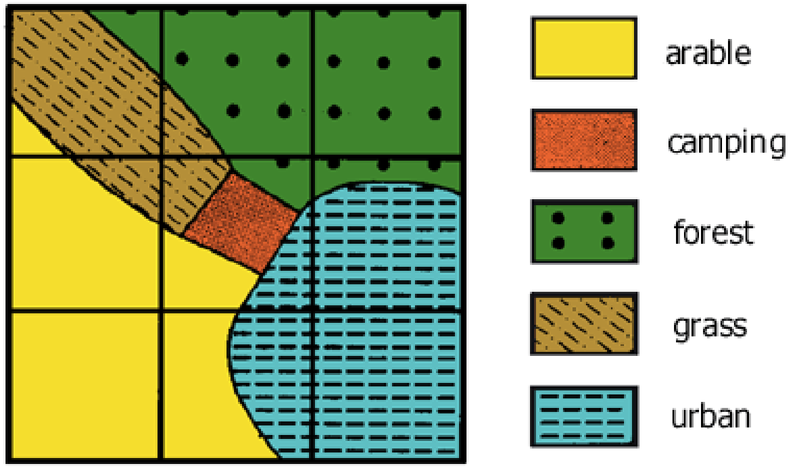


Fig. 3.24: Classification errors occur when the size of the grid cell s larger than the features which are being mapped (Burrough, 1986)

The spectral data needs to be enhanced, filtered or perhaps geometrically transformed with image processing techniques before it can incorporated into a GIS.

3.7 Summary

This unit is about databases namely spatial and non-spatial which have been covered separately in details. The most commonly related concepts of spatial data, like geo referencing, datum, and spheroid have been suitably illustrated. The projection systems which attribute the spatial information to the data have been explained. Later the linking of spatial and non-spatial data for a suitable geographical information system has also been enclosed.

3.8 Glossary

***Datum**- A reference for position on the surface of the Earth. In surveying, a datum is a reference system for computing or correlating the results of surveys. There are two principal types of datums: vertical and horizontal. A vertical datum is a level surface to which heights are referred. The horizontal datum is used as a reference for position.*

Ellipsoid- *A mathematical figure that approximates the shape of the Earth in form and size, and which is used as a reference surface for geodetic surveys. Used interchangeably with Spheriod.*

Non-spatial- *not particularly having an accurate spatial reference*

Projection- *Method by which the curved surface of the earth is portrayed on a flat surface. This generally requires a systematic mathematical transformation of the earth's graticule of lines of longitude and latitude onto a plane.*

Spatial- *of or pertaining to space*

Spheroid- *A mathematical figure that approximates the shape of the Earth in form and size, and which is used as a reference surface for geodetic surveys. Used interchangeably with Ellipsoid.*

3.9 References

1. *http://ads.ahds.ac.uk/project/goodguides/gis/sect36.html*
2. *http://www.geom.unimelb.edu.au/gisweb/SDEModule/SDE_Theory.htm#design*
3. *http://www.wamis.org/agm/pubs/agm8/Paper-8.pdf*
4. *http://en.mimi.hu/gis/spatial_data.html*
5. *http://www.theukwebdesigncompany.com/articles/types-of-databases.php*
6. *http://en.wikibooks.org/wiki/Statistics/Different_Types_of_Data/Quantitative_and_Qualitative_Data*
7. *http://changingminds.org/explanations/research/measurement/types_data.htm*
8. *http://www.icsm.gov.au/mapping/datums1.html#sphere*
9. *http://resources.arcgis.com/content/kbase?fa=articleShow&d=25398*
10. *http://www.kartografie.nl/geometrics/map%20projections/body.htm*

11 *http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Choosing_a_map_projection*

12 *http://www.geo.hunter.cuny.edu/mp/choose.html*

13 *http://www.nationalatlas.gov/articles/mapping/a_projections.html#two*

14 *http://www.trfic.msu.edu/products/profcorner_products/Intro_to_GIS.pdf*

15 *http://teams.gemstone.umd.edu/classof2009/fastr/Jardine%20Article.pdf*

3.10 Suggested Readings

1 *Burrough, Peter A. and Rachael A. McDonnell. 1998. Principles of Geographical Information Systems. Published by Oxford University Press, Toronto. ISBN13: 9780198233657 ISBN10: 0198233655*

2 *Longley, P.A., M.F. Goodchild, D.J. Manguire, D.W. Rhind, Geographical Information System Volume I: Principal and Technical Issues Volume II: Management Issues and Applications Published by John Wiley & Sons ISBN NO: 978-0-471-73545-8*

3 *O'Sullivan, David and David J. Unwin. 2003. Geographic Information Analysis Published by John Wiley & Sons, Inc, Hoboken, New Jersey ISBN NO 10: 0471211761 ISBN 13: 9780471211761*

4 *http://teams.gemstone.umd.edu/classof2009/fastr/Jardine%20Article.pdf*

3.11 Terminal Questions

1 *Give diagram and difference between Spheroid and Geoid.*

2 *What is Datum? Give 2 examples.*

3 *What are the different types of projections? Draw diagrams.*

4 *What is a Cylindrical projection? Give one example of a cylindrical projection.*

5 *Name 3 criteria which is to be kept in mind when storing data.*

6 *Name 3 methods of data entry into GIS.*

7 *What is the full form of GPS? What is a GPS?*

***

UNIT 1: REMOTE SENSING

1.1. Introduction

1.1.1 Electromagnetic Radiation

1.2. Electromagnetic Spectrum

1.2.1 Interactions with the Atmosphere

1.2.2 Radiation - Target Interactions

1.3. Component of Remote sensing

1.3.1 Introduction

1.3.2 Spectral Response

1.3.3 Passive vs. Active Sensing

1.3.4 A mechanical scanning radiometer (Whisk Broom

1.3.5 A push broom radiometer

1.4. Resolutions

1.4.1 Spatial Resolution, Pixel Size, and Scale

1.4.2 Spectral Resolution

1.4.3 Radiometric Resolution

1.4.4 Temporal Resolution

1.5. Summary

1.6. Glossary

1.7. References

1.8. Suggested Readings

1.9. Terminal Questions

1.1 Introduction

"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information." In much of remote sensing, ***the process*** *involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.*

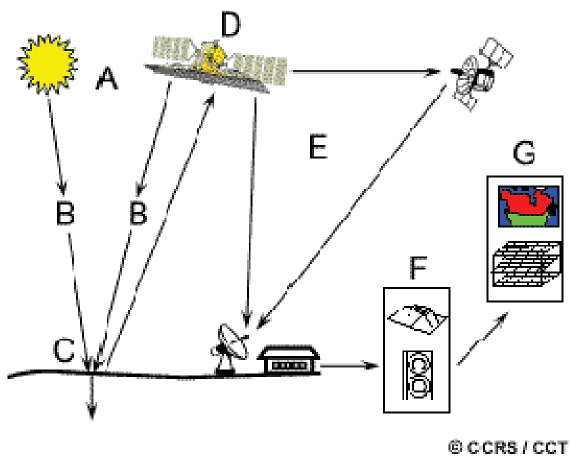


Fig 1.1: Remote sensing

1. Energy Source or Illumination (A) *– the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.*

2. Radiation and the Atmosphere (B) *– as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.*

3. Interaction with the Target (C) *- once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.*

***4. Recording of Energy by the Sensor (D)** - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.*

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

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

***7. Application (G)** - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.*

These seven elements comprise the remote sensing process from beginning to end. We will be covering all of these in sequential order throughout the five chapters of this tutorial, building upon the information learned as we go. Enjoy the journey!

1.1.1 Electromagnetic Radiation

*As was noted in the previous section, the first requirement for remote sensing is to have an **energy source to illuminate the target** (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation.*

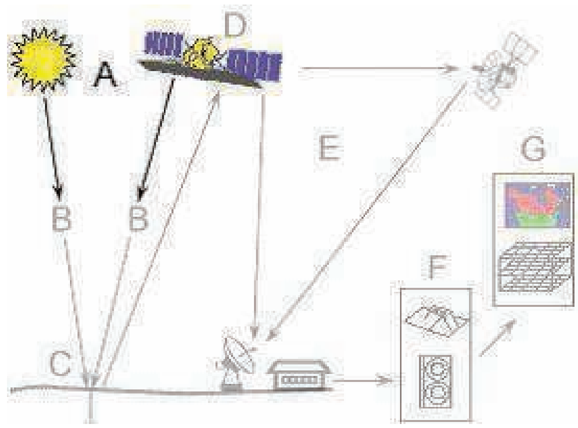


Fig 1.2: Electromagnetic radiation

All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory. ***Electromagnetic radiation*** *consists of an electrical field(E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c). Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing. These are the* ***wavelength and frequency.***

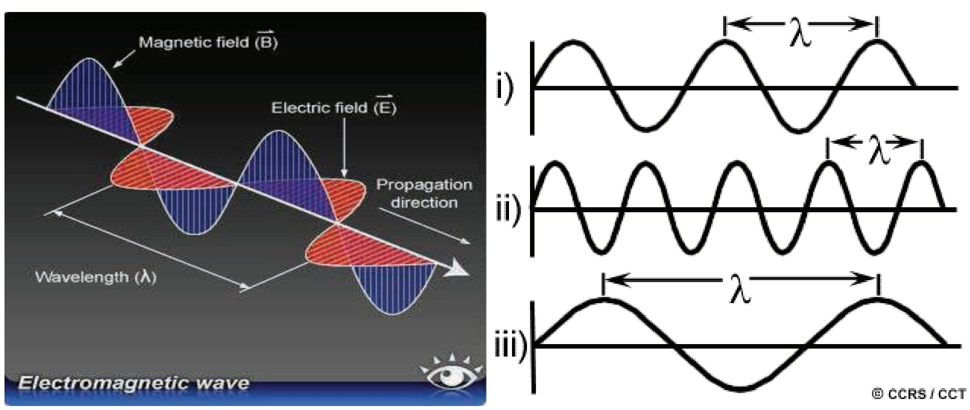


Fig 1.3: wavelength and frequency

The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is usually represented by the Greek letter lambda (λ). Wavelength is measured in metres (m) or some factor of metres such as ***nanometres*** *(nm, 10-9 metres),* ***micrometres*** *(μm, 10-6 metres) (μm, 10-6 metres) or centimetres (cm, 10-2 metres). Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in* ***hertz*** *(Hz), equivalent to one cycle per second, and various multiples of hertz. Wavelength and frequency are related by the following formula:*

$$c=\lambda v$$

where:

λ = wavelength (m)
v= frequency (cycles per second, Hz)
c =speed of light ($3x10^8$ m/s)

Therefore, the two are inversely related to each other. The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency. Understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency is crucial to understanding the information to be extracted from remote sensing data. Next we will be examining the way in which we categorize electromagnetic radiation for just that purpose.

1.2 Electromagnetic Spectrum

The ***electromagnetic spectrum*** *ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum which are useful for remote sensing.*

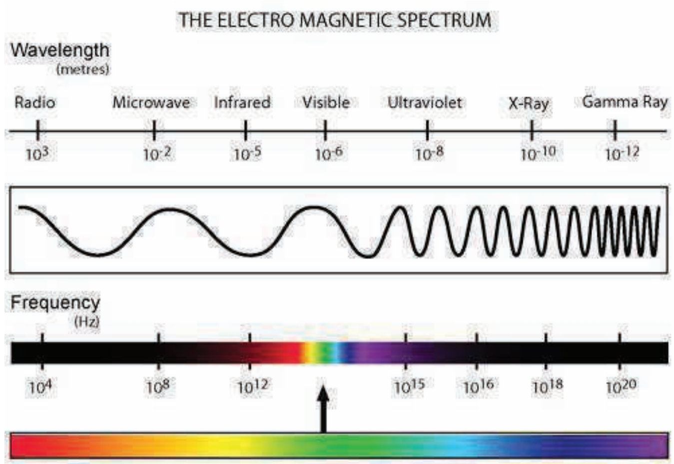


Fig 1.4: Electromagnetic spectrum

*For most purposes, the **ultraviolet or UV** portion of the spectrum has the shortest wavelengths which are practical for remote sensing. This radiation is just beyond the violet portion of the visible wavelengths, hence its name. Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.*

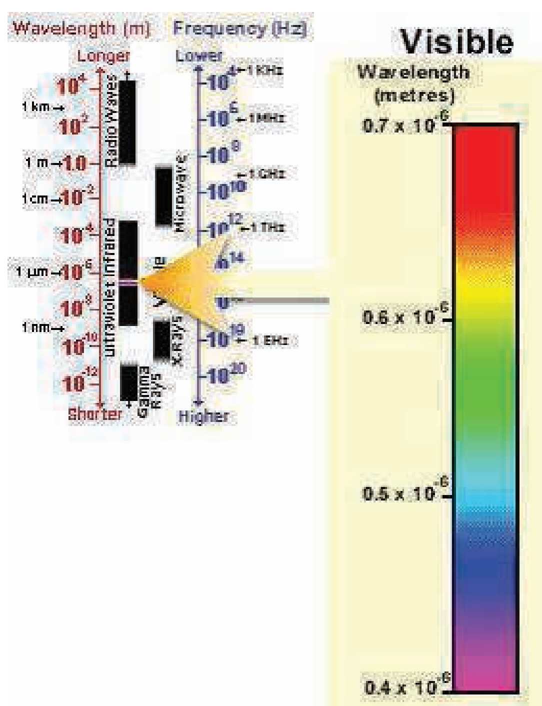


Fig. 1.5: Electromagnetic spectrum

*The light which our eyes - our "remote sensors" - can detect is part of the **visible spectrum**. It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage. The visible wavelengths cover a range from approximately 0.4 to 0.7 µm. The longest visible wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colours from the visible portion of the spectrum are listed below. It is important to note that this is the only portion of the spectrum we can associate with the concept of **colours**.*

***Violet:** 0.4 - 0.446 µm*

***Blue:** 0.446 - 0.500 µm*

***Green:** 0.500 - 0.578 µm*

***Yellow:** 0.578 - 0.592 µm*

***Orange:** 0.592 - 0.620 µm*

***Red:** 0.620 - 0.7 µm*

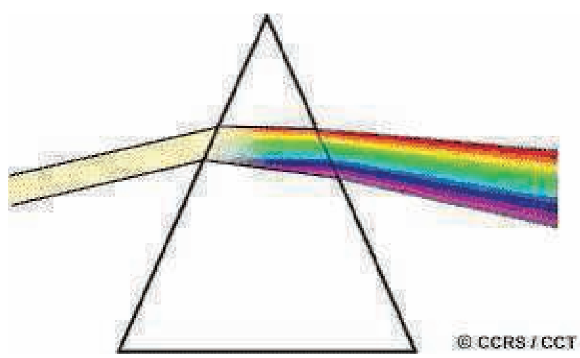


Fig. 1.6: Visible spectrum

Blue**, **green**, and **red** are the **primary colours** or wavelengths of the visible spectrum. They are defined as such because no single primary colour can be created from the other two, but all other colours can be formed by combining blue, green, and red in various* *proportions. Although we see sunlight as a uniform or homogeneous colour, it is actually composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum. The visible portion of this radiation can be shown in its component colours when sunlight is passed through a* ***prism*, which bends the light in differing amounts according to wavelength.*

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

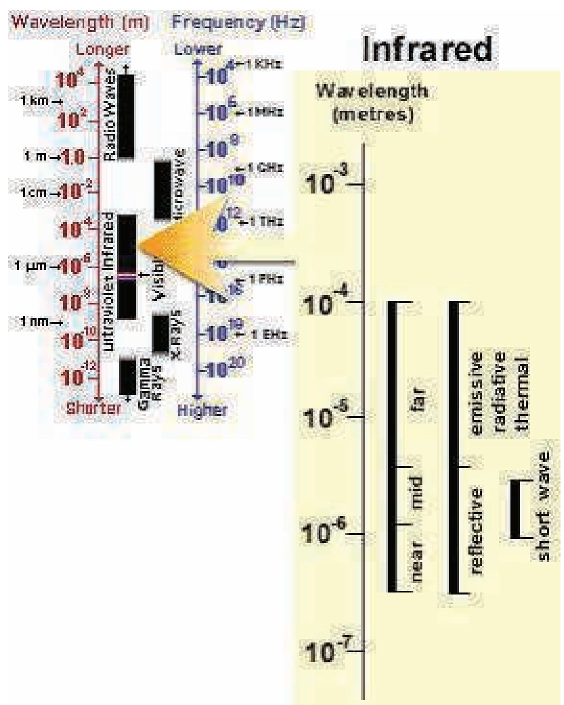


Fig. 1.7: Infrared

Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion. The reflected IR covers wavelengths from approximately 0.7 μm to 3.0 μm. The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths from approximately 3.0 μm to 100 μm.

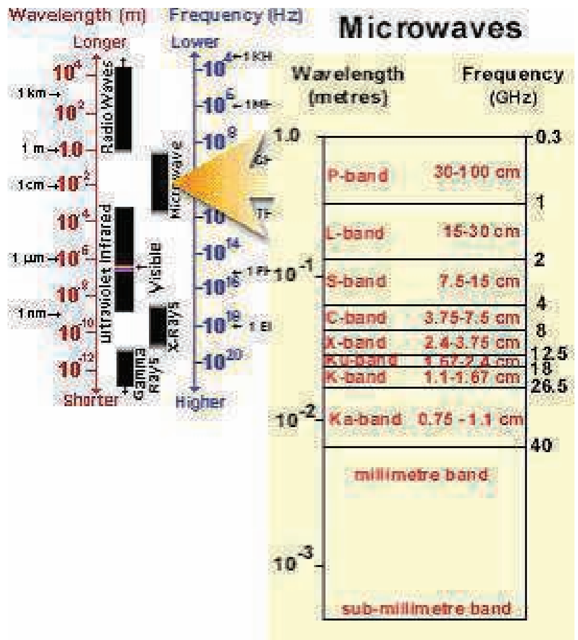


Fig. 1.8: Microwave

*The portion of the spectrum of more recent interest to remote sensing is the **microwave region** from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts. Because of the special nature of this region and its importance to remote sensing in Canada, an entire chapter (Chapter 3) of the tutorial is dedicated to microwave sensing.*

1.2.1 Interactions with the Atmosphere

*Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of **scattering** and **absorption**.*

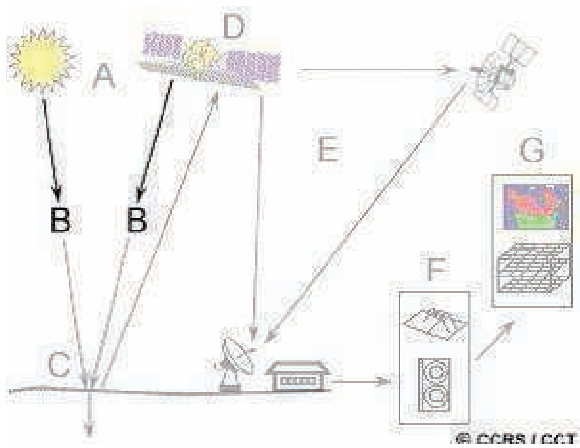


Fig. 1.9: Interactions with the Atmosphere

Scattering *occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. 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 (3) types of scattering which take place.*

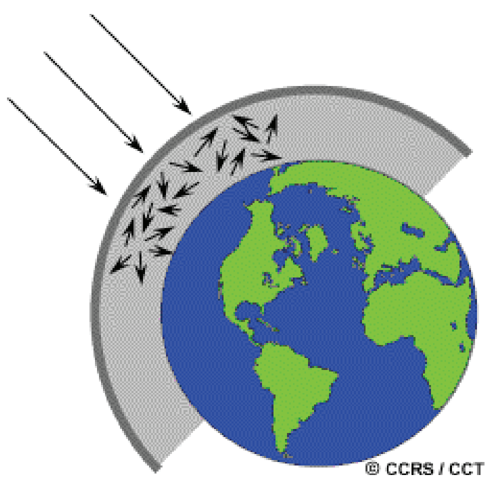


Fig. 1.10: Scattering

Rayleigh scattering *occurs when particles are very small compared to the wavelength of the radiation.*

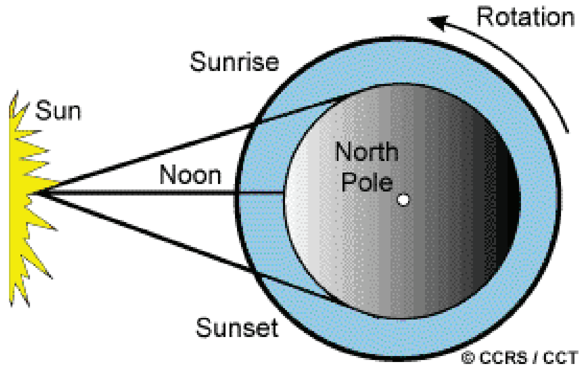


Fig. 1.11: Rayleigh scattering

These could be particles such as small specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day is because of this phenomenon. As sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At ***sunrise and sunset*** *the light has to travel farther through the atmosphere than at midday and the scattering of the shorter wavelengths is more complete; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.*

Mie scattering *occurs when the particles are just about the same size as the wavelength of the radiation.*

Fig. 1.12: Mie scattering

Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud conditions are overcast. The final scattering mechanism of importance is called ***nonselective scattering****. This occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering. Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally. This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities (blue+green+red light = white light).*

Absorption *is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths.*

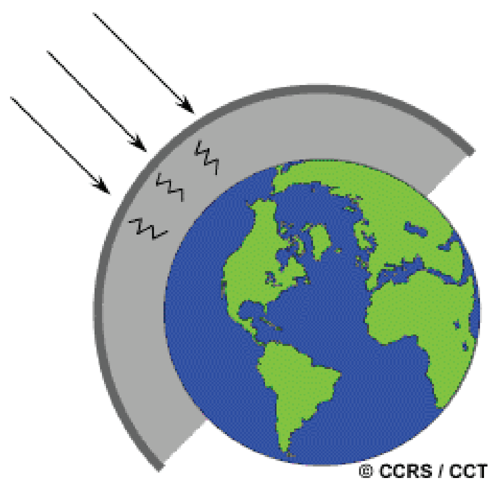


Fig. 1.13: Absorption

Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents which absorb radiation. ***Ozone*** *serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight. You may have heard* ***carbon dioxide*** *referred to as a greenhouse gas. This is because it tends to* *absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere. Water vapour in the atmosphere absorbs much of the incoming longwave infrared and shortwave microwave radiation (between 22μm and 1m). The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e. high humidity).*

Because these gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can "look" for remote sensing purposes.

Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called ***atmospheric windows****. By comparing the characteristics of the two most common energy/radiation sources (the sun and the earth) with the atmospheric windows available to us, we can define those wavelengths that we can use* ***most effectively*** *for remote sensing.*

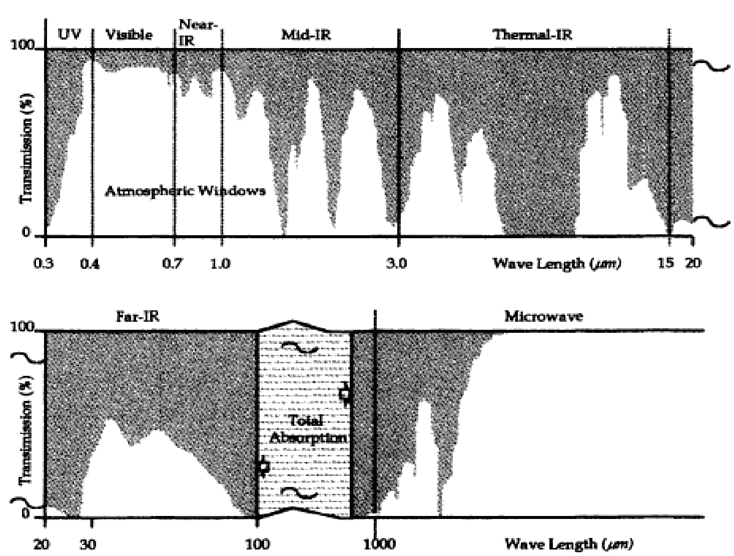


Fig. 1.14: Atmospheric windows

Atmospheric windows (unshaded). Vertical axis is atmospheric transmission (%). Horizontal axis is the logarithm of the wavelength in micrometres

1.2.2 Radiation - Target Interactions

Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. There are three (3) forms of interaction that can take place when energy strikes, or is ***incident (I)*** *upon the surface. These are:* ***absorption (A)****;* ***transmission (T)****; and* ***reflection (R)****. The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.*

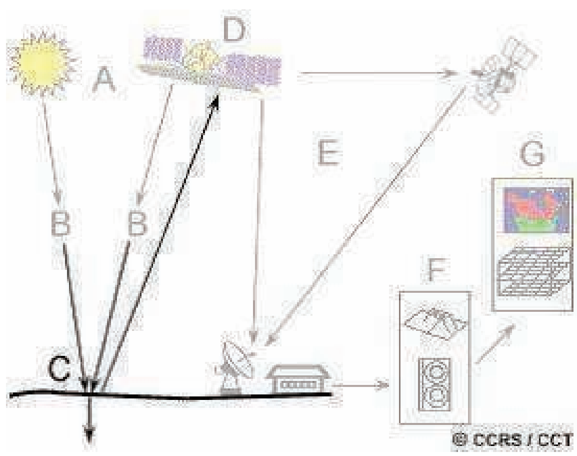


Fig. 1.15: Target interaction

Absorption (A) occurs when radiation (energy) is absorbed into the target while transmission (T) occurs when radiation passes through a target.

Fig. 1.16: Reflection

Reflection (R) occurs when radiation "bounces" off the target and is redirected. In remote sensing, we are most interested in measuring the radiation reflected from targets. We refer to two types of reflection, which represent the two extreme ends of the way in which energy is reflected from a target: ***specular reflection*** *and* ***diffuse reflection****.*

When a surface is smooth we get ***specular*** *or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction.* ***Diffuse*** *reflection occurs when the surface is rough and the energy is reflected almost uniformly in all directions.*

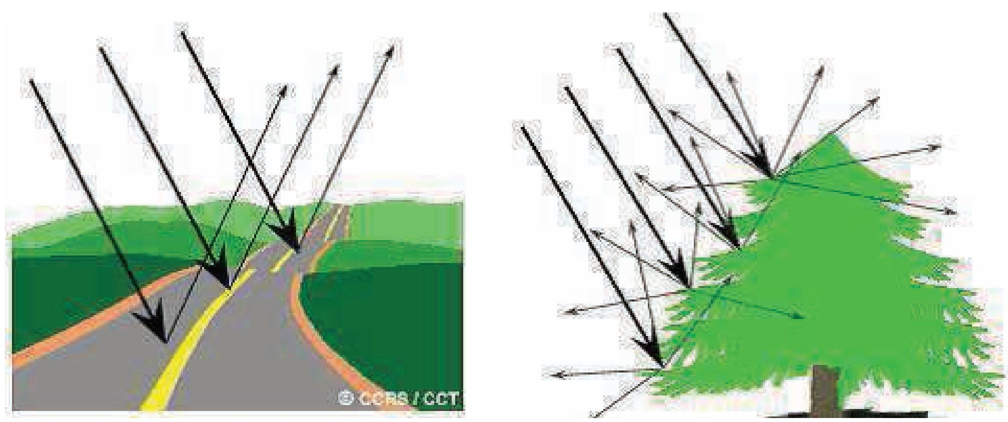


Fig. 1.17: Diffusion

Most earth surface features lie somewhere between perfectly specular or perfectly diffuse reflectors. Whether a particular target reflects specularly or diffusely, or *somewhere in between, depends on the surface roughness of the feature in comparison to the wavelength of the incoming radiation. If the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface, diffuse reflection will dominate. For example, finegrained sand would appear fairly smooth to long wavelength microwaves but would appear quite rough to the visible wavelengths. Let's take a look at a couple of examples of targets at the Earth's surface and how energy at the visible and infrared wavelengths interacts with them.*

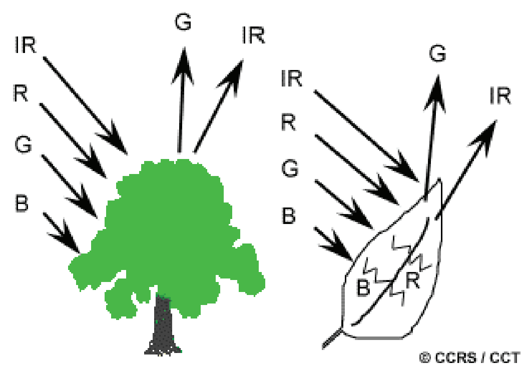


Fig. 1.18: IR interaction

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

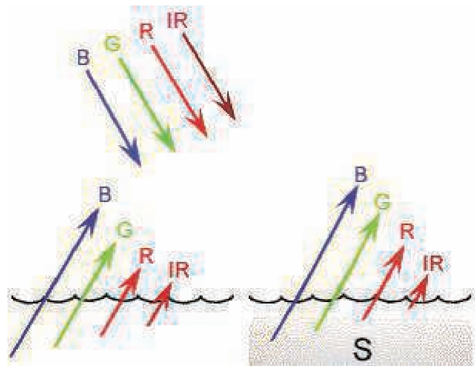


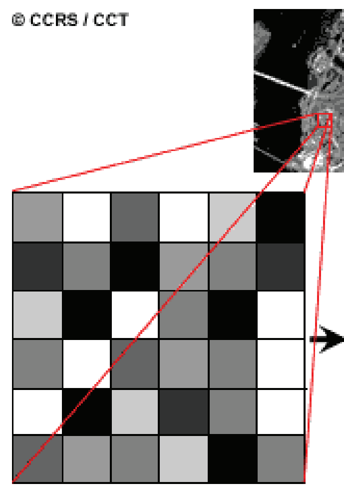
Fig. 1.19: Water

Water: *Longer wavelength visible and near infrared radiation is absorbed more by water than shorter visible wavelengths. Thus water typically looks blue or blue-green due to stronger reflectance at these shorter wavelengths, and darker if viewed at red or near infrared wavelengths. If there is suspended sediment present in the upper layers of the water body, then this will allow better reflectivity and a brighter appearance of the water. The apparent colour of the water will show a slight shift to longer wavelengths. Suspended sediment (S) can be easily confused with shallow (but clear) water, since these two phenomena appear very similar. Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear more green in colour when algae is present. The topography of the water surface (rough, smooth, floating materials, etc.) can also lead to complications for water-related interpretation due to potential problems of specular reflection and other influences on colour and brightness. We can see from these examples that, depending on the complex make-up of the target that is being looked at, and the wavelengths of radiation involved, we can observe very different responses to the mechanisms of absorption, transmission, and reflection. By measuring the energy that is reflected (or emitted) by targets on the Earth's surface over a variety of different wavelengths, we can build up a* ***spectral response*** *for that object. By comparing the response patterns of different features we may be able to distinguish between them, where we might not be able to, if we only compared them at one wavelength. For example, water and vegetation may reflect somewhat similarly in* *the visible wavelengths but are almost always separable in the infrared. Spectral response can be quite variable, even for the same target type, and can also vary with time (e.g. "green-ness" of leaves) and location. Knowing where to "look" spectrally and understanding the factors which influence the spectral response of the features of interest are critical to correctly interpreting the interaction of electromagnetic radiation with the surface.*

1.3 Component of Remote sensing

1.3.1 Introduction

An image refers to any pictorial representation, regardless of what wavelengths or remote sensing device has been used to detect and record the electromagnetic energy. A ***photograph*** *refers specifically to images that have been detected as well as recorded on photographic film. The black and white photo to the left, of part of the city of Ottawa, Canada was taken in the visible part of the spectrum. Photos are normally recorded over the wavelength range from 0.3 µm to 0.9 µm - the visible and reflected infrared. Based on these definitions, we can say that all photographs are images, but not all images are photographs. Therefore, unless we are talking specifically about an image recorded photographically, we use the term image.*



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Fig. 1.20: Digital format

*A photograph could also be represented and displayed in a **digital** format by subdividing the image into small equal-sized and shaped areas, called picture elements or **pixels**, and representing the brightness of each area with a numeric value or **digital number**. Indeed, that is exactly what has been done to the photo to the left. In fact, using the definitions we have just discussed, this is actually a **digital image** of the original photograph! The photograph was scanned and subdivided into pixels with each pixel assigned a digital number representing its relative brightness. The computer displays each digital value as different brightness levels. Sensors that record electromagnetic energy, electronically record the energy as an array of numbers in digital format right from the start. These two different ways of representing and displaying remote sensing data, either pictorially or digitally, are interchangeable as they convey the same information (although some detail may be lost when converting back and forth).*

In previous sections we described the visible portion of the spectrum and the concept of colours. We see colour because our eyes detect the entire visible range of wavelengths and our brains process the information into separate colours. Can you imagine what the world would look like if we could only see very narrow ranges of wavelengths or colours? That is how many sensors work. The information from a narrow wavelength range is gathered and stored in *a **channel**, also sometimes referred to as a **band**. We can combine and display channels of information digitally using the three primary colours (blue, green, and red). The data from each channel is represented as one of the primary colours and, depending on the relative brightness (i.e. the digital value) of each pixel in each channel, the primary colours combine in different proportions to represent different colours.*

Fig. 1.21: Display

*When we use this method to display a single channel or range of wavelengths, we are actually displaying that channel through all three primary colours. Because the brightness level of each pixel is the same for each primary colour, they combine to form a **black and white image**, showing various shades of gray from black to white. When we display more than one channel each as a different primary colour, then the brightness levels may be different for*

1.3.2 Spectral Response

For any given material, the amount of solar radiation that it reflects, absorbs, transmits, or emits varies with wavelength.

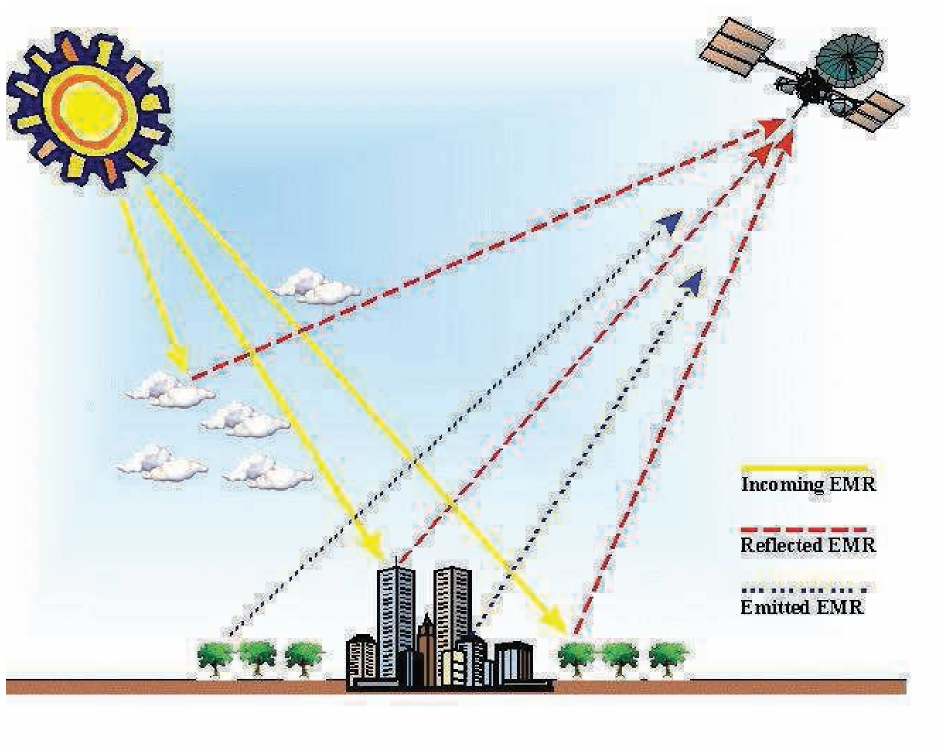


Fig. 1.22: EMR

When that amount (usually intensity, as a percent of maximum) coming from the material is plotted over a range of wavelengths, the connected points produce a curve called the material's ***spectral signature*** *(spectral response curve). Here is a general example of a reflectance plot for some (unspecified) vegetation type (bio-organic material), with the dominating factor influencing each interval of the curve so indicated; note the downturns of the curve that result from selective absorption:*

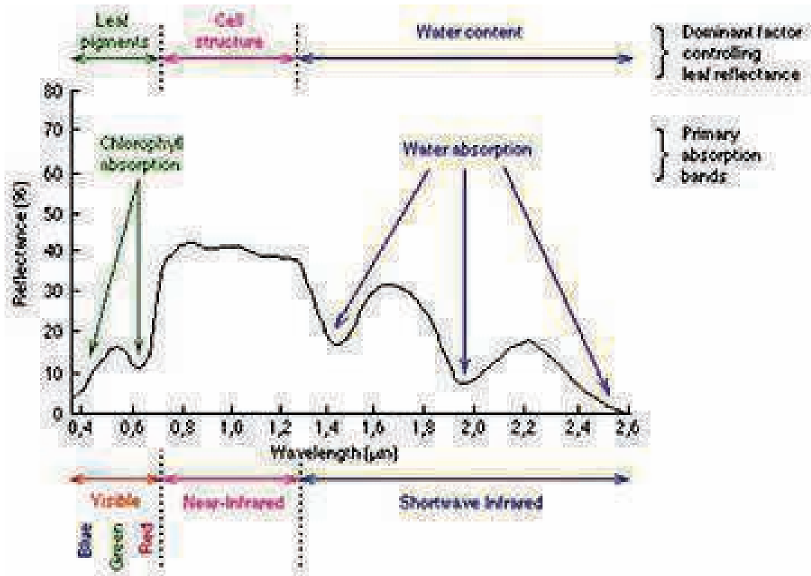
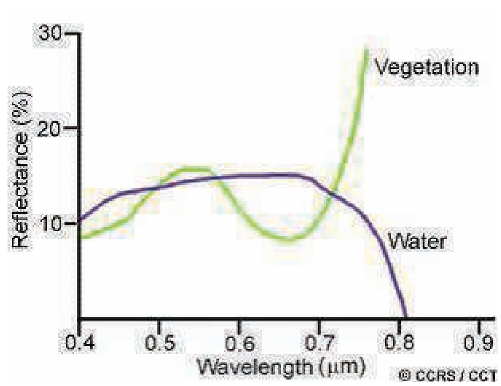
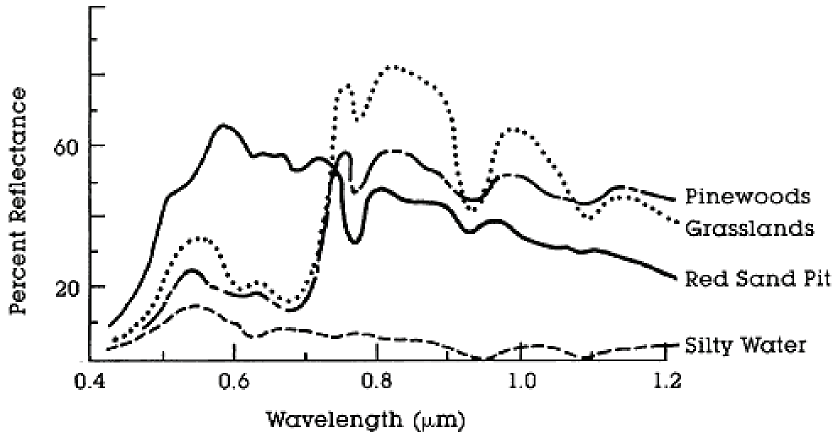


Fig. 1.23: Spectral response curve

This important property of matter makes it possible to identify different substances or classes and to separate them by their individual spectral signatures, as shown in the figure below.





For example, at some wavelengths, sand reflects more energy than green vegetation but at other wavelengths it absorbs more (reflects less) than does the vegetation. In principle, we can recognize various kinds of surface materials and distinguish them from each other by these differences in reflectance. Of course, there must be some suitable method for measuring these differences as a function of wavelength and intensity (as a fraction [normally in percent] of the amount of irradiating radiation). Using reflectance differences, we may be able to distinguish the four common surface materials in the above signatures (GL = grasslands; PW = pinewoods; RS = red sand; SW = silty water) simply by plotting the reflectances of each material at two wavelengths, commonly a few tens (or more) of micrometers apart.

1.3.3 Passive vs. Active Sensing

So far, throughout this chapter, we have made various references to the sun as a source of

energy or radiation. The sun provides a very convenient source of energy for remote sensing. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then reemitted, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called passive sensors. Passive sensors can only be used to detect *energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. There is no reflected energy available from the sun at night. Energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded.*

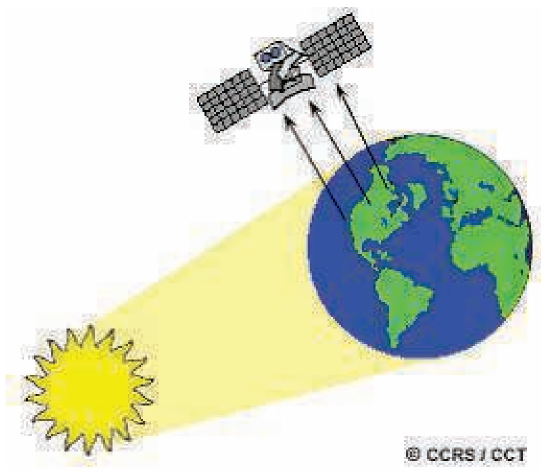


Fig. 1.24: Detecting EMR

These sensors are called radiometers and they can detect EMR within the ultraviolet to microwave wavelengths. Two important spatial characteristics of passive sensors are:

Their "instantaneous field of view" (IFOV) - this is the angle over which the detector is sensitive to radiation. This will control the picture element (pixel) size which gives the ground (spatial) resolution of the ultimate image i.e. the spatial resolution is a function of the detector angle and the height of the sensor above the ground. For more details on spatial, spectral, radiometric and temporal resolutions.

The Concept of IFOV and AFOV (after Avery and Berlin, 1985)

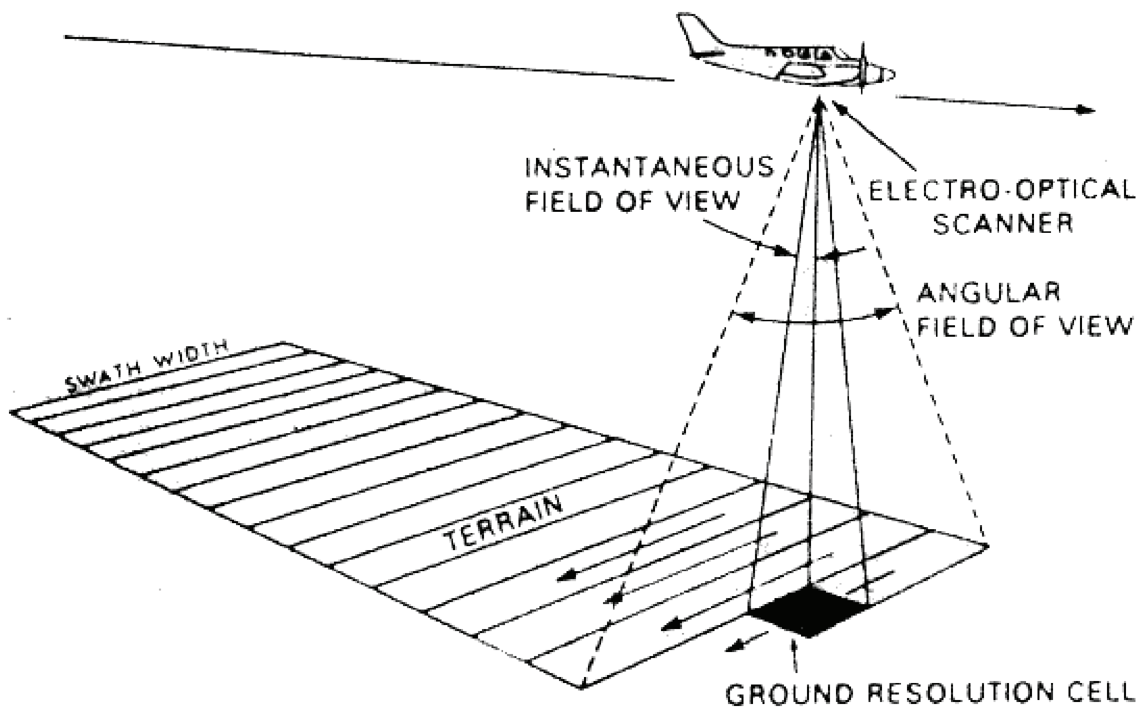


Fig. 1.25: AFOV

The "swath width" - this is the linear ground distance over which the scanner is tracking (at right angles to the line of flight). It is determined by the angular field of view (AFOV - or scanning angle) of the scanner. The greater the scanning angle, the greater the swath width.

There are two main categories of passive sensor:

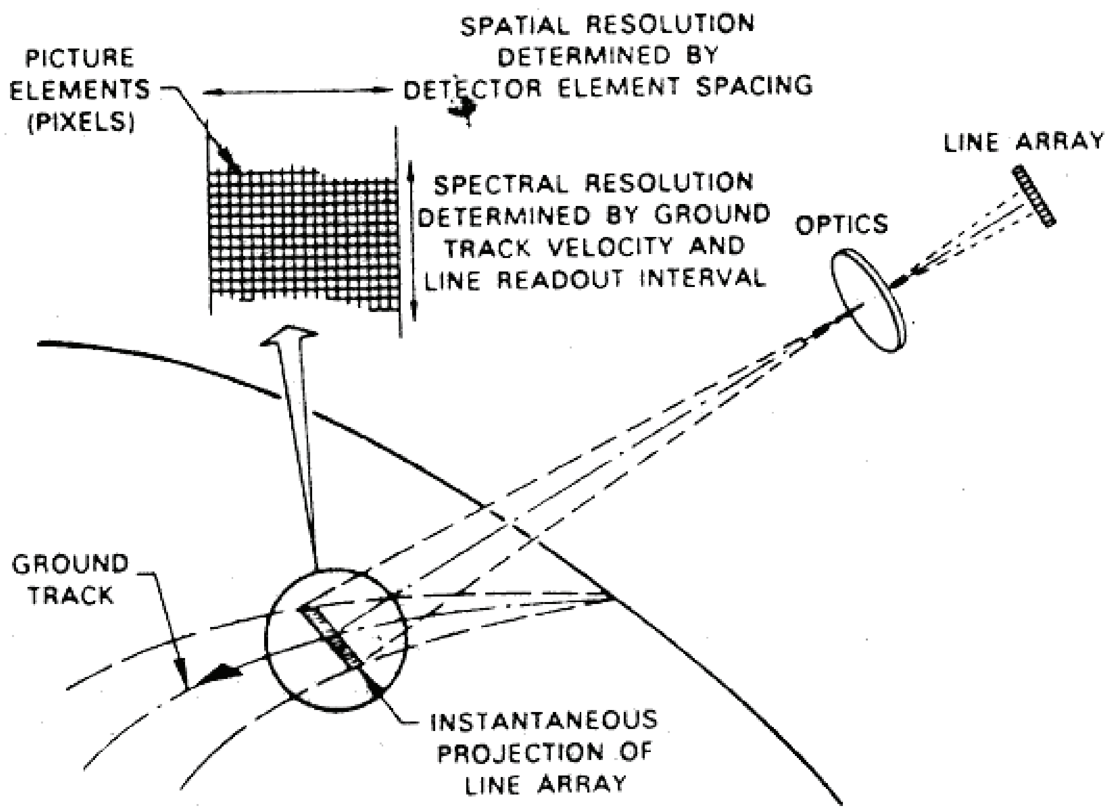
1.3.4 A mechanical scanning radiometer (Whisk Broom).

This is an electro-optical imaging system on which an oscillating or rotating mirror directs the incoming radiation onto a detector as a series of scan-lines perpendicular to the line of flight. The collected energy on the detector is converted into an electrical signal. This signal is then recorded in a suitably coded digital format, together with additional data for radiometric and geometric *calibration and correction, directly on magnetic tape on board the sensor platform.*

1.3.5 A push broom radiometer

This uses a wide angle optical system in which all the scenes across the AFOV are imaged on a detector array at one time, i.e. there is no mechanical movement. As the sensor moves along the flight line, successive lines are imaged by the sensor and sampled by a multiflexer for transmission. The push broom system is generally better than the mechanical scanner since there is less noise in the signal, there are no moving parts and it has a high geometrical accuracy.

Characteristics of a Push Broom Radiometer (after Avery and Berlin, 1985)



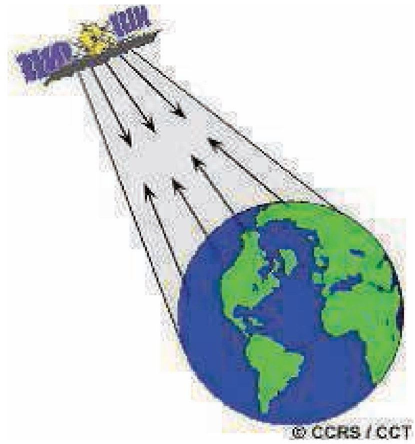


Fig. 1.26: Push Broom Radiometer

Active sensors, on the other hand, provide their own energy source for illumination. The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor. Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season. Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated. However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets. Some examples of active sensors are a laser fluro-sensor and synthetic aperture radar (SAR).

We will review briefly airborne and satellite active systems, which are commonly called Radar, and which are generally classified either imaging or non-imaging:

Imaging Radars. These display the radar backscatter characteristics of the earth's surface in the form of a strip map or a picture of a selected area. A type used in aircraft is the SLAR whose sensor scans an area not directly below the aircraft, but at an angle to the vertical, i.e. it looks sideways to record the relative intensity of the reflections so as to produce an image of a narrow strip of terrain. Sequential strips are recorded as the aircraft moves forward allowing a complete image to be built up. The SLAR is unsuitable for satellites since, to achieve a useful spatial resolution, it would require a very large antenna. A variant used in *satellites is the SAR whose short antenna gives the effect of being several hundred times longer by recording and processing modified data.*

The Synthetic Aperture Radar System (after Avery and Berlin, 1985)

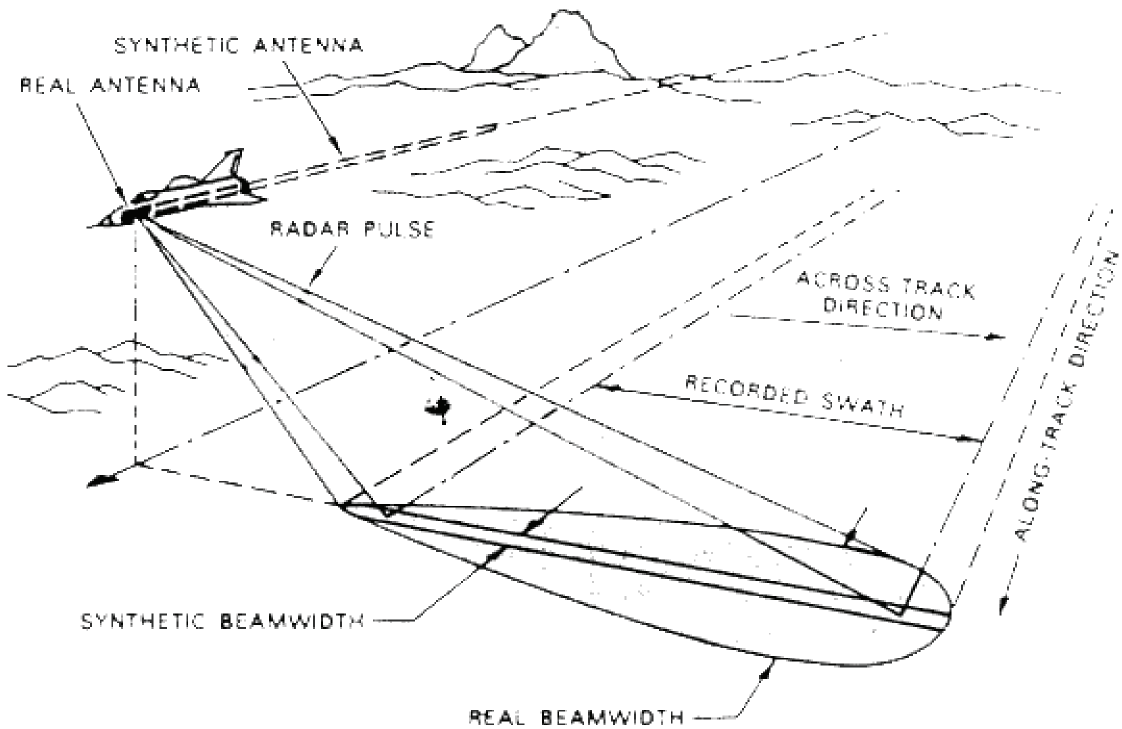


Fig. 1.27

1.4 Resolutions

1.4.1 Spatial Resolution, Pixel Size, and Scale

For some remote sensing instruments, the distance between the target being imaged and the platform, plays a large role in determining the detail of information obtained and the total area imaged by the sensor. Sensors onboard platforms far away from their targets, typically view a larger area, but cannot provide great detail. Compare what an astronaut onboard the space shuttle sees of the Earth to what you can see from an airplane. The astronaut might see your whole province or country in one glance, but couldn't distinguish individual houses. Flying over a city or town, you would be able to see individual buildings *and cars, but you would be viewing a much smaller area than the astronaut. There is a similar difference between satellite images and airphotos. The detail discernible in an image is dependent on the* ***spatial resolution*** *of the sensor and refers to the size of the smallest possible feature that can be detected. Spatial resolution of passive sensors (we will look at the special case of active microwave sensors later) depends primarily on their* ***Instantaneous Field of View (IFOV)****. The IFOV is the angular cone of visibility of the sensor (A) and determines the area on the Earth's surface which is "seen" from a given altitude at one particular moment in time (B). The size of the area viewed is determined by multiplying the IFOV by the distance from the ground to the sensor (C). This area on the ground is called the* ***resolution cell*** *and determines a sensor's maximum spatial resolution. For a homogeneous feature to be detected, its size generally has to be equal to or larger than the resolution cell. If the feature is smaller than this, it may not be detectable as the average brightness of all features in that resolution cell will be recorded. However, smaller features may sometimes be detectable if their reflectance dominates within a articular resolution cell allowing sub-pixel or resolution cell detection.*

As we mentioned in earlier, most remote sensing images are composed of a matrix of picture elements, or ***pixels****, which are the smallest units of an image. Image pixels are normally square and represent a certain area on an image. It is important to distinguish between pixel size and spatial resolution - they are not interchangeable. If a sensor has a spatial resolution of 20 metres and an image from that sensor is displayed at full resolution, each pixel represents an area of 20m x 20m on the ground. In this case the pixel size and resolution are the same. However, it is possible to display an image with a pixel size different than the resolution. Many posters of satellite images of the Earth have their pixels averaged to represent larger areas, although the original spatial resolution of the sensor that collected the imagery remains the same.*

Images where only large features are visible are said to have ***coarse or low resolution.*** *In* ***fine or high resolution*** *images, small objects can be detected.*

Military sensors for example, are designed to view as much detail as possible, and therefore have very fine resolution. Commercial satellites provide imagery with resolutions varying from a few metres to several kilometres. Generally speaking, the finer the resolution, the less total ground area can be seen. The ratio of distance on an image or map, to actual ground distance is referred to as scale. If you had a map with a scale of 1:100,000, an object of 1cm length on the map would actually be an object 100,000cm (1km) long on the ground. Maps or images with small "map-to-ground ratios" are referred to as small scale (e.g. 1:100,000), and those with larger ratios (e.g. 1:5,000) are called large scale.

1.4.2 Spectral Resolution

In Chapter 1, we learned about ***spectral response*** *and* ***spectral emissivity curves*** *which characterize the reflectance and/or emittance of a feature or target over a variety of wavelengths. Different classes of features and details in an image can often be distinguished by comparing their responses over distinct wavelength ranges. Broad classes, such as water and vegetation, can usually be separated using very broad wavelength ranges - the visible and near infrared. Other more specific classes, such as* ***different rock types****, may not be easily distinguishable using either of these broad wavelength ranges and would require comparison at much finer wavelength ranges to separate them. Thus, we would require a sensor with higher* ***spectral resolution****. Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. Black and white film records wavelengths extending over much, or all of the visible portion of the electromagnetic spectrum. Its* ***spectral resolution*** *is fairly coarse, as the various wavelengths of the visible spectrum are not individually distinguished and the overall reflectance in the entire visible portion is recorded. Colour film is also sensitive to the reflected energy over the visible portion of the spectrum, but has higher spectral resolution, as it is individually sensitive to the reflected energy at the blue, green, and red wavelengths of the spectrum. Thus, it can represent features of various colours based on their reflectance in each of these distinct* wavelength ranges. Many remote sensing systems record energy over several separate wavelength ranges at various spectral resolutions. These are referred to as **multi-spectral sensors** and will be described in some detail in following sections. Advanced multi-spectral sensors called **hyperspectral** sensors, detect hundreds of very narrow spectral bands throughout the visible, near-infrared, and mid-infrared portions of the electromagnetic spectrum. Their very high spectral resolution facilitates fine discrimination between different targets based on their spectral response in each of the narrow bands.

1.4.3 Radiometric Resolution

While the arrangement of pixels describes the spatial structure of an image, the radiometric characteristics describe the actual information content in an image. Every time an image is acquired on film or by a sensor, its sensitivity to the magnitude of the electromagnetic energy determines the **radiometric resolution**. The radiometric resolution of an imaging system describes its ability to discriminate very slight differences in energy The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy. Imagery data are represented by positive digital numbers which vary from 0 to (one less than) a selected power of 2. This range corresponds to the number of bits used for coding numbers in binary format. Each bit records an exponent of power 2 (e.g. 1 bit=2 1=2). The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded. Thus, if a sensor used 8 bits to record the data, there would be 28=256 digital values available, ranging from 0 to 255. However, if only 4 bits were used, then only 24=16 values ranging from 0 to 15 would be available. Thus, the radiometric resolution would be much less. Image data are generally displayed in a range of grey tones, with black representing a digital number of 0 and white representing the maximum value (for example, 255 in 8-bit data). By **comparing a 2-bit image with an 8-bit image**, we can see that there is a large difference in the level of detail discernible depending on their radiometric resolutions.

1.4.4 Temporal Resolution

In addition to spatial, spectral, and radiometric resolution, the concept of ***temporal resolution*** *is also important to consider in a remote sensing system. We alluded to this idea in section 2.2 when we discussed the concept of revisit period, which refers to the length of time it takes for a satellite to complete one entire orbit cycle. The revisit period of a satellite sensor is usually several days. Therefore the absolute temporal resolution of a remote sensing system to image the exact same area at the same viewing angle a second time is equal to this period. However, because of some degree of overlap in the imaging swaths of adjacent orbits for most satellites and the increase in this overlap with increasing latitude, some areas of the Earth tend to be re-imaged more frequently. Also, some satellite systems are able to* ***point their sensors to image the same area*** *between different satellite passes separated by periods from one to five days. Thus, the actual temporal resolution of a sensor depends on a variety of factors, including the satellite/sensor capabilities, the swath overlap, and latitude. The ability to collect imagery of the same area of the Earth's surface at different periods of time is one of the most important elements for applying remote sensing data. Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing* ***multi-temporal*** *imagery. For example, during the growing season, most species of vegetation are in a continual state of change and our ability to monitor those subtle changes using remote sensing is dependent on when and how frequently we collect imagery. By imaging on a continuing basis at different times we are able to monitor the changes that take place on the Earth's surface, whether they are naturally occurring (such as changes in natural vegetation cover or flooding) or induced by humans (such as urban development or deforestation). The time factor in imaging is important when:*

persistent clouds offer limited clear views of the Earth's surface (often in the tropics) short-lived phenomena (floods, oil slicks, etc.) need to be imaged multi-temporal comparisons are required (e.g. the spread of a forest disease from one *year to the next) the changing appearance of a feature over time can be used to distinguish it from near similar features (wheat / maize)*

1.5 Summary

The unit begins with an introduction to remote sensing and its basic concepts. The electromagnetic spectrums being the key component have been elaborately discussed. We also learned about the various techniques of satellite remote sensing along with understanding the satellite remotely sensed data components. The resolution of a satellite remote sensing data and its various types has also been covered here.

1.6 Glossary

Bands- *A set of adjacent wavelengths or frequencies with a common characteristic. For example, visible light is one band of the electromagnetic spectrum, which also includes radio, gamma, radar and infrared waves.*

Electromagnetic- *The object / wavelength associated with electric and magnetic fields and their interactions with each other and with electric charges and currents.*

Radar- *Acronym for radio detection and ranging. A device or system that detects surface features on the earth by bouncing radio waves off them and measuring the energy reflected back.*

Radiometric- The sensitivity of a sensor to incoming reflectance

Radiation- *The emission and propagation of energy through space in the form of waves. Electromagnetic energy and sound are examples of radiation.*

Resolution- *The detail with which a map depicts the location and shape of geographic features. The larger the map scale, the higher the possible resolution. As scale decreases, resolution diminishes and feature boundaries must be smoothed, simplified, or not shown at all; for example, small areas may have to be represented as points.*

Sensors- *An electronic device for detecting energy, whether emitted or radiated, and converting it into a signal that can be recorded and displayed as numbers or as an image.Spatial- Related to or existing within space*

Spectral- *of, pertaining to, or produced by a spectrum, or the visible light*

Spectrum- *an array of entities, as light waves or particles, ordered in accordance with the magnitudes of a common physical property, as wavelength or mass: often the band of colors produced when sunlight is passed through a prism, comprising red, orange, yellow, green, blue, indigo, and violet.*

Temporal- *pertaining to or concerned with the objects/phenomenon of the present time in comparison with the same of the past time.*

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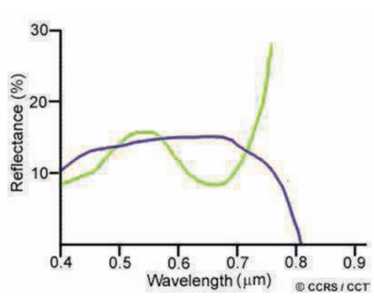
1.9 Terminal Questions

1. *Give a diagrammatic illustration of what is remote sensing.*

2. *What is EMS? Approximately what is the visible range in EMS?*

3. *What is atmospheric window? Why is it important in remote sensing?*

4. *What is a spectral signature?*



5. *Which are the two objects whose reflectance is shown in the picture. Explain why they are so different.*

6. *What are the three different types of resolutions? What do you understand by high resolution & low resolution?*

7. *Which type of resolution is characterized by the wavelength? Explain briefly.*

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UNIT 2: SATELLITES AND SENSORS

2.1 Introduction

2.2 Platforms

2.3 Satellite Remote Sensing

2.3.1 GOES

2.3.2 Landsat Missions

2.3.3 SPOT

2.3.4 Radarsat

2.3.5 Sensors Used In Indian Satellites

2.4 Summary

2.5 Glossary

2.6 References

2.7 Suggested Readings

2.8 Terminal Questions

2.1 Introduction

In order for a sensor to collect and record energy reflected or emitted from a target or surface, it must reside on a stable ***platform*** *removed from the target or surface being observed. Platforms for remote sensors may be situated on the ground, on an aircraft or balloon (or some other platform within the Earth's atmosphere), or on a spacecraft or satellite outside of the Earth's atmosphere.*

2.2 Platforms

Ground-based sensors *are often used to record detailed information about the surface which is compared with information collected from aircraft or satellite sensors. In some cases, this can be used to better characterize the target which is being imaged by these other sensors, making it possible to better understand the information in the imagery.*

Fig. 1.1: Ground-based sensors

Sensors may be placed on a ladder, scaffolding, tall building, cherry-picker, crane, etc. Aerial platforms are primarily stable wing ***aircraft****, although helicopters are occasionally used. Aircraft are often used to collect very detailed images and facilitate the collection of data over virtually any portion of the Earth's surface at any time.*

Fig. 1.2: Space shuttle

In space, remote sensing is sometimes conducted from the ***space shuttle*** *or, more commonly, from satellites.* ***Satellites*** *are objects which revolve around another object - in this case, the Earth. For example, the moon is a natural satellite, whereas man-made satellites include those platforms launched for remote sensing, communication, and telemetry (location and navigation) purposes. Because of their orbits, satellites permit repetitive coverage of the Earth's surface on a continuing basis. Cost is often a significant factor in choosing among the various platform options.*

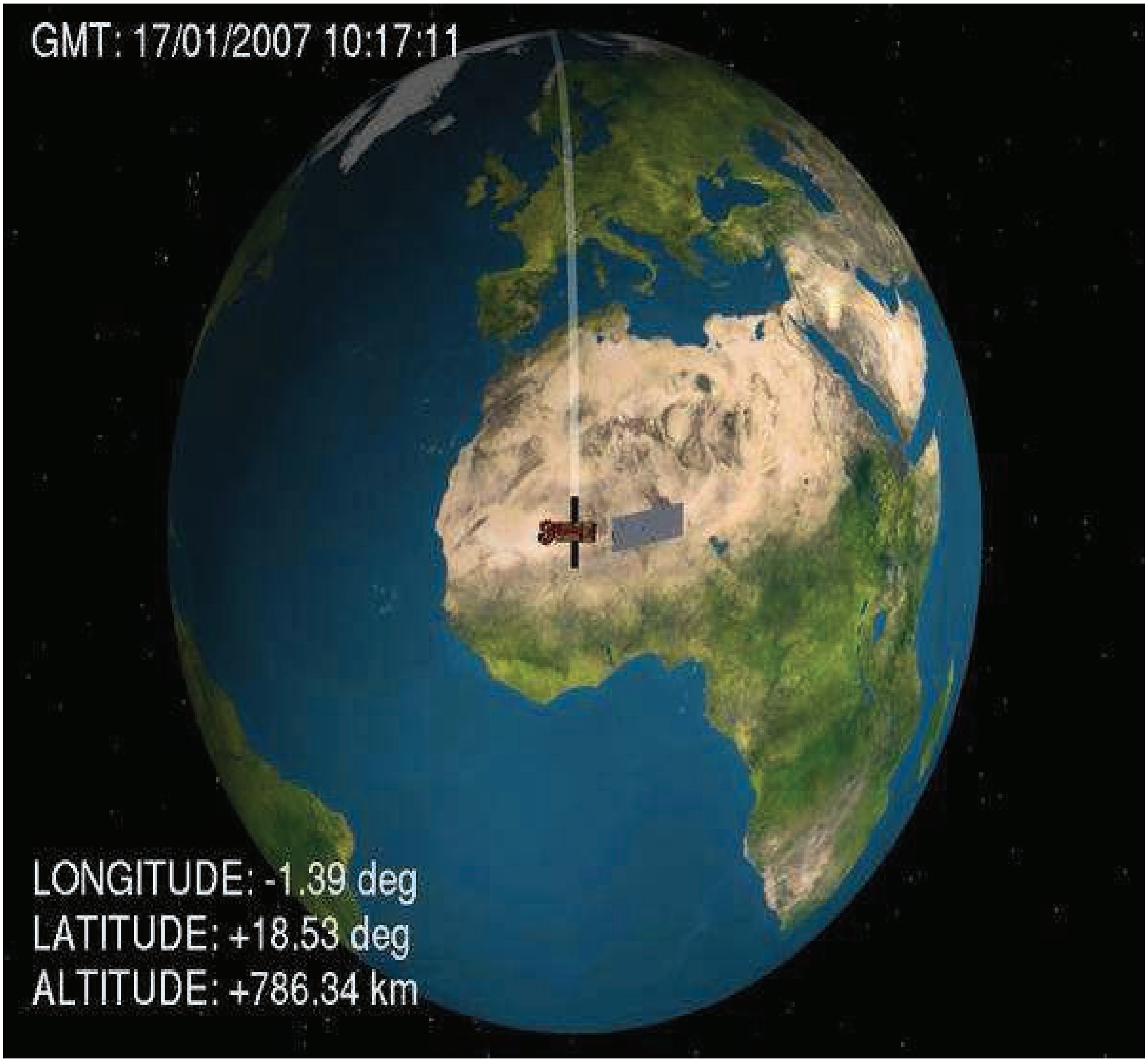

Fig. 1.3(a): Coverage of the Earth's surface

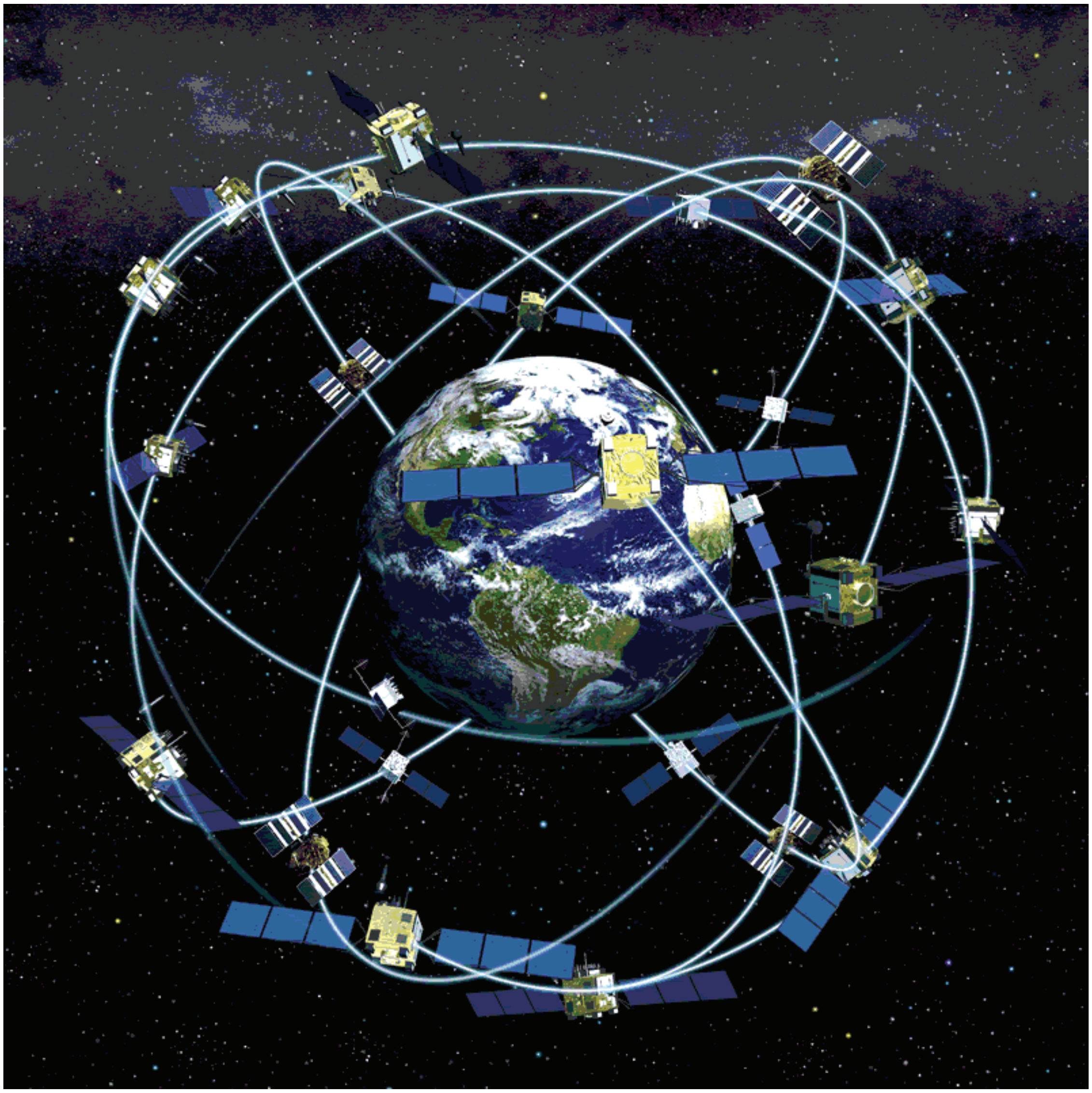

Fig. 1.3(b): Coverage of the Earth's surface

2.3 Satellite Remote Sensing

In the 1960s, a revolution in remote sensing technology began with the deployment of space satellites. From their high vantage-point, satellites have a greatly extended view of the Earth's surface. The first meteorological satellite, TIROS-1, was launched by the United States using an Atlas rocket on April 1, 1960. This early weather satellite used vidicon cameras to scan wide areas of the Earth's surface. Early satellite remote sensors did not use conventional film to produce their images. Instead, the sensors digitally capture the images using a device similar to a television camera. Once captured, this data is then transmitted electronically to receiving stations found on the Earth's surface. The image below is from TIROS-7 of a mid-latitude cyclone off the coast of New Zealand.

Fig. 1.4: TIROS-1 satellite (NASA)

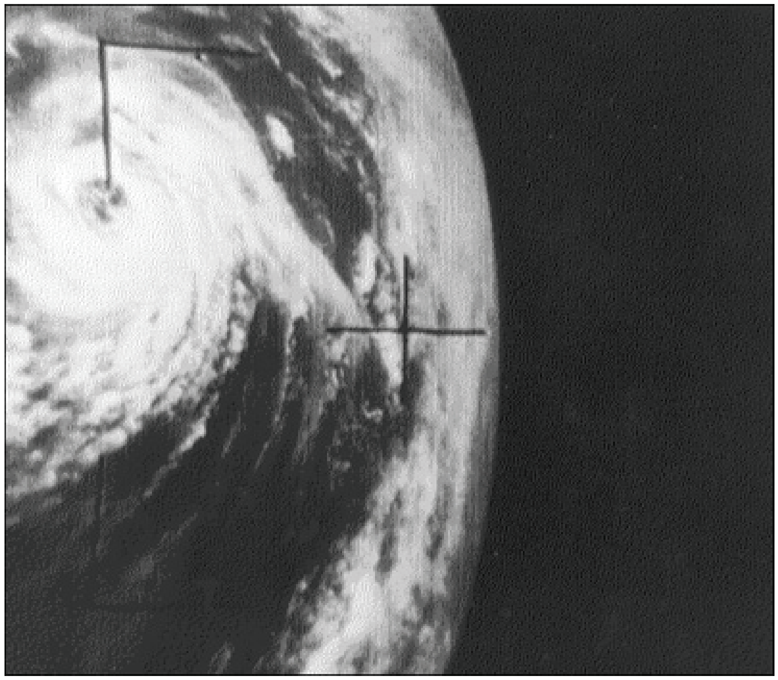

Fig. 1.5: TIROS-7 image of a mid-latitude cyclone off the coast of New Zealand, August 24, 1964

2.3.1 GOES

Today, the GOES (Geostationary Operational Environmental Satellite) system of satellites provides most of the remotely sensed weather information for North America. To cover the complete continent and adjacent oceans two satellites are employed in a geostationary orbit. The western half of North America and the eastern Pacific Ocean is monitored by GOES-10, which is directly above the equator and 135° West longitude. The eastern half of North America and the western Atlantic are cover by GOES-8. The GOES-8 satellite is located overhead of the equator and 75° West longitude. Advanced sensors aboard the GOES satellite produce a continuous data stream so images can be viewed at any instance. The imaging sensor produces visible and infrared images of the

Earth's terrestrial surface and oceans. Infrared images can depict weather conditions even during the night. Another sensor aboard the satellite can determine vertical temperature profiles, vertical moisture profiles, total perceptible water, and atmospheric stability.

Fig. 1.6: Color image from GOES-8 of hurricanes Madeline and Lester off the coast of Mexico, October 17, 1998. (Source: NASA - Looking at Earth From Space).

2.3.2 Landsat Missions

In the 1970s, the second revolution in remote sensing technology began with the deployment of the Landsat satellites. Since this 1972, several generations of Landsat satellites with their Multispectral_Scanners (MSS) have been providing continuous coverage of the Earth for almost 30 years. Current, Landsat satellites orbit the Earth's *surface at an altitude of approximately 700 kilometers. Spatial resolution of objects on the ground surface is 79 x 56 meters. Complete coverage of the globe requires 233 orbits and occurs every 16 days. The Multispectral Scanner records a zone of the Earth's surface that is 185 kilometers wide in four wavelength bands: band 4 at 0.5 to 0.6 micrometers, band 5 at 0.6 to 0.7 micrometers, band 6 at 0.7 to 0.8 micrometers, and band 7 at 0.8 to 1.1 micrometers. Bands 4 and 5 receive the green and red wavelengths in the visible light range of the electromagnetic spectrum. The last two bands image near-infrared wavelengths. A second sensing system was added to Landsat satellites launched after 1982. This imaging system, known as the Thematic_Mapper, records seven wavelength bands from the visible to far-infrared portions of the electromagnetic spectrum. In addition, the ground resolution of this sensor was enhanced to 30 x 20 meters. This modification allows for greatly improved clarity of imaged objects.*

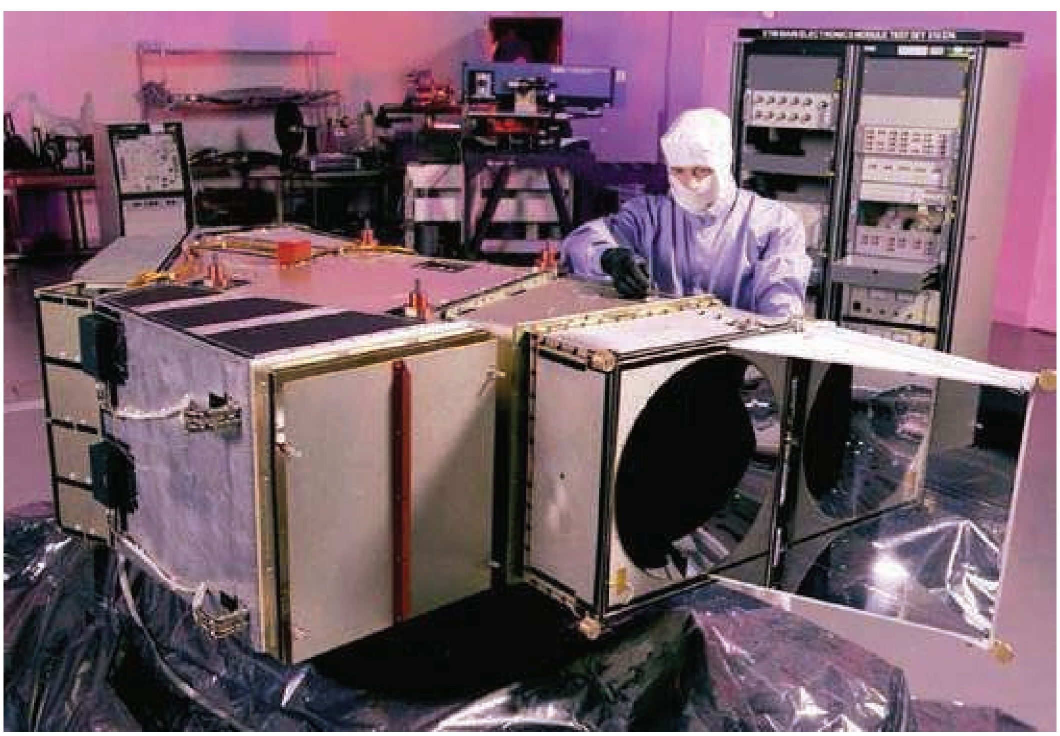

Fig. 1.7: The Landsat 7 enhanced Thematic Mapper instrument

2.3.3 SPOT

The usefulness of satellites for remote sensing has resulted in several other organizations launching their own devices. In France, the SPOT (Satellite Pour l'Observation de la Terre) satellite program has launched five satellites since 1986. Since 1986, SPOT satellites have produced more than 10 million images. SPOT satellites use two different sensing systems to image the planet. One sensing system produces black and white panchromatic images from the visible band (0.51 to 0.73 micrometers) with a ground resolution of 10 x 10 meters. The other sensing device is multispectral capturing green, red, and reflected infrared bands at 20 x 20 meters. SPOT-5, which was launched in 2002, is much improved from the first four versions of SPOT satellites. SPOT-5 has a maximum ground resolution of 2.5 x 2.5 meters in both panchromatic mode and multispectral operation.

Fig. 1.8: SPOT false-color image of the southern portion of Manhatten Island and part of Long Island, New York. The bridges on the image are (left to right): Brooklyn Bridge, Manhattan Bridge, and the Williamsburg Bridge. (Source: SPOT Image).

2.3.4 Radarsat

Radarsat-1 was launched by the Canadian Space Agency in November, 1995. As a remote sensing device, Radarsat is quite different from the Landsat and SPOT satellites. Radarsat is an active remote sensing system that transmits and receives microwave radiation. Landsat and SPOT sensors passively measure reflected radiation at wavelengths roughly equivalent to those detected by our eyes. Radarsat's microwave energy penetrates clouds, rain, dust, or haze and produces images regardless of the Sun's illumination allowing it to image in darkness. Radarsat images have a resolution between 8 to 100 meters. This sensor has found important applications in crop monitoring, *defence surveillance, disaster monitoring, geologic resource mapping, sea-ice mapping and monitoring, oil slick detection, and digital elevation modeling.*

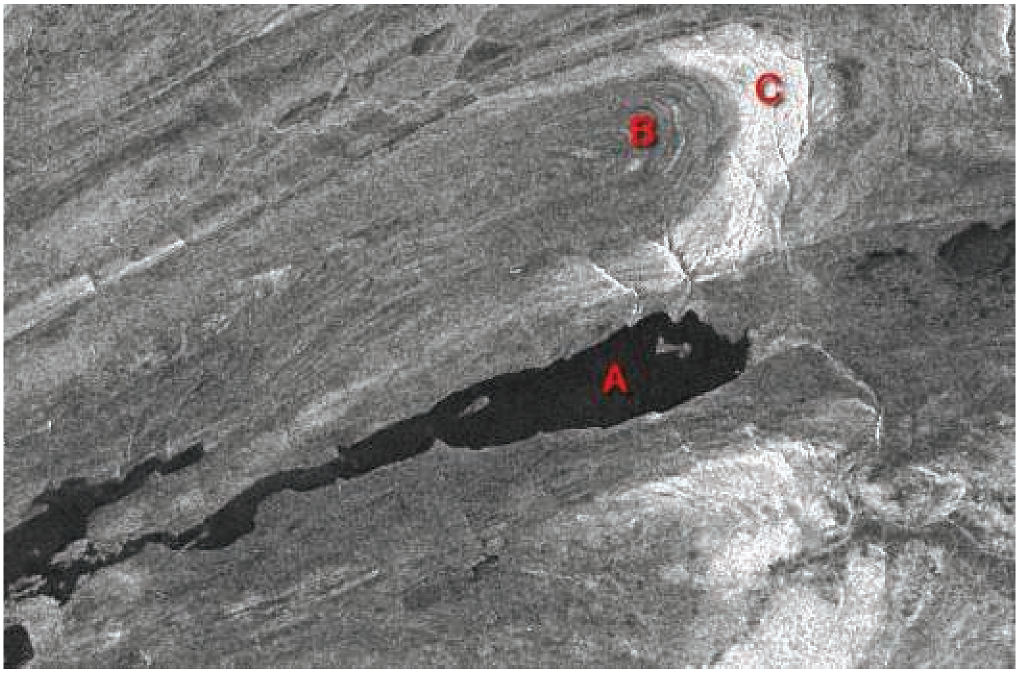

Fig. 1.9: Radarsat image acquired on March 21, 1996, over Bathurst Island in Nunavut, Canada.

This image shows Radarsat's ability to distinguish different types of bedrock. The light shades on this image (C) represent areas of limestone, while the darker regions (B) are composed of sedimentary siltstone. The very dark area marked A is Bracebridge Inlet which joins the Arctic ocean. (Source:Canadian Centre for Remote Sensing - Geological Mapping Bathurst Island, Nunavut, Canada March 21, 1996).

2.3.5 Sensors Used In Indian Satellites

A list of the sensors that have been used in Indian Remote Sensing satellites:

Satellite Microwave Radiometer (SAMIR) *SAMIR was the payload for BHASKAR I and II satellites launched in 1979 and 1981. They sucessfully provided data on the sea surface temperature, ocean winds, moisture content over the land and sea. It was a dicke type radiometer with a temperature resolution better than 1 degree kelvin.*

Two Band T.V. Payload

The Bhaskara satellites I and II *had a two band TV payload for land applications. It gave images of earth from a height of 525 Km. The data were used in meterology, hydrology, and forestry.*

Smart Sensor Rohini Rs-D2*, (the sucessor to the failed Rs-D1) was launched on Apr. 1983. It carried a Smart sensor, which was a 2-Band solid-state device. It had the first CCD camera developed in house.*

LISS-I, II and III

LISS-I (Linear Imaging self Scanner) was a payload for the IRS-1A satellite. This camera operated in four spectral bands. It operated in a push-broom scanning mode using a CCD array. It was again used in IRS-1B. It used 7 bit quantization, and had a swath of 148 Kms. Images of LISS-I were extensively used in forestry, crop acreage, yield estimation, drought monitoring, flood monitoring etc.

LISS-II was similar to LISS-I, but with higher spatial resolution and smaller swath. it was on payload in three satellites : IRS-1A, IRS-1B, IRS-P2.

LISS-III is onboard two satellites IRS-1C and IRS-1D. This is a multi-spectral camera which operates in four bands. It provides color images. Its images were used widely in the area of agriculture, mapping, crop acreage etc.

The Panchromatic Camera

This was carried by IRS-1c and IRS-1D satellites. Pan camera enables the acquisition of images at the resolution of 5.8m, which was the highest resolution offered by a civilian satellite until recently, when American satellite Ikonos with a resolution of 1m surpassed it. The Pan camera uses CCD's to capture images.

Wide Field Sensor

IRS-1C, IRS-1D, IRS-P3, which are all second generation Indian remote sensing satellites, carried the WIFS sensor. The WIFS camera uses an 8 element refractive optics like in LISS-III. Two such cameras are mounted with overlapping pixels of imaging. WIFS data was used in assesment of rabi cropped area, crop inventory, observation of crop phenology etc.

Ocean Color Monitor

IRS-P4, also called Oceansat, carried the ocean color monitor, launched on board PSLV-C1. This payload is meant for oceanographic applications. The OCM is a solid state camera operating in the push-broom scanning mode, using linear array CCD'S as detectors for generating ocean biological parameters.

Very High Resolution RadioMeter

All the INSAT-1 and the INSAT-2, INSAT-3 series communications satellites carry the VHRR to provide various remote sensing applications. Since INSAT satellites are geostationary, VHRR provides round the clock meteorological earth observations, disaster warning signals.

2.4 Summary

This unit begins with an introduction the various platforms available for remote sensing. The most widely used satellites and sensors have been covered here. The Indian satellites and the type of data it provides have also been illustrated.

2.5 Glossary

Aerial- *operating on a track or cable elevated above the ground*

Band- *A set of adjacent wavelengths or frequencies with a common characteristic. For example, visible light is one band of the electromagnetic spectrum, which also includes radio, gamma, radar and infrared waves.*

Satellite- *a device designed to be launched into orbit around the earth, another planet, the sun,*

using an earth-orbiting satellite to transmit communications signals

Sensor- *An electronic device for detecting energy, whether emitted or radiated, and converting it into a signal that can be recorded and displayed as numbers or as an image.*

Geostationary- *Positioned in an orbit above the earth's equator with an angular velocity the same as that of the earth and an inclination and eccentricity approaching zero. A geostationary satellite will orbit as fast as the earth rotates on its axis, so that it remains effectively stationary above a point on the equator. A geostationary satellite is geosynchronous, but geosynchronous satellites are not necessarily geostationary.*

Mulitspectral- *Related to two or more frequencies or wavelengths in the electromagnetic spectrum.*

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2.8 Terminal Questions

1. *What is the difference between a satellite, sensor and platform?*
2. *Name 5 satellites with sensors.*
3. *Name one active remote sensing satellite. What kind of information can be derived from this satellite data?*
4. *LISS III is the sensor of which satellite? How many bands are there in LISS III? Name a few uses of this multispectral data.*
5. *What is the full form of WIFS? Name two use of WIFS data.*

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UNIT 3: GPS: GLOBAL POSITIONING SYSTEM

3.1. Introduction

3.2. Concepts of GPS

3.3. Types of GPS

3.3.1 Components of a GPS Instrumentation

3.3.2 Primary GPS terms

3.4. GPS Errors and Correction

3.4.1 The effect and correction of time error

3.4.2 Satellite geometry

3.4.3 Multipath effect

3.4.4 Atmospheric effects

3.4.5 Clock inaccuracies and rounding errors

3.4.6 Relativistic effects

3.5. Application of GPS

3.6. Summary

3.7. Glossary

3.8. References

3.9. Suggested Readings

3.10. Terminal Questions

3.1 Introduction

Global Positioning System (GPS) technology is a great boon to anyone who has the need to navigate either great or small distances. This wonderful navigation technology was actually first available for government use back in the late 1970s. In the past ten or so years, It has been made available to the general public in the form of handheld receivers that use this satellite technology provided by the U.S. government.

GPS formally known as the NAVSTAR (Navigation Satellite Timing and Ranging) Global Positioning System, originally was developed for the military. Because of its popular navigation capabilities and because you can access GPS technology using small inexpensive equipment, the government mad the system available for civilian use. The USA owns GPS technology and the Department of Defense maintains it. The first satellite was placed in orbit on 22nd February 1978, and there are currently 28 operational satellites orbiting the Earth at a height of 20,180 km on 6 different orbital planes. Their orbits are inclined at 55° to the equator, ensuring that at least 4 satellites are in radio communication with any point on the planet. Each satellite orbits the Earth in approximately 12 hours and has four atomic clocks on board. During the development of the GPS system, particular emphasis was placed on the following three aspects:

1. *It had to provide users with the capability of determining position, speed and time, whether in motion or at rest.*
2. *It had to have a continuous, global, 3-dimensional positioning capability with a high degree of accuracy, irrespective of the weather.*
3. *It had to offer potential for civilian use.*

GPS has also demonstrated a significant benefit to the civilian community who are applying GPS to a rapidly expanding number of applications. What attracts us to GPS is:

1. *The relatively high positioning accuracies, from tens of meters down to the millimeter level.*

2. *The capability of determining velocity and time, to an accuracy commensurate with position.*

3. *The signals are available to users anywhere on the globe: in the air, on the ground, or at sea.*

4. *Its is a positioning system with no user charges, that simply requires the use of relatively low cost hardware.*

5. *It is an all-weather system, available 24 hours a day.*

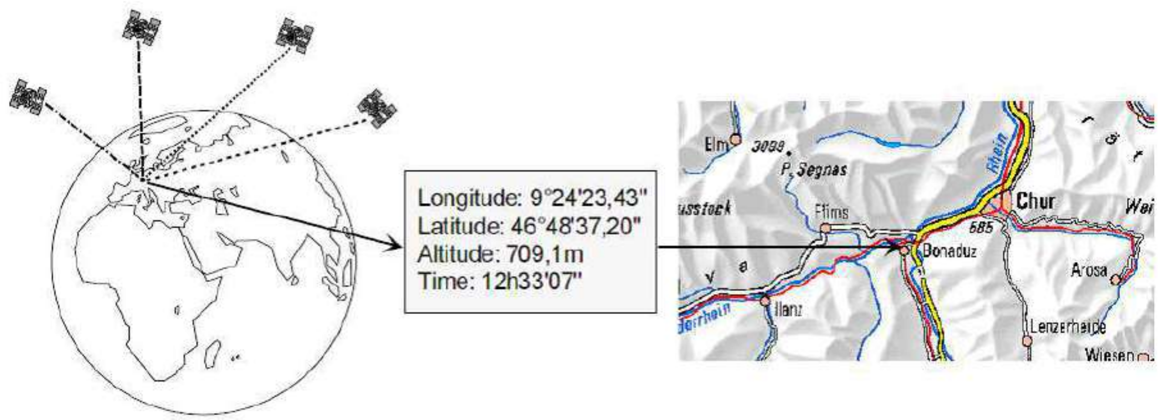
6. *The position information is in three dimensions, that is, vertical as well as horizontal information is provided*

Using the Global Positioning System (GPS, a process used to establish a position at any point on the globe) the following two values can be determined anywhere on Earth:

1. *One's exact location (longitude, latitude and height co-ordinates) accurate to within a range of 20 m to approx. 1 mm.*

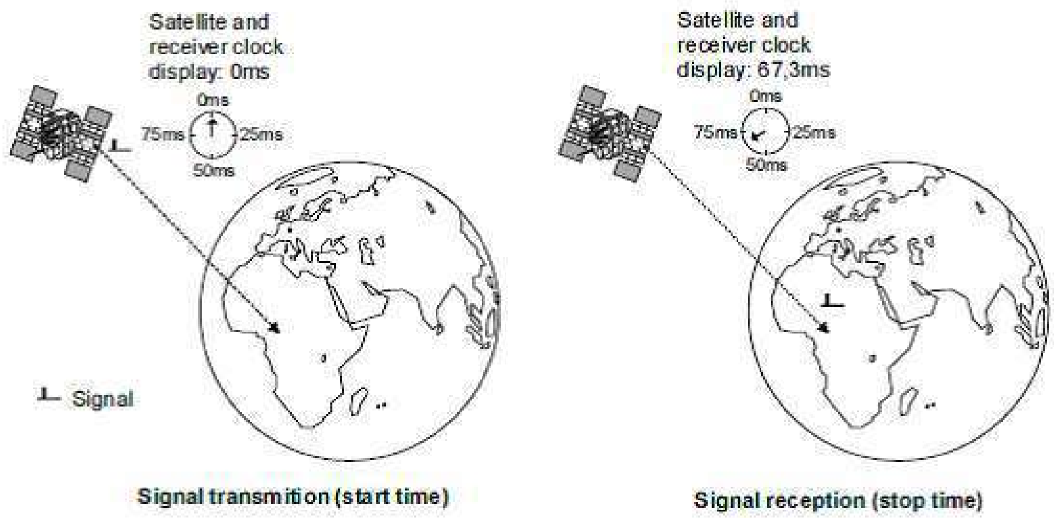
2. *The precise time (Universal Time Coordinated, UTC) accurate to within a range of 60ns to approx. 5ns.*

Speed and direction of travel (course) can be derived from these co-ordinates as well as the time. The coordinates and time values are determined by 28 satellites orbiting the Earth.



3.2 Concepts of GPS

Generating GPS signal transit time 28 satellites inclined at 55° to the equator orbit the Earth every 11 hours and 58 minutes at a height of 20,180 km on 6 different orbital planes (Figure 3). Each one of these satellites has up to four atomic clocks on board. Atomic clocks are currently the most precise instruments known, losing a maximum of one second every 30,000 to 1,000,000 years. In order to make them even more accurate, they are regularly adjusted or synchronised from various control points on Earth. Each satellite transmits its exact position and its precise on board clock time to Earth at a frequency of 1575.42 MHz. These signals are transmitted at the speed of light (300,000 km/s) and therefore require approx. 67.3 ms to reach a position on the Earth's surface located directly below the satellite. The signals require a further 3.33 us for each excess kilometer of travel. If you wish to establish your position on land (or at sea or in the air), all you require is an accurate clock. By comparing the arrival time of the satellite signal with the on board clock time the moment the signal was emitted, it is possible to determine the transit time of that signal (Figure 4).



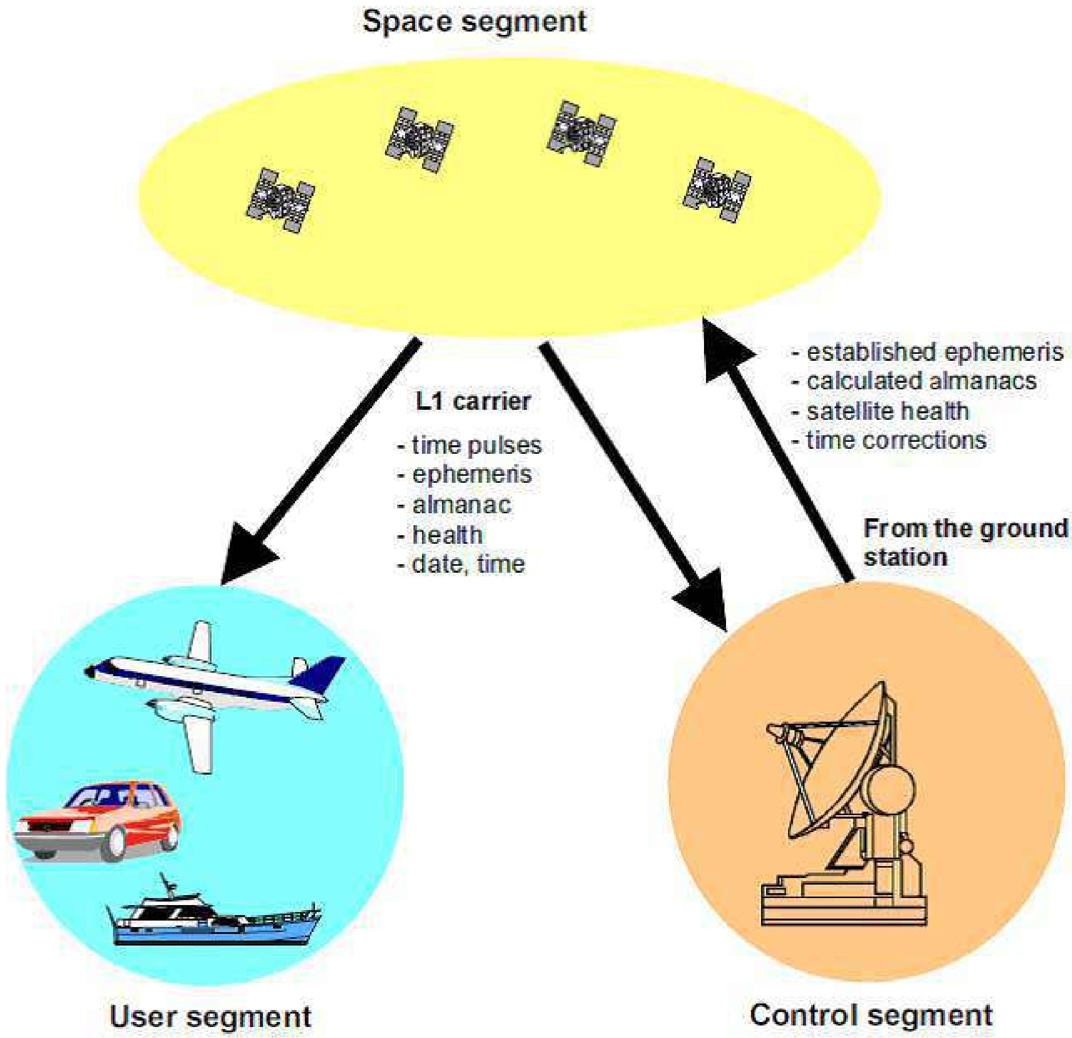
The distance S to the satellite can be determined by using the known transit time τ:

distance travel time x the speed of light

S =τ x c

Measuring signal transit time and knowing the distance to a satellite is still not enough to calculate one's own position in 3-D space. To achieve this, four independent transit time measurements are required. It is for this reason that signal communication with four different satellites is needed to calculate one's exact position. Why this should be so, can best be explained by initially determining one's position on a plane.

3.2.1 GPS system elements



The GPS system consists of three segments. (Good general references on the GPS system are) :

*• The **Space Segment**: comprising the satellites and the transmitted signals.*

*• The **Control Segment**: the ground facilities carrying out the task of satellite tracking, orbit computations, telemetry and supervision necessary for the daily control of the space segment.*

• *The* ***User Segment****: the entire spectrum of applications equipment and computational techniques that are available to the users.*

The Space Segment consists of the constellation of spacecraft and the signals broadcast by them

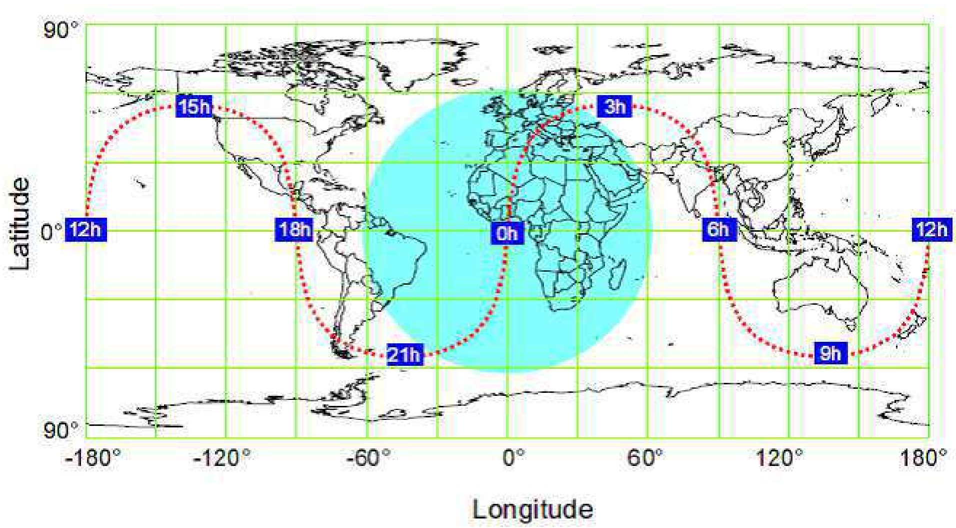
which allow users to determine position, velocity and time. The basic functions of the satellites are to:

• *Receive and store data transmitted by the Control Segment stations.*

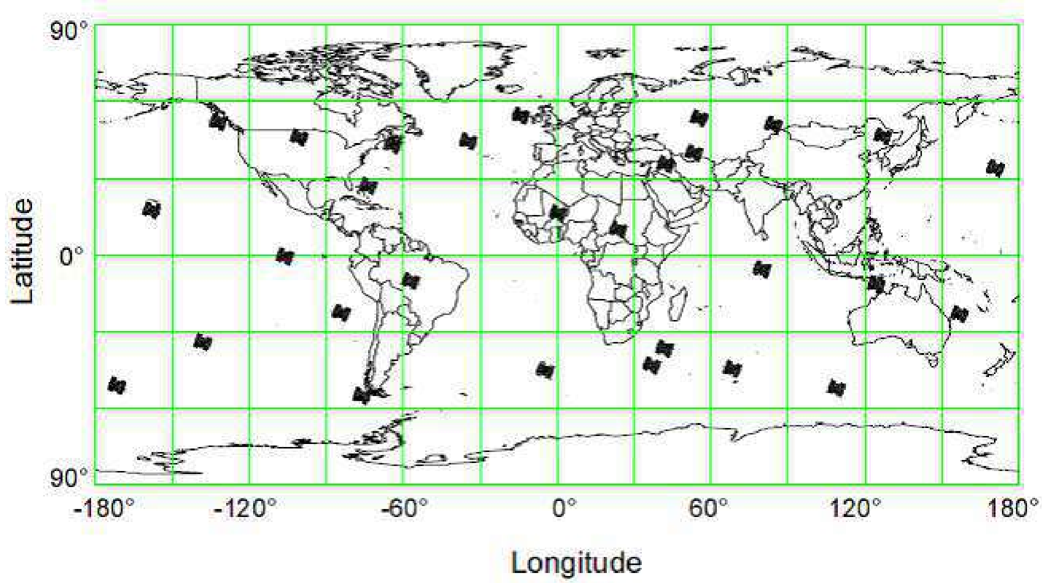
• *Maintain accurate time by means of several onboard atomic clocks.*

• *Transmit information and signals to users on two L-band frequencies.*

• *Provide a stable platform and orbit for the L-band transmitters.*



Satellite signals can be received anywhere within a satellite's effective range. The effective range (shaded area) of a satellite located directly above the equator/zero meridian intersection. The distribution of the 28 satellites at any given time can be seen. It is due to this ingenious pattern of distribution and to the great height at which they orbit that communication with at least 4 satellites is ensured at all times anywhere in the world.



ure 10: Position of the 28 GPS satellites at 12.00 hrs UTC on 14th April 2001

3.2.2 Control segment

The control segment (Operational Control System OCS) consists of a Master Control Station located in the state of Colorado, five monitor stations equipped with atomic clocks that are spread around the globe in the vicinity of the equator, and three ground control stations that transmit information to the satellites.

The most important tasks of the control segment are:

- *Observing the movement of the satellites and computing orbital data (ephemeris)*
- *Monitoring the satellite clocks and predicting their behaviour*
- *Synchronising on board satellite time*
- *Relaying precise orbital data received from satellites in communication*
- *Relaying the approximate orbital data of all satellites (almanac)*
- *Relaying further information, including satellite health, clock errors etc.*

The control segment also oversees the artificial distortion of signals (SA, Selective Availability), in order to degrade the system's positional accuracy for civil use. System accuracy had been intentionally degraded up until May 2000 for political and tactical reasons by the U.S. Department of Defense (DoD), the satellite operators. It was shut down in May 2000, but it can be started up again, if necessary, either on a global or regional basis.

3.2.3 User segment

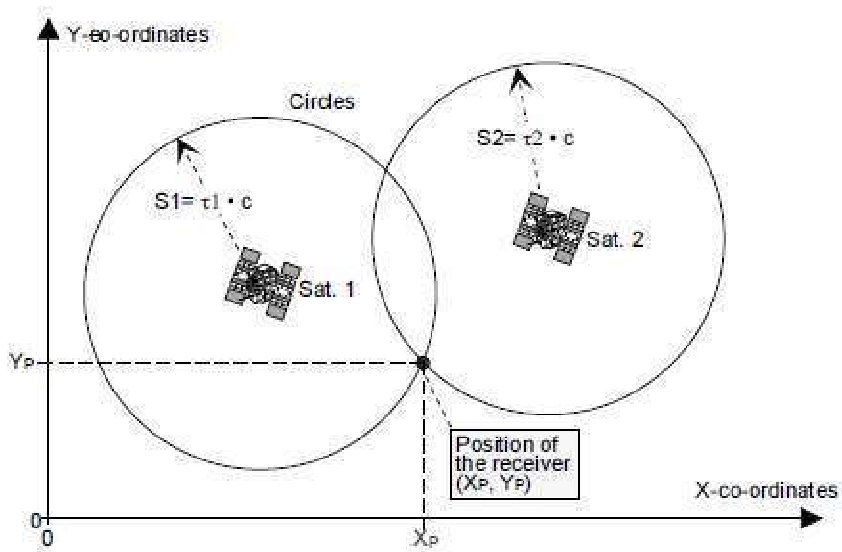
The signals transmitted by the satellites take approx. 67 milliseconds to reach a receiver. As the signals travel at the speed of light, their transit time depends on the distance between the satellites and the user.

Four different signals are generated in the receiver having the same structure as those received from the 4 satellites. By synchronising the signals generated in the receiver with those from the satellites, the four satellite signal time shifts Δt are measured as a timing mark.

3.2.4 Determining a position on a plane

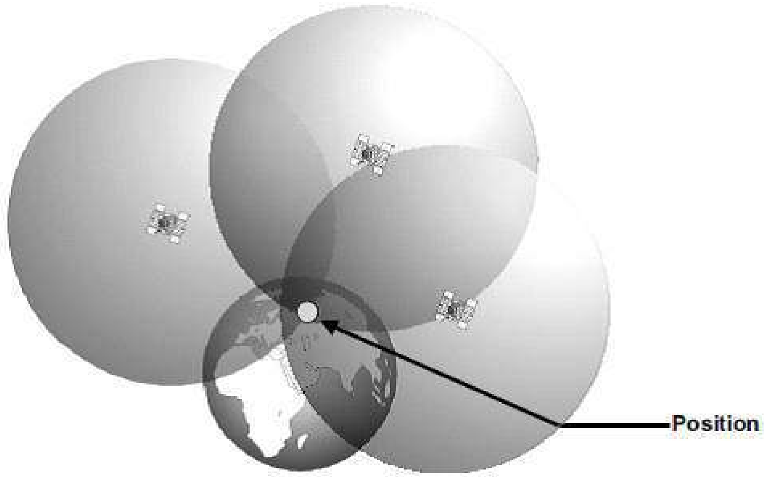
Imagine that you are wandering across a vast plateau and would like to know where you are. Two satellites are orbiting far above you transmitting their own on board clock times and positions. By using the signal transit time to both satellites you can draw two circles with the radii S1 and S2 around the satellites. Each radius corresponds to the distance calculated to the satellite. All possible distances to the satellite are located on the circumference of the circle. If the position above the satellites is excluded, the location of the receiver is at the exact point where the two circles intersect beneath the satellites.

Two satellites are sufficient to determine a position on the X/Y plane.



In reality, a position has to be determined in three-dimensional space, rather than on a plane. As the difference between a plane and three-dimensional space consists of an extra dimension (height Z), an additional third satellite must be available to determine the true position. If the distance to the three satellites is known, all possible positions are located on the surface of three spheres whose radii correspond to the distance calculated.

The position sought is at the point where all three surfaces of the spheres intersect.



All statements made so far will only be valid, if the terrestrial clock and the atomic clocks on board the satellites are synchronised, i.e. signal transit time can be correctly determined.

3.3 Types of GPS

Google Earth and Google Maps are made to work with GPS data

Many services allow you to upload your GPS tracks and waypoints to Google Earth. Others also let you upload your photos and even geo-reference them for you, so they are projected exactly on the spots where they have been taken.

Hybrid GeoTools *make custom and standard software to extend the functionality of popular geographic tools such as Google Earth.*

Hybrid GeoTools' **Active GPX Route Player** *for Google Earth. The "Media Player" of GPS playback. Simple to use yet endlessly customizable, up to 50 routes can be played back at the same time. Adjust time, speed scale, viewing behavior, track and icon appearance and watch progress against an altitude profile. Every turn, acceleration and stop is faithfully recreated.*

New in Version 1.1 - Virtual Cyclist - Set the power, weight, aerodynamics and see how you'd perform on the climbs of the Tour de France.

Hybrid GeoTools' ***3D Route Builder*** *is a GPS Editor for Google Earth. It offers fine grain control of routes directly in Google Earth not only in terms of positioning and altitude but also in time. Easily shift and scale time, correct barometric drift, synch to video files and build accurate GPS (GPX), KML/KMZ and Garmin TCX files from scratch or from existing files. Playback routes in real-time and optionally with absolute altitude - that means tunnels, bridges, cable car rides and flights take on new levels of realism.*

3dtracking *Ltd has just launched a new range of completely free GPS services through their website http://www.3dtracking.net. Simply put, through using your mobile phone or PDA, along with your GPS receiver, you can record and view your movements in detail on Google Earth or Google Maps. You can even use the free service for live tracking using Google Earth or Google Maps. Download of the required 3dtracking GPS software application, as well as use of the website, is completely free (and there are no future* *plans to charge for this either. Ever). The web server also retains all the data you've ever recorded and submitted, so you can always go back and view your older recorded data at any time.*

Adam Schneider has added Google Maps as an output format in ***GPS Visualizer****. You can upload your GPS data file (in a supported format) and instantly view it in Google Maps. It is also available as an output choice in the other input forms, including the address form.*

Phone2GEarth *is an easy Nokia Series 80 GPS software application that allows to log tracks which are directly saved as Google Earth KML files. New and useful features like: - English, Spanish, German and French languages. - Place marks supported with timestamps in the track. - bluetooth autostart, for easy use. - Complete Series 80: 9300, 9500 - Color and phone name configurable. It allows deferent phones, tracks etc. Requirements: * Series 80 (Symbian) Smartphone (9500, 9300). * GPS Bluetooth (NMEA protocol). * Google Earth (Windows).*

Earth Bridge *is designed to bridge the gap between Google Earth and your GPS receiver. See your location on Google Earth in real-time and easily control your view. Record your track as you move. Earth Bridge GPS software requires an NMEA 0183 compatible GPS device connected via a serial interface.*

GEtrax *is a Windows GPS software application that can.*

Plot various format track files in Google Earth.

GPX

XML

OziExplorer

Raw NMEA data (text)

CSV data (text - one type only)

Plot GPX or OziExplorer format waypoint files in Google Earth (as placemarks).

Read live (NMEA) data from any gps (COM port) and plot location and track in Google Earth.

Read a track file directly from a Garmin gps and plot it in Google Earth.

Put tracks (including live data) on a server and email a recipient for remote viewing.

Save tracks in GoogleMap and OziExplorer format.

Save track and waypoint files as GPX format for archiving.

Read track data from existing KML files.

Read Ham radio tracking data from Findu.com or from a receiver and plot the location and track in Google Earth.

GPS Radar *GPS software from JGUI allows you to use your Windows Mobile*) device for the following reasons:*

- *monitor your localization by GPS receiver.*
- *save the track and points of moving.*
- *generate various XML reports.*
- *upload points to dedicated Internet server.*
- *review your moving on designed web pages with Google Maps streets or satellites images.*
- *generate GoogleEarth current location.*
- *generate GoogleEarth track files.*
- *review your moving directly on GoogleEarth interface screen with all its features.*

This GPS software version works well with any Windows Mobile device with GSM network connection built-in. So called: Phone Edition devices. Any GPS receiver is required.

GPS Track *GPS software connects to a GPS and records the path that you travel. Tracks can be uploaded to a web site, sent by email, transferred via Bluetooth, or written to a flash memory card. Google Maps and Google Earth are used to view the tracks. File formats such as GPX and CSV are also supported. Compatibility: This GPS software requires a cell phone or other mobile device with:*

J2ME (Java 2 mobile edition).

Java API for Bluetooth (JSR-82).

A GPS with Bluetooth is also required.

EveryTrail *is an online platform that enables you to visualize your travel and outdoor activities and share these with like minded people from all over the world. With EveryTrail you can easily upload GPS data you recorded while out on the trail and add your photos and notes, to create a visual record of your outdoor activity. EveryTrail was created by a small group of passionate travel and outdoor enthusiasts, out of dissatisfaction with current solutions to share trips with friends and like minded people.*

3.3.1 Components of a GPS Instrumentation

The following components of a generic GPS receiver can be identified (figure 1.9):

Antenna and Preamplifier: Antennas used for GPS receivers have broadbeam characteristics, thus they do not have to be pointed to the signal source like satellite TV receiving dishes. The antennas are compact and a variety of designs are possible. There is a trend to integrating the antenna assembly with the receiver electronics.

Radio Frequency Section and Computer Processor: The RF section contains the signal processing electronics. Different receiver types use somewhat different techniques to process the signal. There is a powerful processor onboard not only to carry out computations such as extracting the ephemerides and determining the elevation/azimuth of the satellites, etc., but also to control the tracking and measurement function within modern digital circuits, and in some cases to carry out digital signal processing.

Control Unit Interface: The control unit enables the operator to interact with the microprocessor. Its size and type varies greatly for different receivers, ranging from a handheld unit to soft keys surrounding an LCD screen fixed to the receiver "box".

Recording Device: in the case of GPS receivers intended for specialised uses such as the surveying the measured data must be stored in some way for later data processing. In the case of ITS applications such as the logging of vehicle movement, only the GPS-derived coordinates and velocity may be recorded. A variety of storage devices were utilised in the past, including cassette and tape recorders, floppy disks and computer tapes, etc., but these days almost all receivers utilise solid state (RAM) memory or removable memory "cards".

Power Supply: Transportable GPS receivers these days need low voltage DC power. The trend towards more energy efficient instrumentation is a strong one and most GPS receivers operate from a number of power sources, including internal NiCad or Lithium batteries, external batteries such as wet cell car batteries, or from mains power.

3.3.2 Primary GPS terms

TRACK: *This indicates the direction in which you move. Sometimes this is called HEADING. For navigation on land this is OK, but a boat or a plane can travel in another direction, than the direction in which it is headed, due to wind or current.*

TRACKLOG: *This is the electronic equivalent of the famous bread crumb trail. If you turned (automatic) tracklog on, your receiver will, at fixed intervals or at special occasions, save the position, together with the time, to its memory. This can be invaluable if at any moment during your trip you (have to) decide to go back exactly along the route that brought you to your actual position.*

TRACBACK: *Among the best known GPS terms, it is the navigation method that will bring you back to your point of departure along the same trail that you traveled to your actual position. In order to be able to use this method, you may need to copy the tracklog to one of the free track channels. (This is where you need your manual for). Often a saved track can only contain 250 points, but be assured that your GPS receiver will do a wonderful job in choosing the points which best represent your traveled track.*

WAYPOINT: *Probably one of the most used general GPS terms. A waypoint is nothing more or less than a saved set of co-ordinates. It does not have to represent a physical point on land. Even at sea or in the air, one can mark a waypoint. Once saved in your GPS receiver, you can turn back to exactly that set of co-ordinates. You can give waypoints meaningful names. They can be created 'on the fly', which means that you can register them at 130 km/h on the road or even at 800 km/h in a plane. Your GPS will attribute it a number, which you can change to any name you want, once you have the time. You can also manually enter a set of co-ordinates, that you found on a map. This way you can plan ahead a trip or a walk with as much detail as you like.*

Waypoints are very powerful navigation aids and for really critical operations it should be considered to not only store their co-ordinates in your GPS receiver, but also in your paper notebook. After all a highly sophisticated device as a GPS receiver could stop functioning correctly for a lot of reasons.

ROUTE: *A route is a series of two or more waypoints. To create a route, you have to tell your GPS to reserve some place in its memory for a new route and then you indicate which waypoints will form the route. You enter them in the* *order in which you want to travel them, but you can easily navigate them in reverse order. You can add waypoints and delete others, but once saved, the order in which your GPS will guide you along the waypoints is fixed.*

This is a great way to plan ahead a walk. You can even create waypoints and routes on your desktop PC and transfer them to your GPS receiver. All you need for this is a cable which links your GPS to a RS232-port(COM) on your computer and a piece of software, that enables you to mark points on a map at your screen. We will treat this in more detail elsewhere on the site. You will see that this is absolutely not rocket-science.

***ROUTE LEG** is the straight line between two adjacent waypoints in a route.*

***GOTO** is also among the best known GPS terms and probably the most used navigation method with a GPS receiver, because it is easily understood and executed. If you tell your companion that you will GOTO waypoint X, it will calculate the direction and distance from your actual location to the set of co-ordinates, represented by the indicated waypoint. Your GPS receiver is unable to know what obstacles, hazards or whatever, if any, there are between you and waypoint X, so it will guide you in a straight line to the indicated point. This is great on open water or in the air, but on land it is often not the best method.*

***BEARING:** Once you told to which point you want to travel, your GPS will continuously calculate in which direction that point is situated, seen from your actual position. That direction is the bearing. If you navigate along a route, the bearing will be the direction to the NEXT waypoint in the route. If you do or can not travel in a straight line to the waypoint, the bearing will fluctuate all the time.*

***TURN:** This GPS term indicates the difference between the direction you should travel in (BEARING) and the direction in which you are actually traveling (TRACK). An indication of '28L' means that you should modify your actual direction of travel with 28° to the Left, if you wish to ever reach your point. In principle, when you have the reading of TURN on your navigation page, you* *don't need the readings of those other two GPS terms BEARING and TRACK, but most people prefer reading these two.*

3.4 GPS Errors and Correction

3.4.1 The effect and correction of time error

We have been assuming up until now that it has been possible to measure signal transit time precisely. However, this is not the case. For the receiver to measure time precisely a highly accurate, synchronised clock is needed. If the transit time is out by just 1 μs this produces a positional error of 300m. As the clocks on board all three satellites are synchronised, the transit time in the case of all three measurements is inaccurate by the same amount. Mathematics is the only thing that can help us now. We are reminded when producing calculations that if N variables are unknown, we need N independent equations.

If the time measurement is accompanied by a constant unknown error, we will have four unknown variables in

3-D space:

- *longitude (X)*
- *latitude (Y)*
- *height (Z)*
- *time error (Δt)*

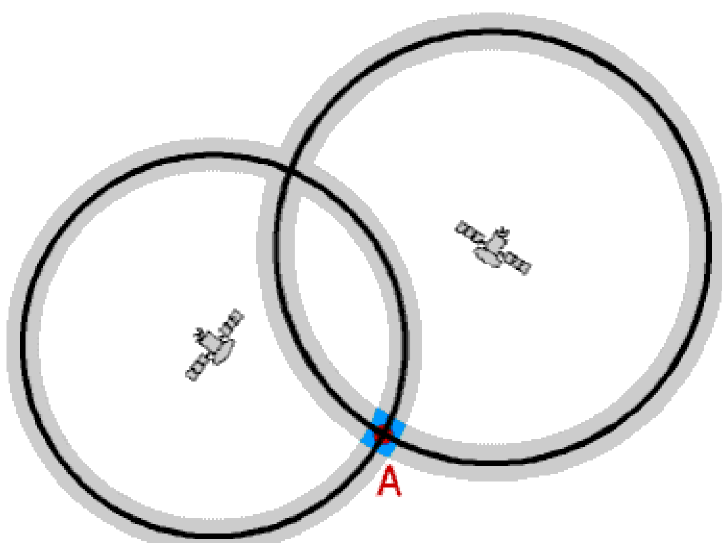
It therefore follows that in three-dimensional space four satellites are needed to determine a position.

3.4.2 Satellite geometry

Another factor influencing the accuracy of the position determination is the "satellite geometry". Simplified, satellite geometry describes the position of the satellites to each other from the view of the receiver.

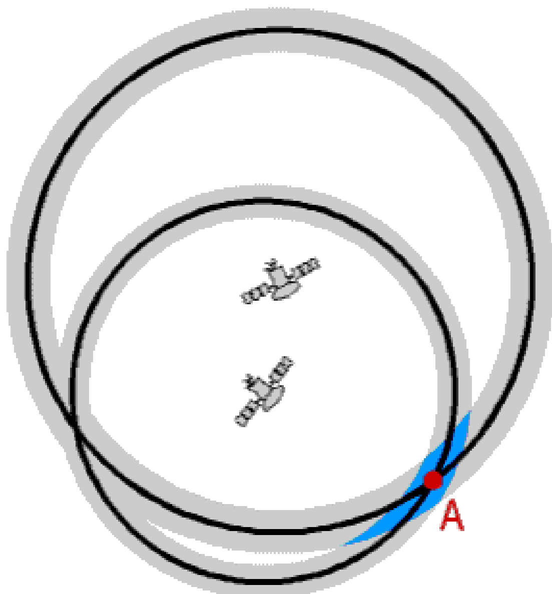
If a receiver sees 4 satellites and all are arranged for example in the north-west, this leads to a "bad" geometry. In the worst case, no position determination is possible at all, when all distance determinations point to the same direction. Even if a position is determined, the error of the positions may be up to 100 – 150 m. If, on the other hand, the 4 satellites are well distributed over the whole firmament the determined position will be much more accurate. Let's assume the satellites are positioned in the north, east, south and west in 90° steps. Distances can then be measured in four different directions, reflecting a „good" satellite geometry.

The following graph shows this for the two-dimensional case.



Good geometrical alignment of two satellites

If the two satellites are in an advantageous position, from the view of the receiver they can be seen in an angle of approximately 90° to each other. The signal runtime can not be determined absolutely precise as explained earlier. The *possible positions are therefore marked by the grey circles. The point of intersection A of the two circles is a rather small, more or less quadratic field (blue), the determined position will be rather accurate.*



Bad geometrical alignment of two satellites

If the satellites are more or less positioned in one line from the view of the receiver, the plane of intersection of possible positions is considerably larger and elongated- The determination of the position is less accurate.

The satellite geometry is also relevant when the receiver is used in vehicles or close to high buildings. If some of the signals are blocked off, the remaining satellites determine the quality of the position determination and if a position fix is possible at all. This can be observed in buildings close to the windows. If a position determination is possible, mostly it is not very accurate. The larger the obscured part of the sky, the more difficult the position determination gets.

Most GPS receivers do not only indicate the number of received satellites, but also their position on the firmament. This enables the user to judge, if a relevant satellite is obscured by an obstacle and if changing the position for a couple of meters might improve the accuracy. Many instruments provide a statement of the *accuracy of the measured values, mostly based on a combination of different factors (which manufacturer do not willingly reveal).*

To indicate the quality of the satellite geometry, the DOP values (dilution of precision) are commonly used. Based on which factors are used for the calculation of the DOP values, different variants are distinguished:

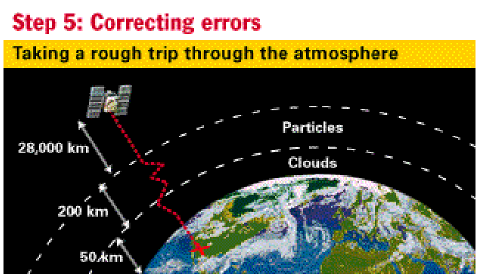
GDOP (Geometric Dilution Of Precision); Overall-accuracy; 3D-coordinates and time

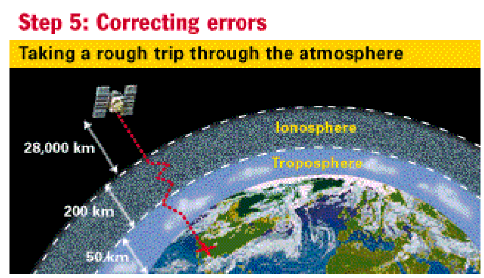
PDOP (Positional Dilution Of Precision) ; Position accuracy; 3D-coordinates

HDOP (Horizontal Dilution Of Precision); horizontal accuracy; 2D-coordinates

VDOP (Vertical Dilution Of Precision); vertical accuracy; height

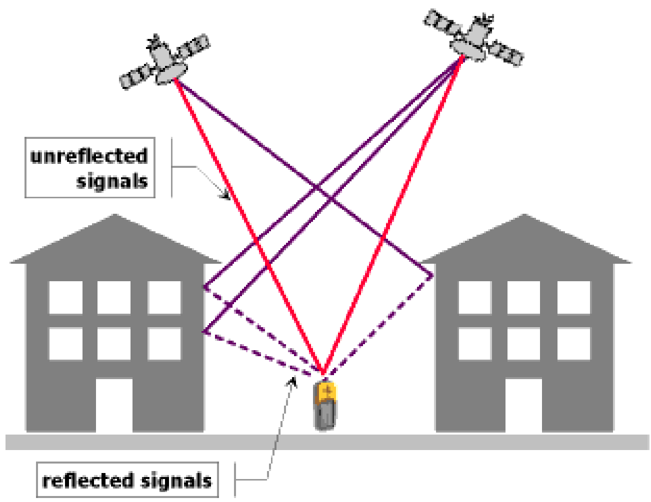
TDOP (Time Dilution Of Precision); time accuracy; time





Although the satellites are positioned in very precise orbits, slight shifts of the orbits are possible due to gravitation forces. Sun and moon have a weak influence on the orbits. The orbit data are controlled and corrected regularly and are sent to the receivers in the package of ephemeris data. Therefore the influence on the correctness of the position determination is rather low, the resulting error being not more than 2 m.

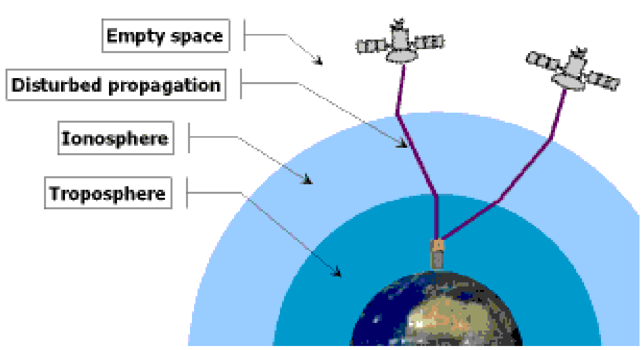
3.4.3 Multipath effect



The multipath effect is caused by reflection of satellite signals (radio waves) on objects. It was the same effect that caused ghost images on television when antennae on the roof were still more common instead of todays satellite dishes.

For GPS signals this effect mainly appears in the neighbourhood of large buildings or other elevations. The reflected signal takes more time to reach the receiver than the direct signal. The resulting error typically lies in the range of a few meters.

3.3.4 Atmospheric effects



Another source of inaccuracy is the reduced speed of propagation in the troposphere and ionosphere. While radio signals travel with the velocity of light in the outer space, their propagation in the ionosphere and troposphere is slower.

In the ionosphere in a height of 80 – 400 km a large number of electrons and positive charged ions are formed by the ionizing force of the sun. The electrons and ions are concentrated in four conductive layers in the ionosphere (D-, E-, F1-, and F2-layer). These layers refract the electromagnetic waves from the satellites, resulting in an elongated runtime of the signals.

These errors are mostly corrected by the receiver by calculations. The typical variations of the velocity while passing the ionosphere for low and high frequencies are well known for standard conditions. Theses variations are taken into account for all calculations of positions. However civil receivers are not capable of correcting unforeseen runtime changes, for example by strong solar winds.

3.3.5 Clock inaccuracies and rounding errors

Despite the synchronization of the receiver clock with the satellite time during the position determination, the remaining inaccuracy of the time still leads to an error of about 2 m in the position determination. Rounding and calculation errors of the receiver sum up approximately to 1 m.

3.3.6 Relativistic effects

The following section shall not provide a comprehensive explanation of the theory of relativity. In the normal life we are quite unaware of the omnipresence of the theory of relativity. However it has an influence on many processes, among them is the proper functioning of the GPS system. This influence will be explained shortly in the following.

As we already learned, the time is a relevant factor in GPS navigation and must be accurate to 20 - 30 nanoseconds to ensure the necessary accuracy. Therefore *the fast movement of the satellites themselves (nearly 12000 km/h) must be considered.*

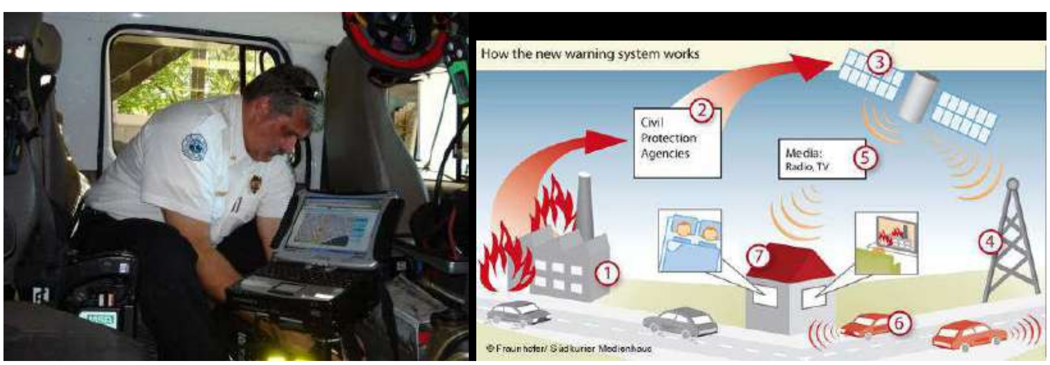
Whoever already dealt with the theory of relativity knows that time runs slower during very fast movements. For satellites moving with a speed of 3874 m/s, clocks run slower when viewed from earth. This relativistic time dilation leads to an inaccuracy of time of approximately 7,2 microseconds per day (1 microsecond = 10-6 seconds).

The theory of relativity also says that time moves the slower the stronger the field of gravitation is. For an observer on the earth surface the clock on board of a satellite is running faster (as the satellite in 20000 km height is exposed to a much weaker field of gravitation than the observer). And this second effect is six times stronger than the time dilation explained above.

3.5 Application of GPS

That's right - we are the 'Users'. All kinds of people use GPS for all kinds of purposes. While the GPS was designed for the Military, the number of civilian users is greater than Military users. Some of the more common uses of the GPS are:

***Emergency Services** - Fire, ambulance or other 911 services to locate people in distress.*



***Aviation** - pilots use it to guide their aircraft.*

***Agriculture** - farmers use it manage their farms better*

Ground Transportation

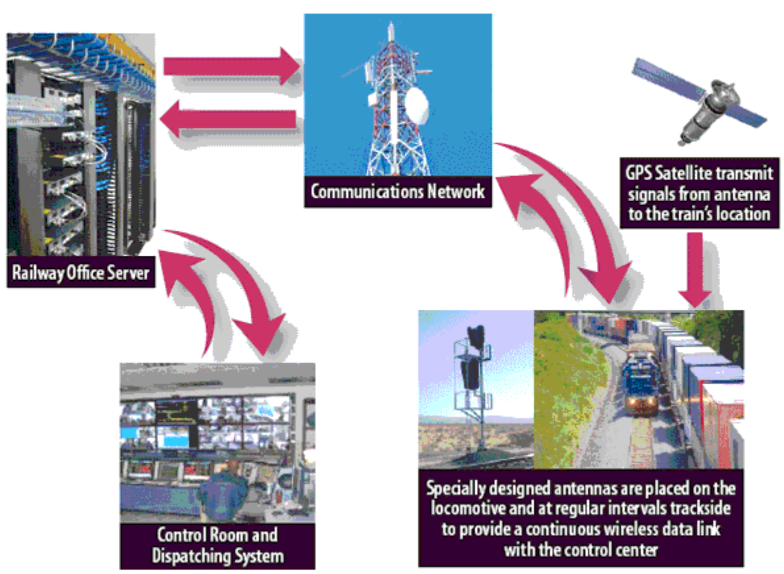
GPS technology helps with automatic vehicle location and in-vehicle navigation systems. Many navigation systems show the vehicle's location on an electronic street map, allowing drivers to keep track of where they are and to look up other destinations. Some systems atutomatically create a route and give turn-by-turn directions. GPS technology also helps monitor and plan routes for delivery vans and emergency vehicles.

GIS (Geographic Information System) Data Collection *- cities use it to locate their services such as power lines and water hydrants even streets*

Marine *- fishermen and vessels at sea use it as a guide to steer their boats or to identify a location on the sea*

Rail

Precise knowledge of train location is essential to prevent collisions, maintain smooth traffic flow, and minimize costly delays. Digital maps and onboard inertial units allow fully-automated train control.



Vehicle Navigation *- so you don't need maps to get to Grandma's house*

Recreation *- hikers and campers use it to keep from getting lost*

There will be many more users to follow in the future...

3.6 Summary

In this unit we have discussed the technology of global positioning system. The key components essential for a global positioning system to function has also been discussed. We also learned about the errors that can be present in a GPS data and therefore what are the most suitable methods of collecting data with a GPS. The types of GPS enables us to understand the various functionality of the GPS, and thus its applications have also been enclosed.

3.7 Glossary

Signal- *Information conveyed via an electric current or electromagnetic wave.*

Synchronization- *The process of automatically updating certain elements of a metadata file.*

Google Earth/Maps- *Software or an interphase where online maps and satellite data can be viewed. This was launched by the network chain Google.*

GPS position- *A satellite based device that records x,y,z coordinates and other data. Ground locations are calculated by signals from satellites orbiting the Earth.*

Navigation- *The combined mental and physical activities involved in traveling to a destination, often a distant or unfamiliar one. The activity of guiding a ship, plane, or other vehicle to a destination, along a planned or improvised route, according to reliable methods.*

Orbital Plane- *All of the planets, comets, and asteroids in the solar system are in orbit around the Sun. All of those orbits line up with each other making a semi-flat disk called the orbital plane. The orbital plane of an object orbiting another is the geometrical plane in which the orbit is embedded.*

3.8 References

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3.9 Suggested Readings

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2. *http://www.kowoma.de/en/gps/errors.htm*
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4. *Fundamentals of Remote Sensing .pdf*

3.10 Terminal Questions

1. *Why do we need a GPS?*
2. *How many satellites are needed by a GPS in a 3D space?*
3. *Name 3 different types of GPS and cite their uses.*
4. *Name any 4 errors in acquiring GPS data. Explain geometric error and its corrections.*
5. *Give 5 examples of application of GPS.*

***

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3DGIS

1.1. INTRODUCTION

Since early '90 GIS has become a sophisticated system for maintaining and analyzing spatial and semantic information on spatial objects. The need for 3D information is rapidly increasing. 2D GIS analysis have shown its limitations in some situations, e.g. noise prediction models (noise spreads out in three dimensions) (Kluijver and Stoter, 2003), water flood models, air pollution models, geological models (Van Wees et al., 2002). Other disciplines that have met the need for 3D geo-information are: 3D urban planning, environmental monitoring, telecommunications, public rescue operations, landscape planning, real-estate market (Stoter and Ploeger, 2003).

The breakthrough of 3D GIS seems not to come off. The developments in the area of 3D GIS are pushed by a growing need for 3D information from one side and new technologies on the other side (Zlatanova et al., 2002).

1.1.1Objective

After going through this unit the learner will able to learn:

- Understand Meaning of 3DGIS
- How to Prepare GIS Modeland How Web GIS work
- Capable To Work on Advance Gis Formats

1.1.3Technology progress

An important development is the improvement of 3D data collection techniques (aerial and close range Photogrammetry, airborne or ground based laser scanning, surveying and GPS). Sensors are faster and more accurate than before. Other new techniques that push 3D GIS developments are hardware developments: processors, memory and disk space devices have become more efficient in processing large data sets. Furthermore elaborated tools to display and interact with 3D data are evolving.GIS software-tools have also made a significant movement towards 3D GIS

.There are few commercial of-the-shelf (COTS) systems that can be categorized as systems that attempt to provide a solution for 3D representation and analysis. Five systems are chosen for detailed consideration, because they constitute a large share of the GIS market and provide some 3D data processing functions. The systems are the 3D Analyst of ArcGIS (see ESRI Inc.), Imagine VirtualGIS (ERDAS Inc., http://www.erdas.com), GeoMedia Terrain (Intergraph Inc., http://www.integraph.com),PAMAP GIS Topographer (PCIGEOMATICS, http:// www.pcigeomatics.com) andAutoCAD Map **3D (**usa.autodesk.com/autocad-map-**3d/**)

Figure 1.1: Commercial GIS: ArcScene, ESRI (left) and Imagine Virtual GIS, ERDAS (right)

1.1.3.1Working with 3D GIS

Many GIS problems can only be solved using 3D. Seeing your data in 3D can very quickly highlight spatial relationships between GIS features, and analytical tools can quantify these relationships into patternsa 3D GIS operates in a runtime environment just like the computer games and simulators. This environment allows users to travel anywhere in the scene at any time. This is in stark contrast to the animation quality movies that can take hours to render single frames and only follow a specified tract. To create an efficient 3D environment, buildings may be constructed as a wire frame and textured with digital images to dramatically reduce the number of polygons drawn by the computer without losing their character and visual appeal (Figure 1.2). Careful use of shadows can provide the illusion of detail in the building model.

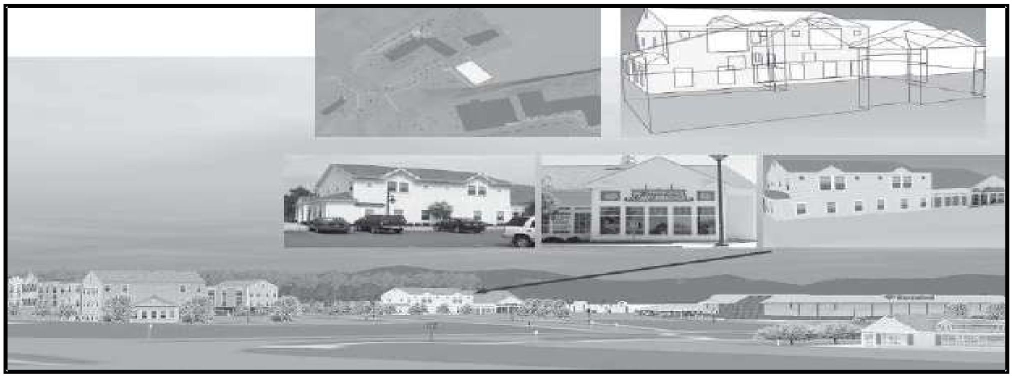


Figure 1.2:Working From 2D Footprints, Building Models Are Constructed As A Wire Frame, Textured From Digital Images, and Completed For Inclusion inthe3D GIS Environments

1.1.3.2 Building Trees

Tree models are usually composed of two or more intersecting polygons with a picture of a tree pasted on all sides. However, for trees that will only be viewed from a distance, a single polygon that uses a lower resolution photo will provide the same visual effect while reducing the graphic impact of the scene.(Figure 1.3) illustrates the construction of a green ash tree for use in a 3DGIS EnvironmentMore 3D visualization environmentsnow support models or symbols thatincorporate levels of detail (LOD), whichcan help improve performance whilemimicking what can or cannot be seenwith the human eye. For example, amodel of a road sign built with LOD mightuse a detailed texture at close range butswitch to simple colors when viewed froma significant distance.Creating a tree model is actuallymuch harder than it looks. The processof extracting a tree from a full digitalpicture to create a texture can be a timeconsuming process. Issues of lighting,feature extraction, size and formattingcan account for hours of work.

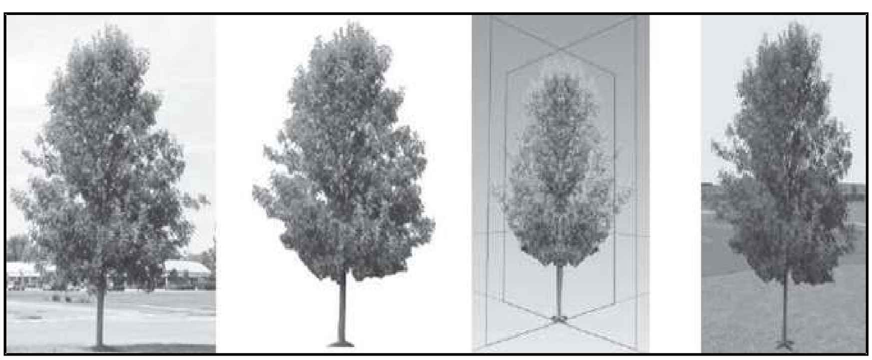
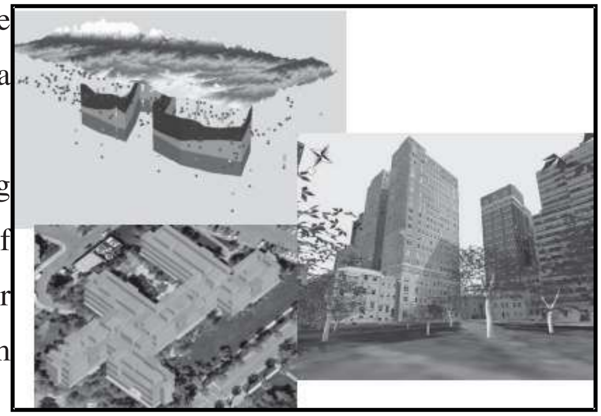


Figure 1.3 : The step involved in the creation of tree symbol: staring with photograph, extracting just the tree, creating the model two polygons and finally positioning the tree on the virtual landscape

1.1.3.2 Visualizing 3D Data

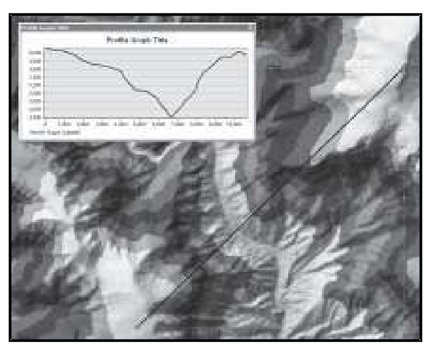
Viewing data in three dimensions gives you new perspectives. Three-dimensional viewing can provide insights that would not be readily apparent from a plan metric map of the same data. For example, instead of inferring the presence of a valley from the configuration of contour lines, you can actually see the valley and perceive the difference in height between the valley floor and a ridge.



ArcGIS 3D Analyst provides two viewing environments for your data. View large volumes of 3D GIS data in a global view usingArcGlobe, or view site-level data in a local coordinate system using ArcScene**Figure** 1.4 Visualizing of 3D data

You can build multilayered 3D environments and control how each layer is symbolized, positioned in 3D space, and rendered. You can also control global properties for the 3D view, such as the illumination or vertical exaggeration. You can select features by using their attributes or their position relative to other features or by clicking individual features in the scene or globe. You can interactively navigate around the 3D view or specify the coordinates of the observer and target for a viewer.

1.1.3.1Analysis in 3D



You can analyze GIS data in three dimensions using geoprocessing tools, and use interactive tools (such as the 3D Measure tool) in a 3D view to solve problems that can't be solved in 2D.Figure 1.5(a): Analysis3D data

You can create and modify functional surfaces with 3D Analyst. 3D surface tools allow you to create surfaces, convert surfaces to 3D features or other surface types, extract surface information, and conduct advanced surface analysis such as slope, aspect, and contouring. Examples of 3D surface

analysis are elevation analysis for residential development, groundwater modeling, disaster management, or floodplain mapping.

Figure 1.5(b): Analysis3D data

A suite of 3D volumetric tools can be used to investigate and determine the relationship between 3D features, such as checking if one feature is located inside another or combining two 3D features into one complex shape. For example, you can calculate maximum building heights based on visibility restrictions.

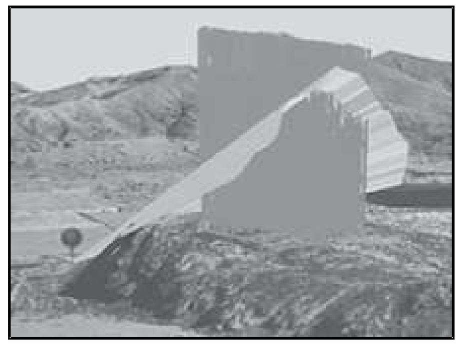


Figure 1.5(c): Analysis 3D data

You can conduct visibility analysis in your 3D GIS environment. A suite of visibility tools exist to conduct visibility analysis. For example, you can use the line-of-sight analysis on a landscape to optimize the location of telecommunication towers, or analyze the effects of a new proposed building on the city skyline.

1.1.4. 3D GIS: Future Vision

Imagine a public meeting where a proposed building is added to a virtual, GIS-enabled landscape. The GIS immediately evaluates the new building for compliance with use constraints as well as setback and height restrictions. The water and waste water systems are connected to the outsidelines (GIS layers) to verify capacity availability. Storm water run-off from the roof and other new impermeable surfaces are evaluated and summarized. Security and emergency vehicle access (including turn around space) are considered from all access routes. Finally, the reviewers can evaluate the appearance and compatibility of the new structure from any vantage point within the existing virtual environmentExpect the opportunities for employing 3D GIS technology to expand at a rapid rate over the next few months and years. Officials are already looking at 3D buildings by floor or even by room in applications related to security and emergency planning.(Figure 1.6)shows thefirst floor of a school as a multi patch feature with the roof and second floor turned off in the display. With detailed terrain and land cover information can we better model both the visual impact and performance of proposed wind turbines on our hillsides? View sheds from the windows of both existing and proposed buildings are now possible in both in a quantified and visual simulation. In reality we have just brushed the surface and exposed only a fraction of other possible technologies that may be applicable to GIS.

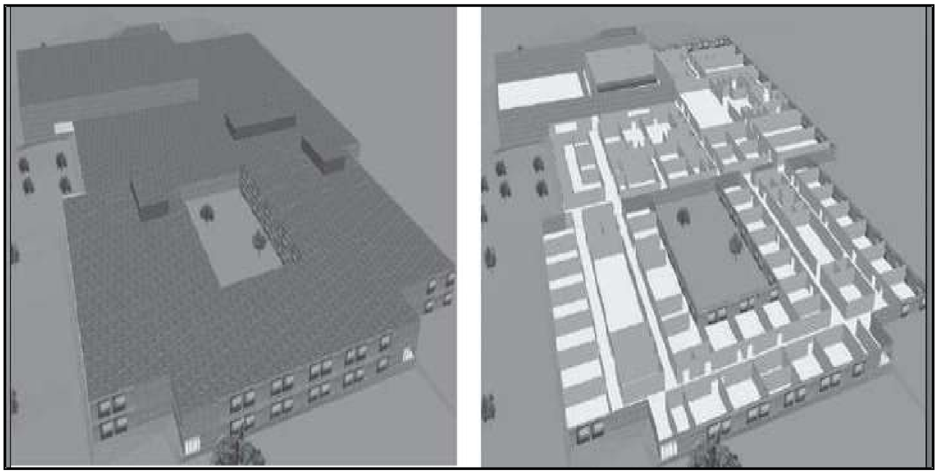


Figure 1.6**:** A building can be modeled in both its exterior presentation and with its interior detail by storing each floor of the building as a multi-patch. This allows the GIS to treat each floor as a layer and store separate attributes related only to that floor.

Check Your Progress

Q.1 Give the Name of 3DGIS software?

Q.2 Fill in the blank.

a)ArcGIS 3D Analyst provides two viewing environments for your data ……..& ArcScence

b)A suite of 3D volumetric tools can be used to investigate and determine the relationship between ……………..

Q. 3 True false against the following:

a)You can build multilayered 3D environments and control how each layer is symbolized, positioned in 3D space

b)Tree models are usually composed of one intersecting polygons with a picture of a tree pasted on all sides.

GIS MODELING

1.2 Introduction

Modeling can be defined in the context of geographic information systems (GIS) as occurring whenever operations of the GIS attempt to emulate processes in the real world, at one point in time or over an extended period. Models are useful and used in a vast array of GIS applications, from simple evaluation to the prediction of future landscapes

What is model? A model is a simplified representation of a phenomenon or a system. A map is model. So are the vector and raster data models for representing spatial features and the relational model for representing a database system A model helps us better understand a phenomenon or a system by retaining the significant feature and relationships of reality

The term modeling is used in several different contexts in the world of GIS, so it would be wise to start with an effort to clarify its meaning, at least in the context of this book. There are two particularly important meanings. First, a data model is defined as a set of expectations about data—a template into which the data needed for a particular application can be fitted. For example, a table is a very simple example of a data model, and in the way in which tables are often used in GIS, the rows of the table correspond to a group or class of real-world features, such as counties, lakes, or trees, and the columns correspond to the various characteristics of the features, in other words, the attributes. This table template turns out to be very useful because it provides a good fit to the nature of data in many GIS applications. In essence, GIS data models allow the user to create a representation of how the world looks. Second, a model (without the data qualification) is a representation of one or more processes that are believed to occur in the real world—in other words, of how the world works. A model is a computer program that takes a digital ++representation of one or more aspects of the real world and transforms them to create a new representation

1. 2.2Classification of GIS models

1. 2.2.1Descriptive or Prescriptive

A descriptive model describes the existing condition of spatial data, and a prescriptive model offers a prediction of what the conditions could be or should be. If we use maps as analogies, a vegetation map would represent a descriptive model and a potential natural vegetation map would represent a prescriptive model. The vegetation map shows existing vegetation, whereas the potential natural vegetation map predicts the vegetation that could occupy a site without disturbance or climate change

1. 2.2.2 Deterministic or Stochastic

Both deterministic and stochastic models are mathematical models represented by equations with parameters and variables. A stochastic model considers the presence of some randomness in one or more of its parameters or variables, but a deterministic model does not. As a result of random processes, the predictions of a stochastic model can have measures of error or uncertainty, typically expressed in probabilistic or statistical model.

1. 2.2.3Static or Dynamic

A dynamic model emphasizes the changes of spatial data and the interactions between variables, whereas a static model deals with the state of spatial data at a given time. Time is important to show the process of change in a dynamic model (peuquet 1994). Many environmental models such as groundwater pollution and soil water distribution are best studied as dynamic models (Rogoeski and Goyne 2002)

1. 2.2.4Deductive or Inductive

A deductive model represents the conclusion derived from a set of premises. These premises are often based on scientific theories or physical laws. An inductive model represents the conclusion derived from empirical data and observations. To assess the potential for a landslide, for example, one can use a deductive model based on laws in physics or use an inductive model based on recorded data from past landslides (Brimicombe 2003)

1.2.3. The Modeling process

In GIS models follows some steps, in which first step define the purpose of model. This analogous to defining a research problem, means what kind of task done by model, Is this compulsory to create model for this work? What kind of data (spatial) and time scales are good for this particular model?

Second step is to divide model into it elements and to define the each elements properties like a flow chart. Third step is use model on real work and run on the software, then you can see how model calibrate the input data and give results. The modeller can split observed data into two subset one subset for developing the model and the other subset for model validation (e.g, chang and Li 2000)

1.2.3.1. Binary models

A binary models based on logical expressions, for select spatial features, from different gis database or raster layer and the result of this models is in binary format . A vector based binary model need overlay process to done the combine geometries and attributes to be used in data query into a composite feature layer (Figure 1.7)

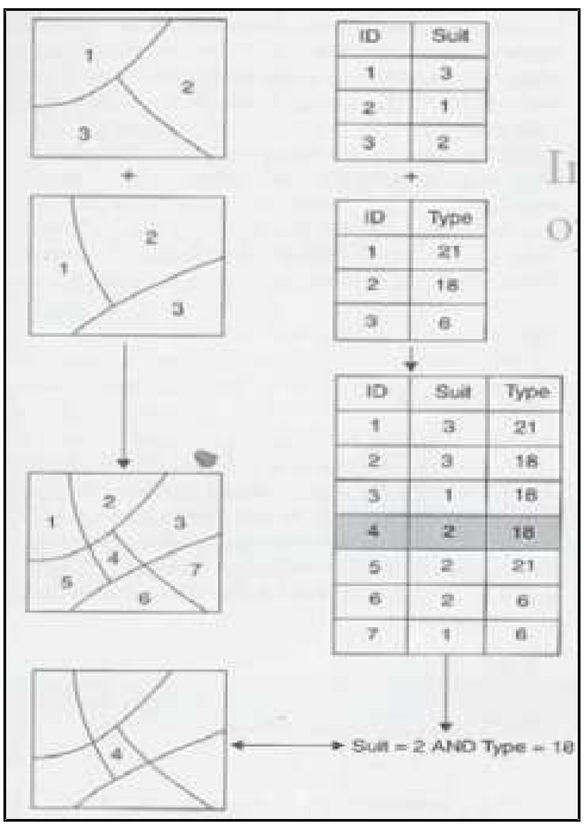


Figure 1.7(a):To build a vector- binary model, first overlay the layer so that their spatial features and attributes (suit and Type) are combined .Then, use the query statement, suit = 2 AND Type = 18, to select polygon 4 and it to the output layer.

But in Raster –based binary model can be derived directly from querying multiple raster's, with each raster representing a criterion (Figure1.8)

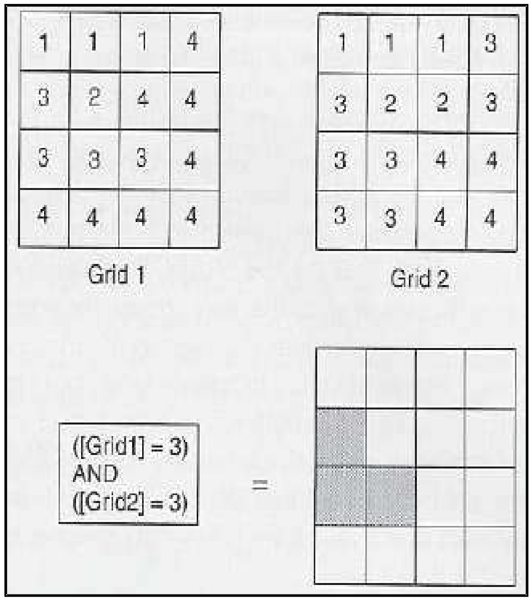


Figure1.8 (b) this diagram illustrate a raster –based binary model use the query statement, [GRID1] =3AND [GRID 2] = 3, to select three cells (shaded) and save them to the output grid

1.2.3.2INDEX MODELS

An index model calculates the index value for each unit area and produces a ranked map based on the index values. An index model is similar to a binary model in that both involve multi criteria evaluation and both depend on overlay operations for data processing. But an index model produces for each unit area an index value rather than a simple yes or no.

1.2.3.2.1The Weighted Linear Combination Method

The primary consideration in developing an index model, either vector –or raster based, is the method for computing the index value. The weighted linear combination method is a common method for computing the index value (Saaty 1980; Banai-kashani 1989; Malczewski 2000).

1.2.3.3 REGRESSION MODELS

A regression model relates a dependent variable to a number of independent (explanatory) variables in an equation, which can then be used for prediction or estimation (Rogerson 2001). Like an index model, a regression model can use overlay operation in a GIS to combine variables needed for the analysis. There are two types of regression model; linear regression and logistic regression

1.2.3.3.1Linear Regression models

Amultiple linear regression model is defined by:

$$Y = a + b_1x_1 + b_2\, x_2 + ... \, b_n\, x_n$$

Where y is is the dependent variable, x_i is the independent variable i, and $b_{1.........}b_n$ are the regression coefficients . All variables in the equation are numeric variables. They can also be the transformation of some variables. Common transformations include square, square root, and logarithmic.

The primary purpose of linear regression is to predict values of y from values of x, but linear regression requires several assumptions about the error, or residual, between the predicated value and the actual value (Miles and shevlin 2001)

The errors have a normal distribution for each set of values of the independent variables

The errors have the expected (mean) value of zero

The variance of the errors is constant for all value of the independent variables

The errors are independent of one variable

Regression models have been used for modelling snow accumulation (chang and Li 2000), wildlife home ranges (Anderson et al.2005), non-point pollution risk (potter et al.2004)

1.2.3.3.2 Logistic Regression model

Logistic regression is used when the dependent variable is categorical (e.g. presence or absence) and the independent variable are categorical, numeric, or both (menard 2002). Although having the same form as linear regression, logistic regression uses the logit of y as the dependent variable:

$\text{logit}(y) = a + b_1x_1 + b_2 x_2 + b_3 x_3 + \ldots\ldots\ldots\ldots$

The logit of y is the natural logarithm of the odds (also called odds ratio):

The main advantage of using logistic regression is that it does not require the assumptions needed for linear regression. Logistic regression models have been developed for predicting grassland bird habitat (Forman et al. 2002), fish habitat (Eikaas et al. 2005) landslide susceptibility (Lee 2005)

1.2.3.4. Process Models

A process model integrates existing knowledge about the environment processes in the real world into a set of relationship and equations for quantifying the processes (Beck et al.1993). Modules or sub-models are often needed to cover different components of a process model .some of these modules may use mathematical equations derived from empirical data, whereas others may use equations derived from laws in physics. A process model offers both a predictive capability and an explanation that is inherent in the proposed processes (Hardisty at al.1993) Therefore; process models are by definition predictive and dynamic models.

Check Your Progress

Q.4 What is Index Model?

Q.5 Fill in the blank.

a)……………. and stochastic models are mathematical models represented by equations

b)Groundwater pollution and soil water distribution are best studied as …………models

Q. 6 True false against the following:

a)A binary models based on logical expressions, for two spatial features

b)The main advantage of using logistic regression is that it does not require the assumptions needed for linear regression.

WEB GIS

1.3.1 Introduction

GIS software has enabled users to view spatial data in its proper format. As a result, the interpretation of spatial data has become easy and increasingly simple to understand. Unfortunately, everyone does not have access to GIS, nor would he be able to spend the time necessary to use it efficiently. Web GIS becomes a cheap and easy way of disseminating geospatial data and processing tools. Many organizations are interested to distribute maps and processing tools without time and location restriction to users. Internet technology has made its way to many government organizations as well as numerous households. The ability to get information through Internet made spatial data providers to explore the Internet resources fordisseminating spatial information.

1.3.2. Web GIS Technology

Development of the Web and expansion of the Internet provide two key capabilities that can greatly help geoscientists.First, the Web allows visual interaction with data. By setting up a Web Server, clients can produce maps. Since the mapsand charts are published on the Internet, other clients can view these updates, helping to speed up the evaluation process.Second, because of the near ubiquitous nature of the Internet, the geospatial data can be widely accessible. Clients can workon it from almost any location. Both of these features altars the way geoscientists do their work in the very near future. Thecombination of easy access to data and visual presentation of it addresses some of the primary difficulties in performinggeosciences evaluations (Gillavry, 2000).

Web GIS is not without its faults. The primary problem is speed; GIS relies on extensive use of graphics. Connectionspeeds over the Internet can make heavy use of graphics intolerably slow for users. It will not match the complexity ofdedicated GIS programs. On the other hand, Web GIS does notrequire the same resources as these programs (GisSoftware). Powerful computers, extensive training, and expensive site licenses are notrequired for a site wide GIS solution (Strand, 1998).

1.3.2.1 Transferred Geo Data

Except attribute data, a decisive question for using GIS in the Internet is the data format (vector or raster), which is used totransfer data to client. For data transmission to the client, map is converted into no space raster or a suitable vector format.When raster data is transferred, a standard Web browser without extension can be used, since Web browser displays GIFand JPEG. That means the data on the server has to be converted to a raster format. The data volume due to the knownimage size and the original data on the server is safe as only an image is sent to the client. The disadvantage of using rasterdata is the lack of comfort of handling and regarding cartographic aspects

Because of low vector data volume, it transmits faster than raster. Vector data handled by a standard Web browser withextended functionality (e.g. using plug-ins). The user gets a more functionality with vector data. For example, single objectscan be selected directly or highlighted. One more advantage of using vector data is the possibility of local processing; it isnot necessary to contact the server per executed browser action. The amount of vector data sent over Web could be three tofour times less than the amount of raster data needed for equivalent resolution resulting in faster response time and greaterproductivity (Nayak, 2000). Disadvantages of vector data are manufacturer dependence, as well as, changing data volume;the amount of data varies with the selected area.

Different consortia are developing future standard formats for transferring data over the Internet. The Open GISconsortium, for example, presents Geography Markup Language (GML). GML shall enable the transport and storage ofgeographical information in extensible Markup Language (XML). Geographic information includes both properties and thegeometry of geographic features (www.opengis.org). The W3C submits Scalable Vector Graphics (SVG), which is alanguage for describing two dimensional vector and mixed vector/raster graphics in XML (www.w3.org).

1.3.2.2 Interactive Web Maps

There are several technology levels to publish map data on the Web, ranging from sites that simply publish static Webmaps to more sophisticated sites which support dynamic maps, interactively customized maps and multiple computerplatforms and operating systems. In terms of Web GIS, the most challenging map is the interactive one. Within the OpenGIS Consortium, a Special Interest Group (SIG) for WWW Mapping is working on issues of Web-based GIS publishing.This group has recently developed an essential model of interactive portrayal (Figure 1.9).

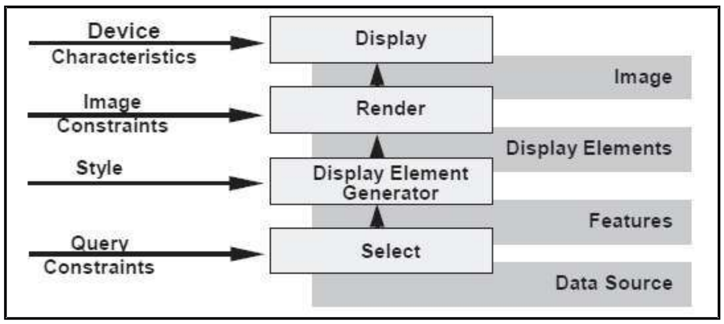


Figure1.9:Open GIS model of portrayal workflow (Doyle 1999)

This model is a very useful tool to analyze and compare different architectures for Internet Map Servers and other Internetbased GIS applications. Moreover, it is more precise than the common expression, which often leads to misunderstandings.The interactive portrayal model has four tiers:

- The Selection process retrieves data from a geospatial data source according to query constraints such as a searcharea or thematic selections
- The Display Element Generator process turns the selected geospatial data into a sequence of display elements. It attaches styles such as symbols, line styles, fill styles to spatial features, generates annotation from alphanumeric attributes, sorts the display elements in a certain order and does other graphical processing
- The Render takes the display elements and generates a rendered map. Examples of rendered maps are In-memory display lists, GIF-files or postscript files
- The Display process makes the rendered map visible to the user on a suitable display device Between these four tiers, there are three different types of data

1.3.2.3. Internet Map Servers

Internet Map Server (IMS) applications allow GIS database custodians to easily make their spatial data accessible through a web browser interface to end-users. High-speed corporate intranets make an ideal network for distributing data in this manner, given the fact that bandwidth requirements can be high. Making data available to the entire world is certainly feasible and any organization that has a public website can certainly add an IMS without opening up too many additionalsecurity holes. For a working IMS, software requires two components to function. A geospatial data processing engine that runs on theserver side as a service, Servlet or Common Gateway Interface (CGI) application, and processes the raw spatial data into a map and a standard web server that manages the incoming requests and replies with the proper map data back to the client side browser or application window. The end product is either a JPEG or GIF image or vector, which is transmitted back tothe client browser or a stream of data that is interpreted by a plug-in to the client browser. IMS that transmit back an image have a limited capability that does not extend much beyond pan, zoom, and basic vector attribute query. The featurestreaming IMS requires a downloadable plug-in, but allows for advanced buffer, query, labeling and sub setting operations to be performed. Some IMS sites offer both a plug-in and a simple HTML version, which is nice for plug-in weary surfers.

1.3.3. Web GIS Architectures

In performing the GIS analysis tasks, Web GIS is similar to the client/server typical three-tier architecture. The geo-processing is breaking down into server-side and client-side tasks. A client typically is a Web browser. The server-sideconsists of a Web Server, Web GIS software and Database (Figure 1.10) (Helali, 2001).

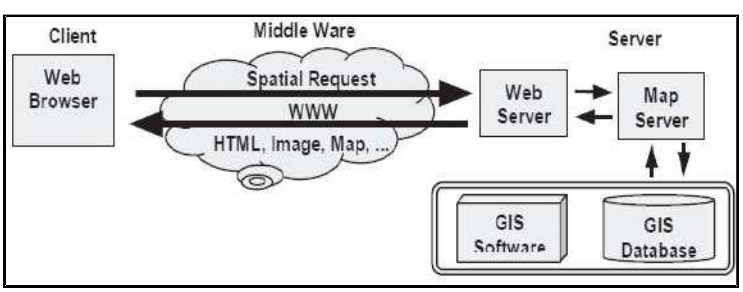


Figure 1.10: How a typical web gis model works

This model of network widely exists within enterprises, in which some computers act as servers and others act as clients.Sever simply have the proprietary GIS running, and add a client interface at the client side and a middleware at the serverside to communicate between the client and the proprietary GIS software.

Recent development in object oriented programming make it possible to produce software components, and send them tothe client before running it in the client machine, such as Java classes, ActiveX components and plug-ins. This comes out tothe thick client GIS. The thick-client architecture let the client machine do the most processing works locally. Both thin andthick-client systems have some advantages and drawbacks, but they are not the best solution in terms of taking advantage ofnetwork resources.

1.3.3.1 Thin Client Architecture (Server Side Applications)

The thin client architecture is used in typical architecture. In a thin-client system, the clients only have user interfaces tocommunicate with the server and display the results. All the processing is done on the server actually as shown in Figure 2.The server computers usually have more power than the client, and manage the centralized resources. Besides, the mainfunctionality is on the Server side in thin architecture there is also the possibility for utility programs at the server side to belinked to the server software. (Figure 1.11) shows schematic communication between Web browser, Web Server and GISserver. On the Web Server side, there are some possibilities to realize the GIS connection to the World Wide Web; CGI,Web Server Application Programming Interface (API), Active Server Pages (ASP), Java Server Pages (JSP) and Java-Servlet. The descriptions of the five possibilities mentioned above are in Helali, (2001)

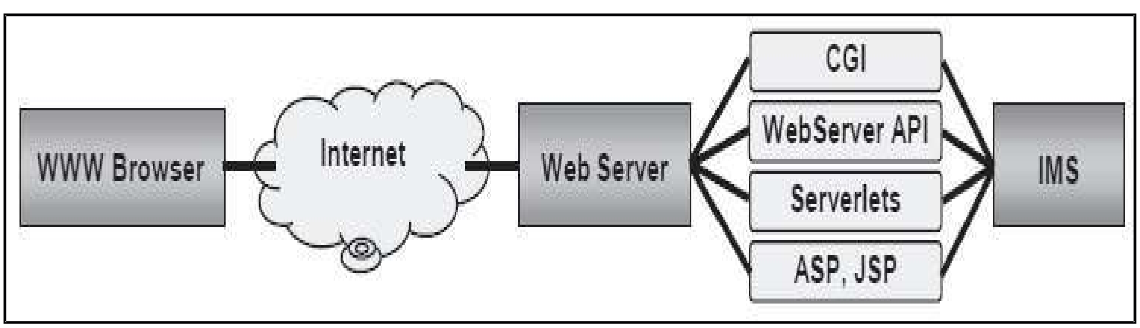


Figure 1.11: server side Application

The user on the client side does not need any knowledge about the linkage of the IMS at the server side, but the systemadministrator or application developers should be familiar with these techniques. This Architecture used in ESRI ArcViewIMS, MapObjects IMS and MapInfo MapXtreme systems.

1.3.3.2 Thick Client Architecture (Client Side Applications)

In general, a Web browser can handle HTML documents, and embedded raster images in the standard formats. To deal withother data formats like vector data, video clips or music files, the browser's functionality has to be extended. Using exactlythe same client sever communication in Thin Client architecture, vector files format could not be used. To overcome thisproblem most browser applications offer a mechanism that allows third tier programs to work together with the browser asa Plug-in. The user interface functionality has progressed from simple document fetching to more interactive applications. Thisprogress is as follows: HTML, CGI, using HTML forms and CGI, Java script to increase user interface capabilities, Javaapplets to provide client-side functionality. Currently user interface capabilities combined with remote invocations (Figure 1.12) (Byong-Lyol, 1998).

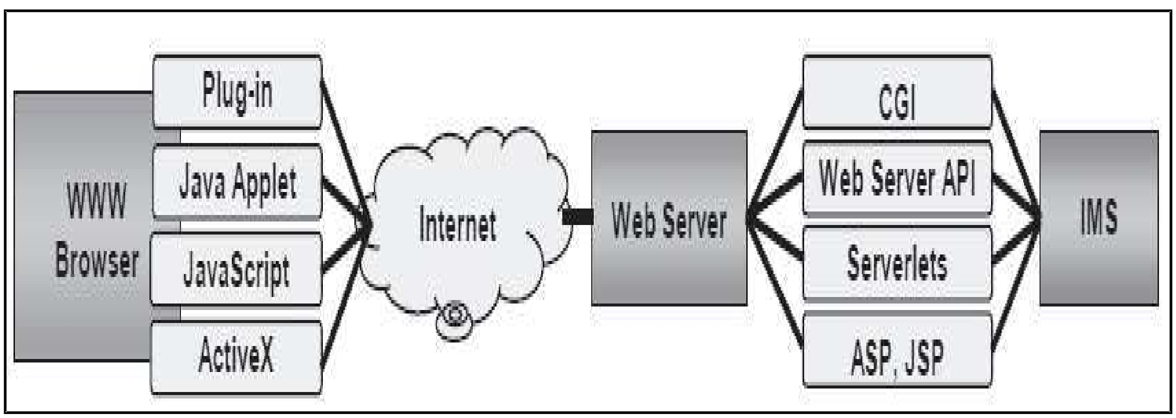


Figure 1.12: client side Application

1.3.3.3 Medium Client Architecture

For avoiding vector data in client side and reducing problems of previous architectures, Medium Client is suggested. Withusing extensions in both client and server side, clients may have more functionally than Thin client architecture. In Figure 1.13these four components in interactive map are pictured as services, each with interfaces, which can be invoked by clients ofthat service

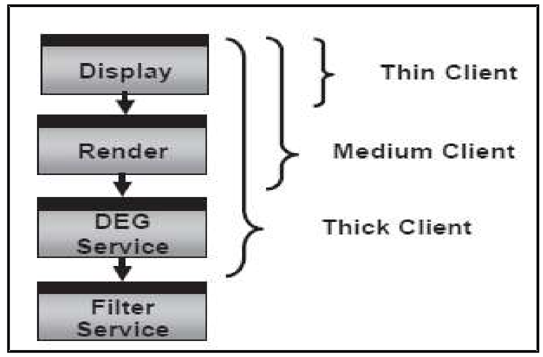


Figure1.13: Medium Client position in open GIS point of view

In other words, if a user's computer contains just the display service, then that user would be said to be using a thin client.If the user's computer additionally contained a render service, then that user would be said to be using a medium client.And finally, if the user's computer also contained the display element generator service that would indicate the user is usinga thick client.

1.3.4. Web GIS Development

Developing a Web GIS is more than simply buying the appropriate hardware and software. Several strategies have beenproposed to provide successful implementation (Alesheikh & Helali 2001). The implementation strategies have beenscientifically assessed and modified so that the requirement of any project can be met with minimum cost and time. Figure 1.14 shows the Web GIS development cycle, which is described in terms of 8 major activities starting with therequirement analysis and ending with on-going use and maintenance of the Web GIS system

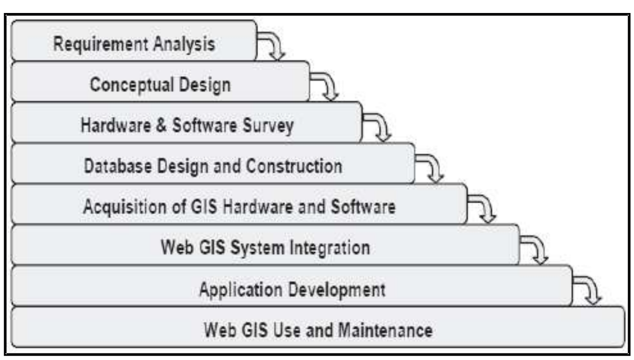


Figure 1.14: Web GIS Development cycle

1.3.4.1 Requirement Analysis

The object of the project is to disseminate road information through the Internet, so that constituents can easilyaccess the data. The requirement analysis step has been performed through interviewing potential users. This step producedtwo critical pieces of information:

- A list of functions that is needed. The required functions are the basic visualization functions such as Pan, Zoom, and more advanced functions such as object identification, spatial query, and shortest path. Clients can use these functions to view road information, and peripheral constructs such as gas stations and rest areas.
- A master list of available/needed geographic data. During theproject several roadlayershas captured for information using GPS.In this project, only 25 layers of information have been used that includes; police station, restaurants, gas station

The information gained in the requirement analysis activity went directly into the Conceptual GIS Design activity.

1.3.4.2 Conceptual Design

Once the required data has been identified, the data model that identifies the entities and their relationships were designed.Since, the data will be delivered through a central server, and clients will have access to raster formats, Medium Clientarchitecture was chosen providing the users with access to interactive maps.

1.3.4.3 Survey of Available Software and Hardware

Selecting suitable software is an important step in a successful implementation. Software was evaluated on functionalityand performance and independent of the hardware and operating system and also respect to the required functionsand cost. Web GIS requires specific hardware configuration. Since the volume of transferred data is huge, the speed of Internetconnection is vitally important. Most of the data are sent from map server to clients; as such the Send speed should be more than 128kbs and for computerProcessors should Dual or core 2 Duo with 2GB Ram.

1.3.4.4 Database Design and Construction

The primary purpose of this phase of the Web GIS development process was to specify "how" the Web GIS performs therequired applications. Database design involved defining how graphics will be symbolized (i.e., color, weight, size,symbols, etc.), how graphics files will be structured, how non graphic attribute files will be structured, what is the activelayer, in what scale shall the layers expose, how GIS products will be presented (e.g., map sheet layouts, report formats,etc.), and what management and security restrictions will be imposed on file access. Completing the following activitiesdoes this:

- Selecting a source (document, map, digital file, etc) for each entity and attribute included in the Entity-Relationship diagram
- Setting-up the actual database design (logical/physical design)
- Defining the procedures for converting data from source media to the database. Since the formats of the data were selected to be ESRI compatible, the needed data were converted to such format
- Define procedures for managing and maintaining the database.
-

1.3.4.5 Acquisition of GIS Hardware and Software

The database design activity was conducted concurrently with the pilot study and benchmark activities. Actual proceduresand the physical database design cannot be completed before specific GIS hardware and software has been selected while atthe same time GIS hardware and software selection cannot be finalized until the selected GIS can be shown to adequatelyperform the required functions on the data. Thus, these three activities (design, testing, and Hardware/Software acquisition)have been conducted concurrently and iteratively.

1.3.4.6 Web GIS System Integration

At this point in the Web GIS development process the Web GIS hardware and software have been acquired and dataconversion is complete. The object of this phase was then to integrate different components of the hardware and software,to test them to make sure they work as expected, and to initiate all procedures necessary to use the GIS.

1.3.4.7 Application Development

The initial Requirement Analysis contained some applications of a complex nature. However, the majority of initialapplications was straightforward, and can be implemented using the basic functionality that is part of the Web GIS software(e.g., display). The more complex applications were not supported by the basic functions of Web GIS but have beenprogrammed. Ease of use, user-friendliness, and reducing the volume of data transfer were the critical issues considered inthe development.

1.3.4.8 Web GIS Use and Maintenance

The final step in web GIS implementation was to put the system to use. With system integration and testing completed and all applications available for use, the system was released to users. Two activities were in place:

- User support and service, in which new applications will be determined, and
- System maintenance (database, hardware, software), in which the Web GIS must run smoothly

Check Your Progress

Q.7 What is Internet Map Server?

Q.8 Fill in the blank.

a)For avoiding vector data in client side use………………. architectures

b)Web browser can handle……….. documents and embedded raster images in the standard formats.

1.4. Summary

This unit elaborate Advance Gis types and explain how advance Gis provides users with freedom to analyze spatial problems within their specific industry. And discuss on three different advanceGis format, like what is 3DGIS, how we visualizing &analysis 3Ddata, basic components of models and its applications of models and introduction of webGis and it structure

1.5. Glossary

- **Model: -** simplified representation of a phenomenon or system.
- **Binary model: -** A Gis model that uses logical expressions to select feature from a composite feature layer or multiple rasters.
- **KML:-K**eyhole **M**arkup **L**anguage is an XML-based language to express geo-graphic annotation and visualization on existing or future Web-based, two-dimensional maps and three-dimensional Earth browsers. KML was developed to use it with Google Earth, and was originally named Keyhole Earth Viewer.
- **Java Script: -**Java script is a scripting language most often used for client-side web developments. It was the originating dialect of the ecmascript standard. It is a dynamic, weakly typed, prototype-based language with first-class functions. JavaScriptwas influenced by many languages and was designed to be easier for non-programmers to work with.
- **3D graphics: -**3D graphiccreate the illusion of depth in 2D-images. 3D computer graphics rely on many of the same algorithms as 2D computer vector graphics do in awire frame model. 2D applications use 3D techniques to achieve certain effects, and 3D may still use 2D techniques for rendering.
- **Cache: Cache: - is** a temporary storage area, where frequently accessed data can be stored for rapid access. Once the data is stored in a cache, future use can be made by accessing the cached copy rather than re-computing the original data, reducing the average access time considerably. If a user revisits a Web page after only a short interval, the page data may not need to be re-obtained from the Web server.

1.6. Answer to check your progress/Possible Answers to SAQ

Ans.1 ArcGIS, Imagine VirtualGIS (ERDAS), GeoMedia Terrain, PAMAP GIS Topographer (PCIGEOMATICS), AutoCAD Map **3D**

Ans.2 Fill in the blank.

(**a**)ArcGlobe (**b**) 3D features

Ans. 3 True false against the following:

(**a**) True (**b**) False

Ans.4 An index model calculates the index value for each unit area and produces a ranked map based on the index values. An index model is similar to a binary model in that both involve multi criteria evaluation and both depend on overlay operations for data processing. But an index model produces for each unit area an index value rather than a simple yes or no.

Ans.5 Fill in the blank.

(**a**) Deterministic (**b**) Dynamic

Ans. 6 True false against the following:

(**a**) False (**b**) True

Ans.7 Internet Map Server (IMS) applications allow GIS database custodians to easily make their spatial data accessible through a web browser interface to end-users. High-speed corporate intranets make an ideal network for distributing data in this manner, given the fact that bandwidth requirements can be high. Making data available to the entire world is certainly feasible and any organization that has a public website can certainly add an IMS without opening up too many additional security holes

Ans.8 Fill in the blank.

(**a**)Medium Client (**b**) HTML

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8-http://www.isprs.org/proceedings/xxxiv/part4/pdfpapers/422.pdf

9-web Gis: principles and applications [paperback] Pinde fu (author), jiulin sun (author)

10-fundamentals-of-remote-sensing.-by Noam Levin ,November 1999

1.8. Suggested Readings

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Paul A Longley (Author), Michael Batty (Editor), Mac Rubel (Editor), Paul A. Longley (Author)

2.GIS Tutorial 3: Advanced Workbook [David W. Allen (Author), Jeffery M. Coffey (Author)

1.9. Terminal Questions

Q1.Write the names of different 3D GIS Software

Q2.What is Web GIS Architectures?

Q3.Different between Thick and Thin client architecture

Q4.Describe the difference between a descriptive model and a prescriptive model

Q5.How does an index model differ from a binary model?

Q6. What kinds of variables can be used in a logistic regression model?

Q7. Explain the weighted linear combination Method

Q8. How does a static model differ from a dynamic model

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THERMAL REMOTE SENSING

2.1. INTRODUCTION

The basis of passive imaging systems is that sensor detects and measure the E.M. radiation reflected or emitted from different surface features. Two surfaces may have very similar reflected characteristics within in visible and infrared part of E.M. spectrum and may not be distinguishable, but because they may have dissimilar thermal properties. They may be distinguished in thermal infrared spectrum. Objects radiate energy as a function of their temperature in thermal infrared wavelength. This emitted energy may be remote sensed using thermal sensor in the wavelength range from 3 to 14 µm. its generally record broad spectral bands typically 8.0 to 14 µm for image from aircraft and 10.5to 12.0 µm for image from satellites.

2.2 Objective

After going through this unit the learner will able to learn:

- Types of Advance Remote sensing
- Thermal Hyperspectral , Microwave , Lidar
- Applications of Advance Remote Sensing.

2.3. Thermal Properties of Objects

All object having temperature above 0°k emit thermal radiation whose intensity and spectral composition are a function of material type and temperature of the object, According Stefan Boltzmann law, the energy radiate by an object at a particulartemperature is given by-

$M = \sigma T^4$Where, "σ" is the Stefan Boltzmann constant $5.67*10^{-11}$ $w/m^2/k^4$

"T"- absolute temperature "M"- (radiant existence) W/M^2

AS “M” various with forth power of “T”. The object even with close difference in temperature can be distinguished from remote sensing measurement.

A black body obeys this law, whereas natural bodies do not obey this law and a constant emissivity (έ) has to be introduced in the above equation.

$M = έ \sigma T4$ Where έ is the emissivity

The emissivity is a measure of the ability of a material both to radiate and to absorb energy and is define as-

- Energy actually emitted by unit area of surface in unit time at a given temperature
- Energy emitted by unit area of a black body in unit time at the same temperature.
- The emissivity of a black body is equal to 1 and all other materials have a value less than one.

2.4. Technical Termsin Thermalremote sensing

- **Kinetic Heat**– kinetic heat is the kinetic energy of particles of matter in random motion, which causes the particles to collide resulting in change of energy state and emission of E.M. radiation. The kinetic heat energy of the object thus converted in to radiant energy.
- **Radiant Flux**- the E.M. energy radiated from a source is called radiant flux and is measured in watts per square centimeter.
- **Kinetic Temperature**- the concentration of kinetic heat of a material is called kinetic and is measured by thermometer placed in direct contact with the material.
- The concentration of radiant flux of a body is called radiant temperature. This may be measured remotely by devices that detect E.M. radiation in thermal infrared region
- **Thermal Capacity-(C)**It is the ability of material to store heat and is define as the number of calories required to raise 1 gm of a material to 1°c and is expressed in calories/g/°c. Most metals have low value of c (approx 0.09), while many natural surface like vegetation, rock and soil have thermal capacity value of 0.2, and water has value of 1

2.5. EnergyExchange Theory

Heat energy istransferred from one place to another by three mechanisms;

- **Conduction** →Heat may be conducted directly from one object to another as when a pan is direct physical contact with a hot burner
- **Convection**→ Heat transfer through the physical movement of heated matter .the circulation of heated water and air example of convection.
- **Radiation** → Heat transfer in form of E.M. waves. Heat from the sun reaches the earth by radiation. It is primary interest to uses remote sensing science because it is only form energy transfer that can take place in vacuum such as the regionbetween the sun and the earth.

2.6. IR Region and ElectroMagnetic Spectrum

The IR region is that portion of the EM spectrum ranging in wave length from 0.7 to 1000 µm. The reflected IR region range from 0.7 to 3.0 µm and is dominated by reflected solar energy, Band 4, 5 & 7 of the LAND SAT TM recorded this region. The reflected IR region also includes the photographic IR band (0.7 to 0.9 µm)which may be detected by direct IR sensitive film.

IR radiation at wavelength of 3 to 14 µm is called the thermal IR regions

Thermal IR imagery is usually obtained in the wave length region.

(i) 3 to 5.5 µm range and

(ii) 8 to 14 µm range because of atmospheric absorption at other wave length.

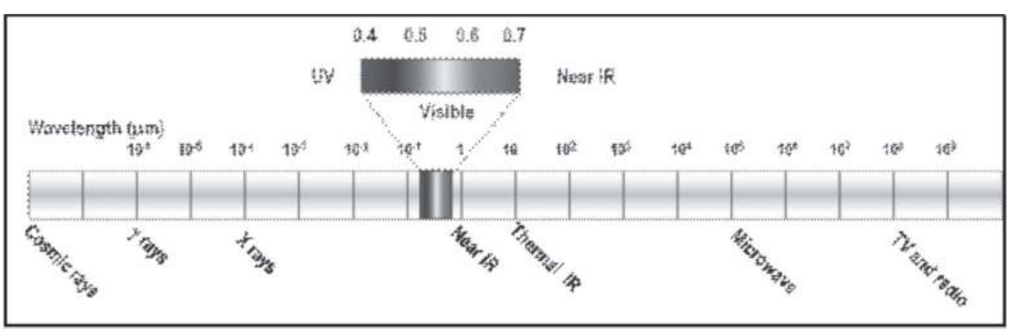


Figure 2.2 Electromagnetic Spectrum

1. Energy in g-ray, X-ray & UV region is absorbed by the earth's atmosphere, hence not used for remote sensing.
2. Spectral sensitivity of human eye extends from 0.4 to 0.7 µm
3. Remote sensing deals with energy in visible, infrared, thermal and microwave regions.
4. These regions are further subdivided into bands

2.7. Interaction of Thermal Radiation with Terrain Elements

In thermal remote sensing we are interested in the radiation emitted from terrain features.In the process the energy incident on the surface of a terrain element. Elements can be absorbed, reflected or transmitted. According with the principle of conservation of energy,we can state the relationship between incident energy and its disposition upon interaction with a terrain element as

$E_I = E_A + E_R + E_T$
Where:-
E_I=Incident Energy
E_A=Absorb Energy
E_R=Reflected Energy
E_T=Transmitted Energy

Energy Interactions with the Earth's Surface
Energy Balance Equation:

$E_I = E_R + E_A + E_T$

Incident = Reflected + Absorbed + Transmitted

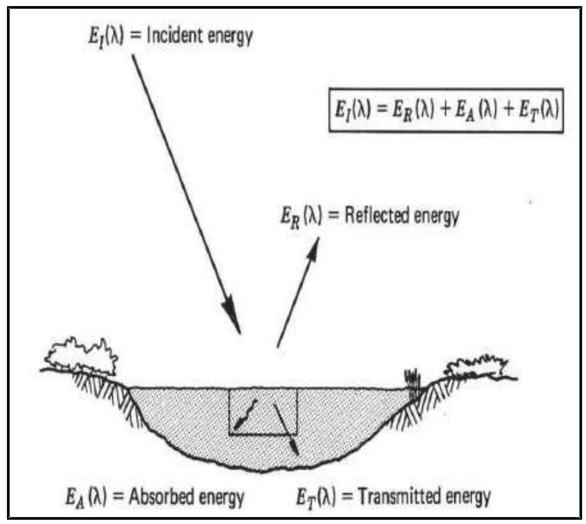


Figure 2.3 Showing Interactions mechanism

Interaction with matter can change the following properties of incident radiation.

Intensity, Direction, Wavelength, Polarization, Phase

This equation is divided by the quantity E_I

$$E_I / E_I = E_A / E_I + E_R / E_I + E_T / E_I$$

The terms on the right side of this equation comprise ratio that are convenient in further describing .We define this as

$\alpha(\lambda) = E_A / E_I$, $\rho(\lambda) = E_R / E_I$, $\tau(\lambda) = E_T / E_I$

We can now restate this equation in this form:-

$\alpha(\lambda)+\rho(\lambda)+\tau(\lambda)=1$

This equation defines the inter-relation among a terrain elements absorbing reflecting and transmitting properties.

According the Kirchhoff radiation law the spectral emissivity of an object equals its Spectralabsorbance

$$\acute{\varepsilon}(\lambda)=\alpha(\lambda)$$

if $\tau(\lambda)=0$

Thus According this

$$\alpha(\lambda)+\rho(\lambda)=1$$

This equation has direct relationship between an object emissivity and its reflectance in the thermal region of the spectrum. The lower an objects reflectance, the higher its emissivity

2.8. Factors Affecting Thermal Image Quality

Image quality depends upon three main group of factor

2.8.1 Ground Properties

Lateral variation in the relevant ground properties (namely, thermal properties such as thermal inertia, emissive etc. as may be) across the scene influences the radiometric image quality.

2.8.2 Environment Factors

a. **Solar Illumination and Time ofSurvey:-**Remote sensing data should be acquired at a time when energy condition is stable and optimum for detecting differences in ground properties. In the solar reflection region energy condition depend on the Azimuth and angle of sun elevation and the time go survey. Thermal-IR survey is usually carried out in the predawn hours when ground temperatures arequite stable.
b. **Path Radiance:-**Path radiance works as a background single and tends to reduce image contrast ratio. In the thermal-IR region, the major cause of path radiance is atmospheric emission; its effect can be minimized by confining sensing to atmospheric windows.

Digital techniques are also available for reducing the effects of path radiance and improvingthe image quality.

c. **Meteorological Factors:-**Meteorological factors such as rain, wind, cloud cover etc. may significantly alter the ground properties and influence response in the optical region.

For example- rain increases soil moisture, which alters ground Albino and thermal inertia.

d. **Atmospheric Factors:-**

A) AbsorptionandTransmission:-Energy is absorbed by various molecules in the AtmosphereOzone, water vapour and carbon dioxide are most efficient absorbersHalf of the spectrum between 0 – 22 m is not useful for RS.Optical RS: 0.4 – 2 m, Thermal: 3 – 5 m and 8 – 14 m

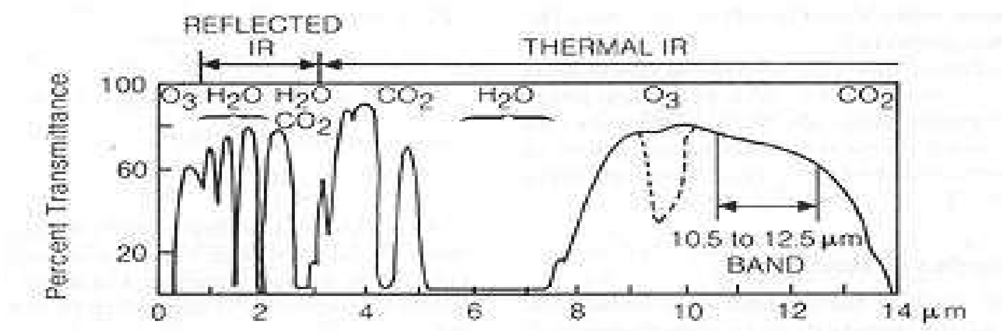


Figure2.4 Atmospheric windows

b) Atmosphericfactors:-The atmospheric has a significant effect on the on the intensity and spectral composition of the energy recorded by a thermal system. The effect that the atmosphere has on a ground signal will depend on the degree of atmospheric absorption, scatter and emission at the time and place of sensing. Gases and suspended particles in the atmosphere may absorb radiation emitted from ground object, resulting in a decrease in the energy reaching a thermal sensor.Dust, carbon particles, smoke and water droplets are also effect to thermal radiation.

2.8.3Sensor System Factors

a. **Effect of Optical Imaging System:-**The optical imaging component namely lenses, mirrors, prisms etc. are not absolutely perfect but real and therefore minor diffraction, aberrations etc. are present However, their effects are quite negligible.

b. Image Motion:-The relative moment of the sensor platform with respect to the ground being imaged during the period streaks on the image. Forward motion compensation (FMC) device have to be used for better result. FMC device may still be necessary in order to achieve high spatial resolution

c. Stripping:-When a series of detector elements is used for imaging a scene (e.g. in the case of Land sat MSS and TM or in CCD linear or area arrays), the radiometric response of all the detector elements may not be identical. This non identical response of all the causes striping and could lead to a serious duration in image quality

d.

2.9. Thermal IR image Sources

Several instruments are available for the remote acquisition of surface information in TIR region

The majority of them are Either Airborne or Space borne with a few field instruments.

- **Heat Capacity mapping Mission (HCMM)**= 10.5- 12.5 µm; Resolution 600m
- **Thermal Infrared Multispectral Scanner (TIMS)**= 6bands between 8-12 µm
- **NOAA AVHRR =** 5 bands; Resolution 1.1km
- **Landsat Thematic Mapper TM Band 6 =** 10.4 -12.5 µm; 60 m resolution
- **Advanced Space Borne Thermal Emission Reflectance Radiometer (ASTER) (Terra)**

  High Resolution Multispectral imager

  3 bands in VNIR (0.5- 1.0 µm); 15 meter

  6 bands in SWIR (1.0 -2.5 µm); 30 m resolution

  5 bands in TIR (8- 12 µm); 90 m resolution
- **ATLAS (Airborne Terrestrial Applications Sensor)**

  6 visible, 2 TM mid IR, and 6

  Thermal bands ranging from 8.2-12.5µm

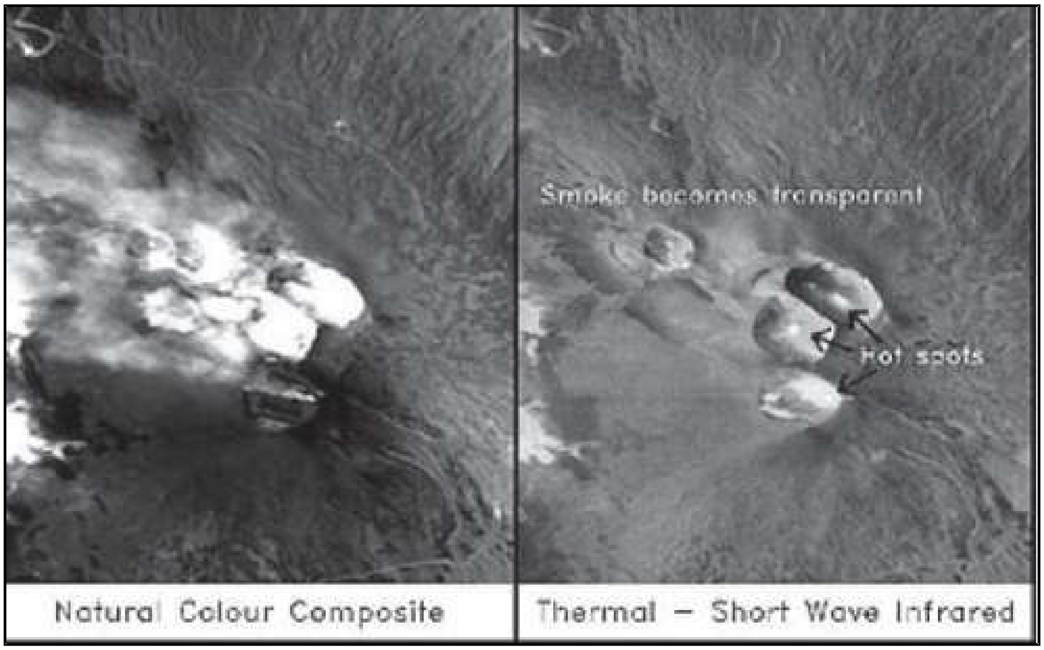


Figure2.5 Difference between NCC image and Thermal SWIR image

Check Your Progress

Q.1 What is Thermal Remote Sensing?

Q.2 What is Kinetic Heat?

Q.3 Fill in the blank.

a)The IR region is that portion of the EM spectrum ranging in wave length from ………….

b)………………..works as a background single and tends to reduce image contrast ratio

c) Thermal Infrared Multispectral Scanner (TIMS) …………...bands between 8-12 µm

Q. 4 True false against the following:

a)Heat transfer through the physical movement of heated matter .the circulation of heated water and air example of convection.

b)E.M. energy radiated from a source is called radiant flux and is measured in watts per square inch

Microwave RemoteSensing

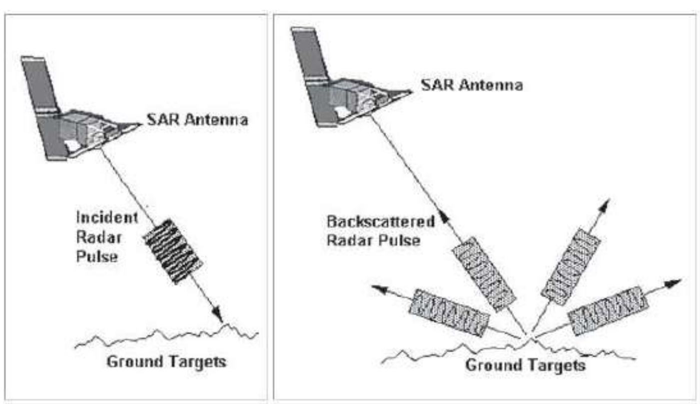
2.10.1 INTRODUCTION

Microwave remote sensinguse microwave radiation wavelength from about one centimeter to a few tens of centimeters enables observation in all weather conditions without any restriction by cloud or rain. This is an advantage that is not possible with the visible and /or infrared remote sensing. In addition , microwave remote sensing provides unique information on for example , sea wind and wave direction, which are derived from frequency characteristics, Doppler effect ,polarization , back scattering etc. that cannot be observed by visible and infrared sensors . However the need for sophisticated data analysis is the disadvantage in using microwave remote sensing

Synthetic aperture radar (SAR), microwave scatter meters, radar altimeters etc are active microwave sensors.

2.10.2. Synthetic Aperture Radar (SAR)

In synthetic aperture radar (SAR) imaging, microwave pulses are transmitted by an antenna towards the earth surface. The microwave energy scattered back to the spacecraft is measured. The SAR makes use of the radar principle to form an image by utilizing the time delay of the backscattered signals



A radar pulse is transmitted from the antenna to the ground	The radar pulse is scattered by the ground targets back to the antenna.

Figure 2.6Interaction s of radar pulse with earth surface

In real aperture radar imaging, the ground **resolution** is limited by the size of the microwave beam sent out from the antenna. Finer details on the ground can be resolved by using a narrower beam. The beam width is inversely proportional to the size of the antenna, i.e. the longer the antenna, the narrower the beam.

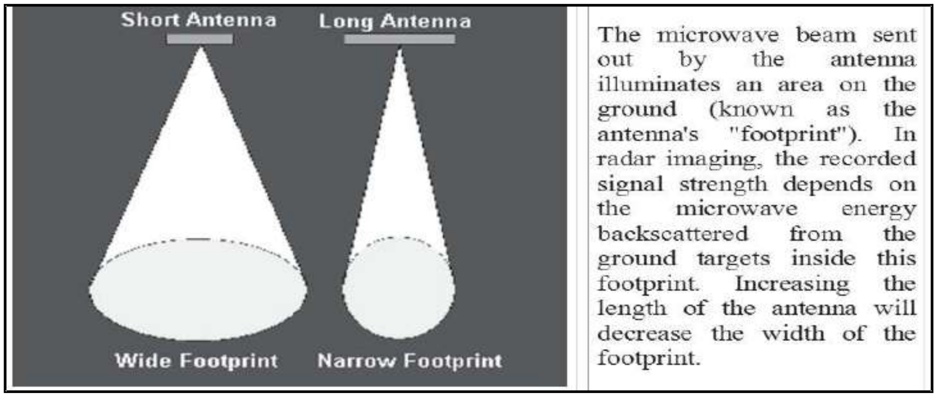
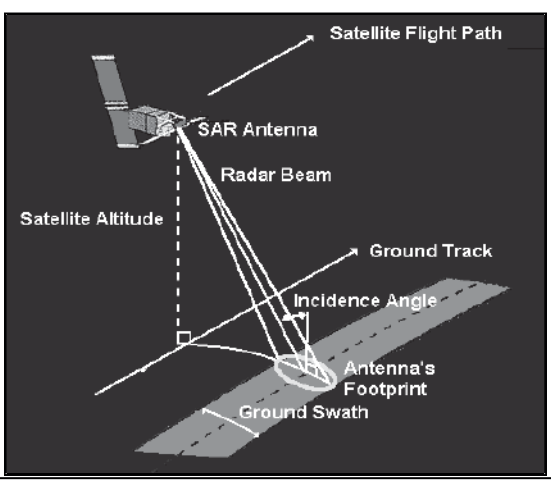


Figure 2.7

It is not feasible for a spacecraft to carry a very long antenna which is required for high resolution imaging of the earth surface. To overcome this limitation, SAR capitalizes on the motion of the space craft to emulate a large antenna (about 4 km for the ERS SAR) from the small antenna (10 m on the ERS satellite) it actually carries on board imaging geometry for a typical strip-mapping synthetic aperture radar imaging system. The antenna's footprint sweeps out a strip parallel to the direction of the satellite's ground track.



2.10.3. Interaction between Microwaves and Earth's Surface

When microwaves strike a surface, the proportion of energy scattered back to the sensor depends on many factors:

- Physical factors such as the dielectric constant of the surface materials which also depends strongly on the moisture content;
- Geometric factors such as surface roughness, slopes, orientation of the objects relative to the radar beam direction;
- The types of land cover (soil, vegetation or man-made objects).
- Microwave frequency, polarization and incident angle.

2.10.4. SAR Images

Synthetic Aperture Radar (SAR) images can be obtained from satellites such as ERS, JERS and RADARSAT. Since radar interacts with the ground features in ways different from the optical radiation, special care has to be taken when interpreting radar images.

An example of a ERSSAR image is shown below together with a SPOTmultispectralnatural colour composite image of the same area for comparison.

Figure 2.9 ERS SAR image (pixel size=12.5 m) SPOT multispectral image in natural color (Pixel size = 20m)

The urban area on the left appears bright in the SAR image while the vegetated areas on the right have intermediate tone. The clearings and water (sea and river) appear dark in the image. These features will be explained in the following sections. The SAR image was acquired in September 1995 while the SPOT image was acquired in February 1994. Additional clearings can be seen in the SAR image

2.10.5. Speckle Noise

Unlike optical images, radar images are formed by coherent interaction of the transmitted microwave with the targets. Hence, it suffers from the effects of **speckle noise** which arises from coherent summation of the signals scattered from ground scatterers distributed randomly within each pixel. A radar image appears noisier than an optical image. The speckle noise is sometimes suppressed by applying a **speckle removal filter** on the digital image before display and further analysis.

Figure 2.10 this image is extracted from the above SAR image showing the clearing areas between the rivers and the coastline. The image appears “grainy “due to the presence of speckles

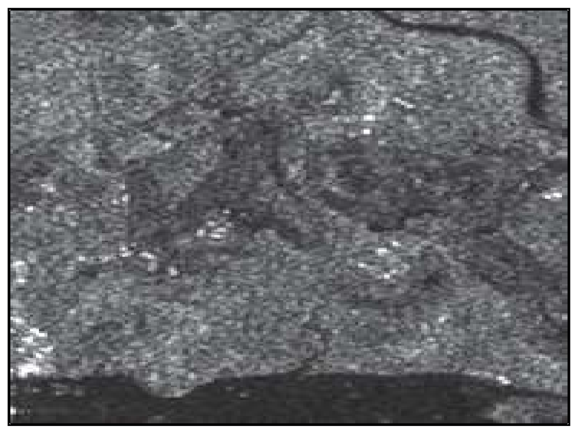
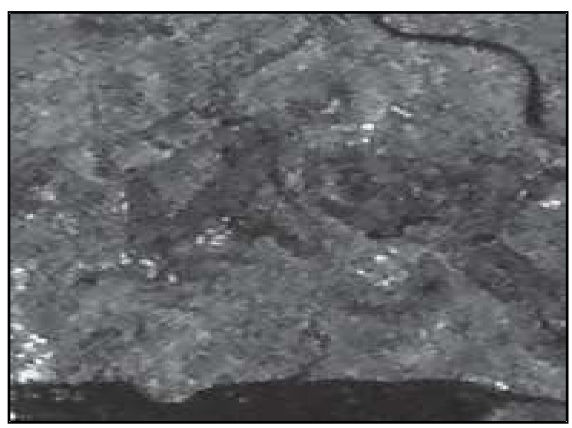


Figure 2.11 this image shows the effects of applying a speckle removal filter to the SAR image. The vegetated areas and the clearing now appear more homogeneous



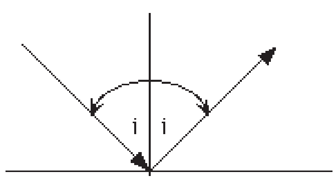
2.10.6. Backscattered Radar Intensity

A single radar image is usually displayed as a grey scale image, such as the one shown above. The intensity of each pixel represents the proportion of microwave backscattered from that area on the ground which depends on a variety of factors: types, sizes, shapes and orientations of the scatterers in the target area; moisture content of the target area; frequency and polarization of the radar pulses; as well as the incident angles of the radar beam. The pixel intensity values are often converted to a physical quantity called the backscattering coefficient or normalized radar cross-section measured in decibel (dB) units with values ranging from +5 dB for very bright objects to -40 dB for very dark surfaces.

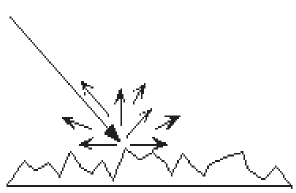
2.10.7. Interpreting SAR Images

Interpreting a radar image is not a straightforward task. It very often requires some familiarity with the ground conditions of the areas imaged. As a useful rule of thumb, the higher the backscattered intensity, the rougher is the surface being imaged

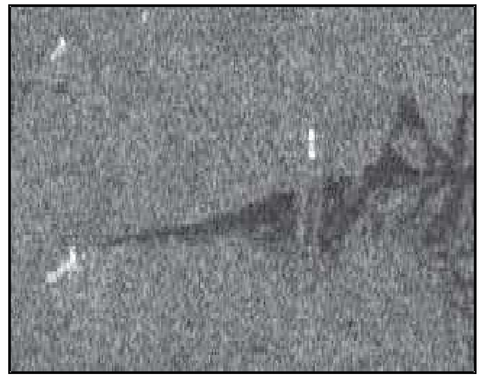
Flat surfaces such as paved roads, runways or calm water normally appear as dark areas in a radar image since most of the incident radar pulses are specularly reflected away.



Specular Reflection: A smooth surface acts like a mirror for the incident radar pulse. Most of the incident radar energy is reflected away according to the law of Specular reflection, i.e. the angle of reflection is equal to the angle of incidence. Very little energy is scattered back to the radar sensor.



Diffused Reflection: A rough surface reflects the incident radar pulse in all directions. Part of the radar energy is scattered back to the radar sensor. The amount of energy backscattered depends on the properties of the target on the ground.

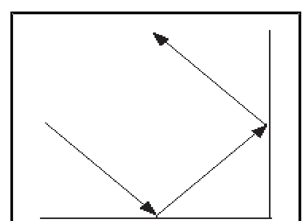


Calm sea surfaces appear dark in SAR images. However, rough sea surfaces may appear bright especially when the incidence angle is small. The presence of oil films smoothen out the sea surface. Under certain conditions when the sea surface is sufficiently rough, oil films can be detected as dark patches against a bright background.

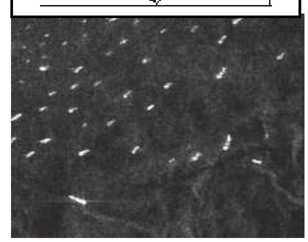
Figure 2.12a ship (bright target near the bottom left corner) is seen discharging oil into the sea in this ERS SAR image

Trees and other vegetations are usually moderately rough on the wavelength scale. Hence, they appear as moderately bright features in the image. The tropical rain forests have a characteristic backscatter coefficient of between -6 and -7 dB, which is spatially homogeneous and remains stable in time. For this reason, the tropical rainforests have been used as calibrating targets in performing radiometric calibration of SAR images.

Very bright targets may appear in the image due to the **corner-reflector** or **double-bounce** effect where the radar pulse bounces off the horizontal ground (or the sea) towards the target, and then reflected from one vertical surface of the target back to the sensor. Examples of such targets are ships on the sea, high-rise buildings and regular metallic objects such as cargo containers. Built-up areas and many man-made features usually appear as bright patches in a radar image due to the corner reflector effect.

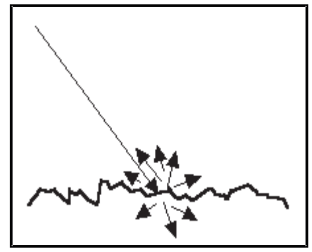


Corner Reflection: When two smooth surfaces form a right angle facing the radar beam, the beam bounces twice off the surfaces and most of the radar energy is reflected back to the radar sensor.

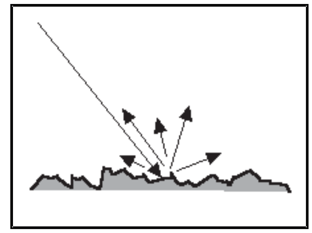


This SAR image shows an area of the sea near a busy port. Many ships can be seen as bright spots in this image due to corner reflection. The sea is calm, and hence the ships can be easily detected against the dark background. (Figure 2.13)

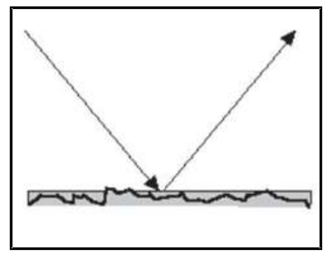
The brightness of areas covered by bare soil may vary from very dark to very bright depending on its roughness and moisture content. Typically, rough soil appears bright in the image. For similar soil roughness, the surface with higher moisture content will appear brighter.



Dry Soil: Some of the incident radar energy is able to penetrate into the soil surface, resulting in less backscattered intensity(Figure 2.14)



Wet soil: The large difference in electrical properties between water and air results in higher backscattered radar intensity(Figure 2.15)



Flooded soil: Radar is specularly reflected off the water surface, resulting in low backscattered intensity. The flooded area appears dark in the SAR image(Figure 2.16)

2.10.8Multi-Temporal SAR Images

If more than one radar images of the same area acquired at different time are available, they can be combined to give a multi-temporal colour composite image of the area. For example, if three images are available, then one image can be assigned to the Red, the second to the Green and the third to the Blue colour channels for display. This technique is especially useful in detecting landcover changes over the period of image acquisition. The areas where no change in landcover occurs will appear in grey while areas with landcover changes will appear as colourful patches in the image.

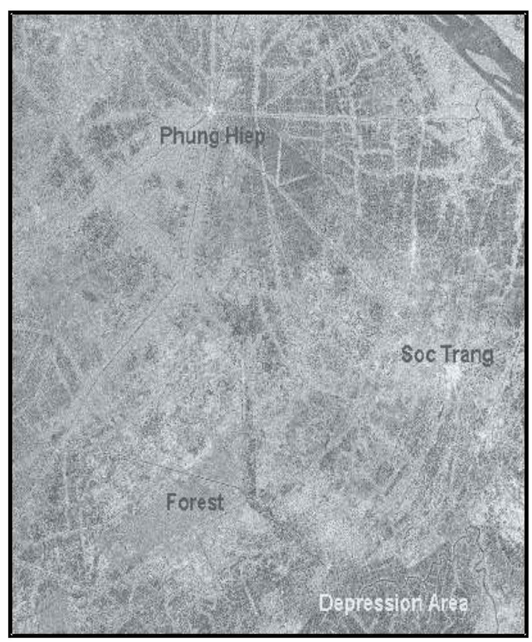


Figure 2.17Multi-Temporal Colour Composite SAR Image

This image is an example of a multi-temporal colour composite SAR image. The area shown is part of the rice growing areas in the Mekong River delta, Vietnam, near the towns of Soc Trang and Phung Hiep. Three SAR images acquired by the ERS satellite during 5 May, 9 June and 14 July in 1996 are assigned to the red, green and blue channels respectively for display. The colourful areas are the rice growing areas, where the landcovers change rapidly during the rice season. The greyish linear features are the more permanent trees lining the canals. The grey patch near the bottom of the image is wetland forest. The two towns appear as bright white spots in this image. An area of depression flooded with water during this season is visible as a dark region.

Check Your Progress

Q. 5 Fill in the blanks

a) Calm sea surfaces appear …………………in SAR images

b)Very bright targets may appear in the image due to the …………..

Q. 6 True false against the following.

a) SAR, microwave scatter meters, radar altimeters are active microwave sensors.

b) A single radar image is usually displayed as a grey scale image

Hyperspectral

2.11.1 INTRODUCTION

Recent advances in remote sensing and geographic information has led the way for the development of Hyperspectral sensors. Hyperspectral remote sensing, also known as imaging spectroscopy, is a relatively new technology that is currently being investigated by researchers and scientists with regard to the detection and identification of minerals, terrestrial vegetation, and man-made materials and backgrounds.

The concept of Hyperspectral remote sensing began in the mid-80 and to this point has been used most widely by geologists for the mapping of minerals. Actual detection of materials is dependent on the spectral coverage, spectral resolution, and signal-to-noise of the spectrometer, the abundance of the material and the strength of absorption features for that material in the wavelength region measured.

Hyperspectral remote sensing combines imaging and spectroscopy in single systems which often includes large data sets and require new processing methods. Hyperspectral data sets are generally composed of about 100 to 200 spectral bands of relatively narrow bandwidths (5-10 nm), Hyperspectral imagery is typically collected (and represented) as a data cube with spatial information collected in the X-Y plane, and spectral information represented in the Z-direction

2.11.2Differences between Hyperspectral and Multispectral Imaging

The distinction between hyper- and multi-spectral is sometimes based on an arbitrary "number of bands" or on the type of measurement, depending on what is appropriate to the purpose.Multispectral imaging deals with several images at discrete and somewhat narrow bands. Being "discrete and somewhat narrow" is what distinguishes multispectral in the visible from color photography. A multispectral sensor may have many

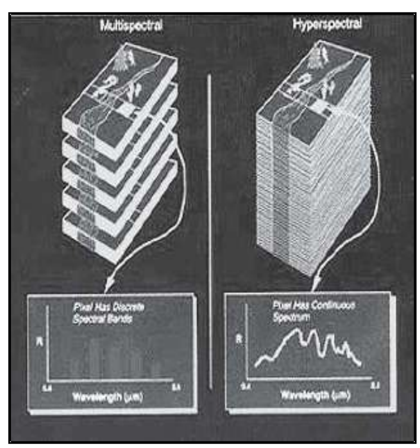


Fig: 2.18 Multispectral/ Hyperspectral comparison

Bands covering the spectrum from the visible to the longwave infrared Multispectral images do not produce the "spectrum" of an object. Landsat is an excellent example.

Hyperspectral deals with imaging narrow spectral bands over a continuous spectral range, and produce the spectra of all pixels in the scene. So a sensor with only 20 bands can also be Hyperspectral when it covers the range from 500 to 700 nm with 20 bands each 10 nm wide. (While a sensor with 20 discrete bands covering the VIS, NIR, SWIR, MWIR, and LWIR would be considered multispectral.)

2.11.3 Processing of Hyperspectral Imagery

Recent advances in sensor technology have led to the development of Hyperspectral sensors capable of collecting imagery containing several hundred bands over the spectrum. However, the increase in the number of bands is both a blessing and a curse. The large number of bands provides the opportunity for more materials to be discriminated by their respective spectral response. However, this large number of bands is the characteristic which leads to complexity in analysis techniques. The techniques described in the following sections are those which are widely used by the USGS, NASA's Jet Propulsion Laboratory, ENVI, and others. There are, however, other methods and algorithms to extract information from Hyperspectral sensors.

2.11.3.1. Radiometric Correction

Hyperspectral imaging sensors collect radiance data from either airborne or space borne platforms which must be converted to apparent surface reflectance before analysis techniques can take place. Atmospheric correction techniques have been developed that use the data themselves to remove spectral atmospheric transmission and scattered path radiance.

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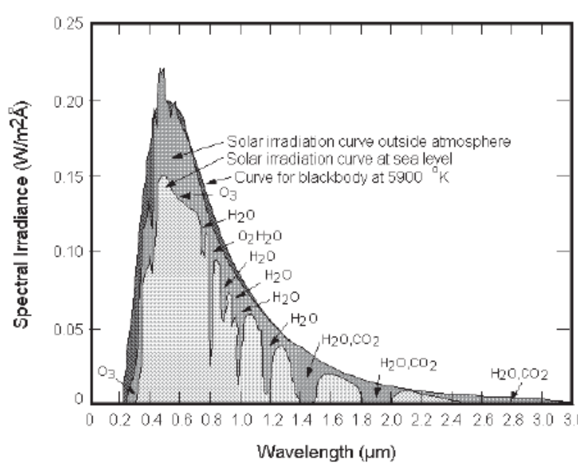


Figure 2.19 Solar spectrums with Atmospheric absorptions

The ATREM software was developed to determine the scaled surface reflectance from Hyperspectral imagery from both AVIRIS and HYDICE sensors. The atmospheric scattering used by ATREM is modeled after the MODTRAN 5S code. The ATREM software assumes that the surface is horizontal and has a Lambertian reflectance. If topography is known, then the scaled surface reflectance can be converted into real surface reflectance.

The ATREM model is a good approximation to radiometric correction of the imagery. However, calibration of the ATREM surface reflectance to *in situ* measurements should improve the final results. A by-product from the ATREM software is an image of the columnar water vapor which was removed from the input Hyperspectral data. The two figures below represent an AVIRIS frame prior to the ATREM correction and a water vapor scene removed from an AVIRIS scene which was acquired over the Kennedy Space Center on March 23, 1996. The images show a significant amount of water vapor removed from the imagery which causes attenuation of the upwelling radiance.

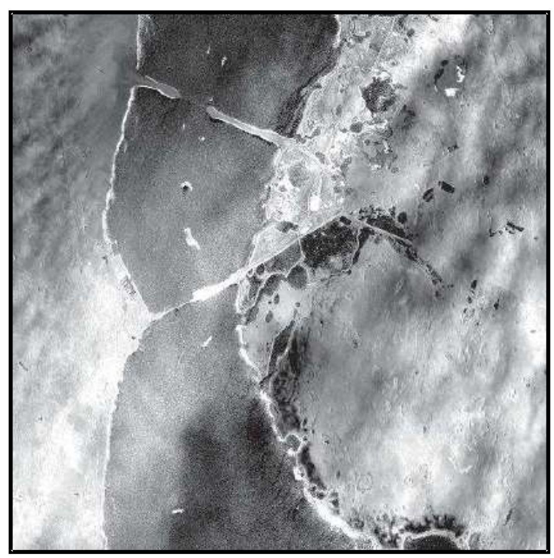


Figure2.20 OriginalAVIRIS Data Over KSC (Bands 20, 29 40)

Columnar Water Vapor Image Removed From AVIRISData Using ATREMProgram

2.11.3.2. Minimum Noise Fraction (MNF) Transformation

While Hyperspectral imagery is capable of providing a continuous spectrum ranging from 0.4 to 2.5 microns (in the case of AVIRIS) for a given pixel, it also generates a vast amount of data required for processing and analysis. Due to the nature of Hyperspectral imagery (i.e. narrow wavebands), much of the data in the 0.4-2.5 micron spectrum is redundant.

A minimum noise fraction (MNF) transformation is used to reduce the dimensionality of the hyperspectral data by segregating the noise in the data. The MNF transform is a linear transformation which is essentially two cascaded Principal Components Analysis (PCA) transformations. The first transformation decorrelates and rescales the noise in the data. This results in transformed data in which the noise has unit variance and no band to band correlations. [ENVI] The second transformation is a standard PCA of the noise-whitened data.

For this particular example, an AVIRIS frame over the Kennedy Space Center was radio-metrically corrected using ATREM and a MNF transformation was performed on the ATREM-corrected imagery. In this particular frame, the first 14 eigenvectors of the MNF transformation contain coherent information which can be used for further processing

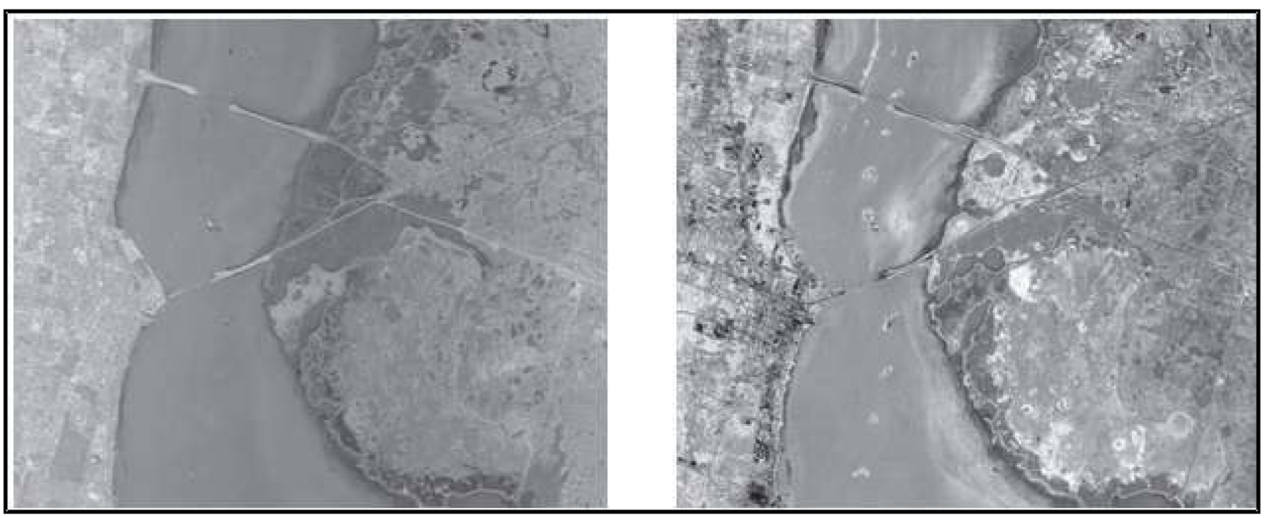


Figure 2.21Eigenvectors 1, 2, &Of MNF Transform Data Eigenvectors 6, 9, &12of MNF Transform Data

2.11.3.3. Pixel Purity Index

The Pixel Purity Index (PPI) is a prsocessing technique designed to determine which pixels are the most spectrally **unique** or **pure**. Due to the large amount of data, PPI is usually performed on MNF data which has been reduced to coherent images. The most spectrally pure pixels occur when there is mixing of end members. The PPI is computed by continually projecting n-dimensional scatter plots onto a random vector. The extreme pixels for each projection are recorded and the total number of **hits** is stored into an image. These pixels are excellent candidates for selecting end members which can be used in subsequent processing

2.11.4. Analysis of Hyperspectral Imagery

2.11.4.1. Spectral Angle Mapper Classification

The Spectral Angle Mapper Classification (SAM) is an automated method for directly comparing image spectra to known spectra (usually determined in a lab or in the field with a spectrometer) or an end member. This method treats both (the questioned and known) spectra as vectors and calculates the spectral angle between them. This method is insensitive to illumination since the SAM algorithm uses only the vector **direction** and not the vector **length**. The result of the SAM classification is an image showing the best match at each pixel. This method is typically used as a first cut for determining the mineralogy and works well in areas of homogeneous regions. The USGS maintains a large spectral library, mostly composed of mineral and soil types, which image spectra, can be directly compared.

2.11.4.2. Spectral Unmixing/Matched Filtering

Most surfaces on the earth, geologic or vegetated, are not homogeneous which results in a mixture of signatures characterized by a single pixel. Depending on how the materials are mixing on the surface results in the type of mathematical models capable of determining their abundances. If the mixing is rather large than the mixing of the signatures can be represented as a linear model. However, if the mixing is microscopic, then the mixing models become more complex andnon-linear

Matched filtering is based on a well known signal processing method and creates a quick means of detecting specific minerals based on matches to specific library or endmember spectra. The matched filtering algorithm maximizes the response of a known end member while suppressing the response of the background. The result of the matched filtering resembles the results from the linear unmixing methods and is usually represented as a grayscale image with values ranging from 0 to 1 which correspond the relative degree of the match.

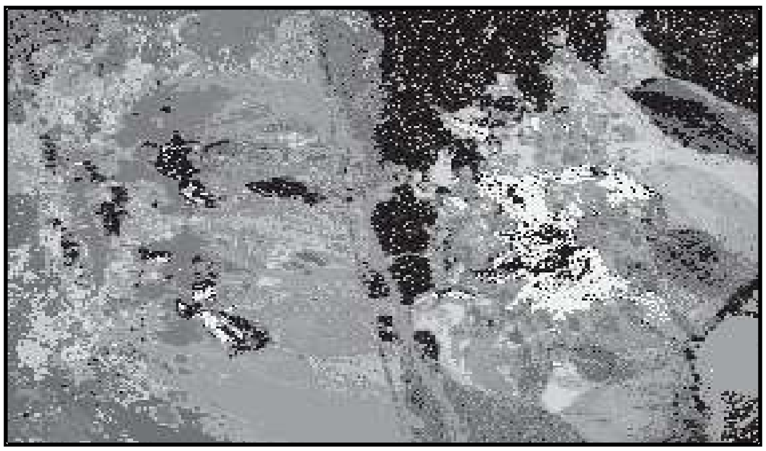


Figure 2.23 Classified Image of 1995 AVIRIS Frame Over Cuprite, Nevada Using Spectral Unmixing Techniques

Check Your Progress

Q.7. what is the Difference between Hyperspectral and Multispectral Image?

Q.8 Fill in the blank.

a)Hyperspectral data sets are generally composed of about …………….spectral bands of relatively narrow bandwidths (5-10 nm),

b)The ………………software was developed to determine the scaled surface reflectance from Hyperspectral imagery from both AVIRIS and HYDICE sensors

c) ………………..transformation is used to reduce the dimensionality of the Hyperspectral data by segregating the noise in the data.

LIDAR

2.12.1 INTRODUCTION

Lidar (light detection and ranging) has become an established method for collecting very dense and accurate elevation values. This active remote sensing technique is similar to radar but uses light pulses instead of radio waves. Lidar is typically "flown" or collected from planes (Figure 2.24) and produces a rapid collection of points (more than 70,000 per second) over a large collection area. Collection of elevation data using lidar has several advantages over most other techniques. Chief among them are higher resolutions, centimeter accuracies, and penetration in forested terrain.

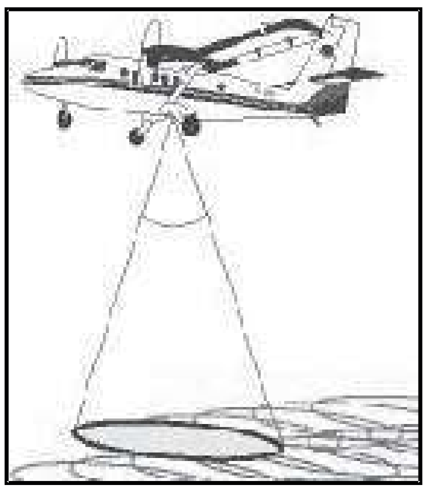


Figure 2.24 Airborne Lidar Schematic

2.12.1What Is Airborne Lidar?

Lidar, which is commonly spelled LiDAR and also known as LADAR or Laser Altimetry, is an acronym for light detection and ranging. It is analogous to radar (radio detection and ranging), except that it is based on discrete light pulses and measured travel times. The location and elevation of the reflecting surface are derived from 1) the time difference between the laser pulse being emitted and returned, 2) the angle that the pulse was 'fired' at, and 3) the location and height of the aircraft (i.e. the sensor location).Because the energy for measurement is generated by the sensor (i.e., the laser), lidar is defined as an active sensor. This allows lidar to becollected at night when the air is clearer and contains less air traffic than the daytime. In fact, most lidar data are collected at night, but unlike radar, lidar cannot penetrate clouds, rain, or dense haze and must be flown during fair weather. Lidar instruments can rapidly measure the Earth's surface, at sampling rates greater than 150 kilohertz (i.e., 150,000 pulses per second). The resulting product is a densely spaced network of highly accurate Georeferanced elevation points (Figure 2.25) often called a point cloud—that can be used to generate three-dimensional representations of the Earth's surface and its features. Bathymetric lidar, which uses a different laser (green vs. infrared wavelength), can be used in areas with relatively clear water to measure the seafloor elevation. Typically, lidar elevations are accurate to about 6 to 12 inches (15 to 30 centimeters) but have relative accuracies (e.g., heights of hills, banks, and dunes) that can be better than that.

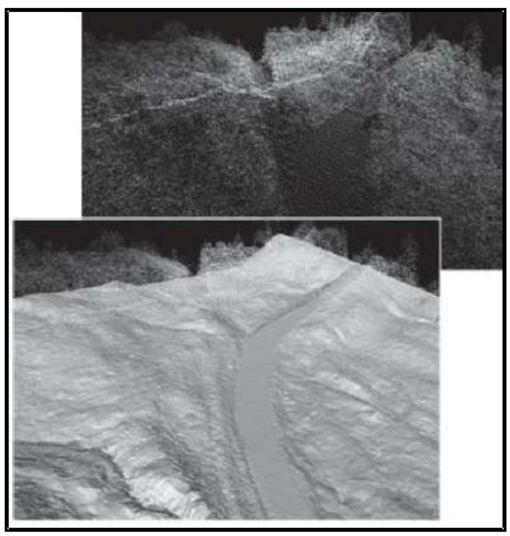


Figure2.25 Lidar point and surface products

The ability to "see under trees" is a reoccurring issue when acquiring elevation data using remote sensing data collected from above the Earth's surface (e.g., airplanes or satellites). Lidar is able to see through holes in the canopy or vegetation. Dense forests or areas with complete coverage (as in a rain forest), however, often have few "openings" and so have poor ground representation (i.e., all the points fall on trees). A rule of thumb is that if you can look up and see the sky through the trees, then that location can be measured with Lidar. For this reason,

Collecting lidar in "leaf off" conditions is advantageous for measuring ground features in heavily forested areas.

2.12.3 Basic Principles and Techniques

The basic idea (Figure 2.26) is fairly straightforward: measure the time that it takes a laser pulse to strike an object and return to the aircraft, which has a known location, determine the distance using the travel time, record the laser angle, and then, from this information, compute where the reflecting object (e.g., ground, tree, car, etc.) is located in three dimensions

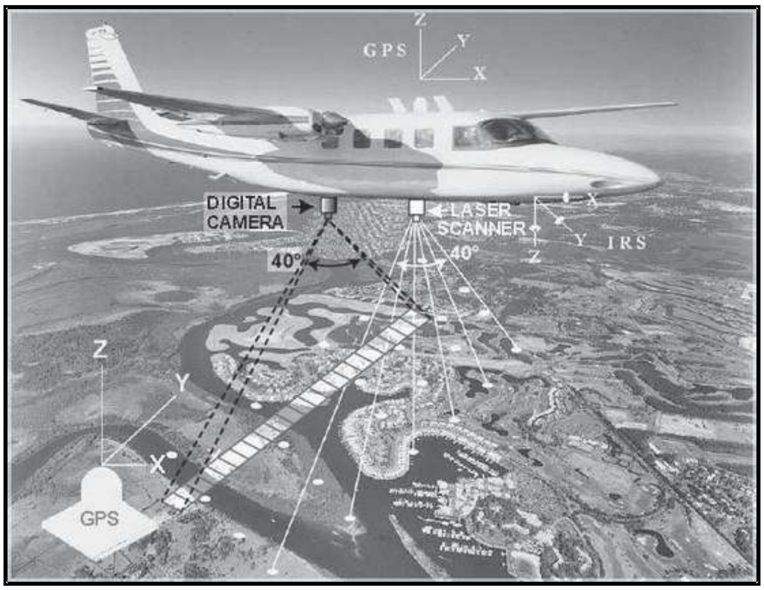


Figure 2.26 Basic Lidar Data Collection Schematic (Jie Shan, Purdue University)

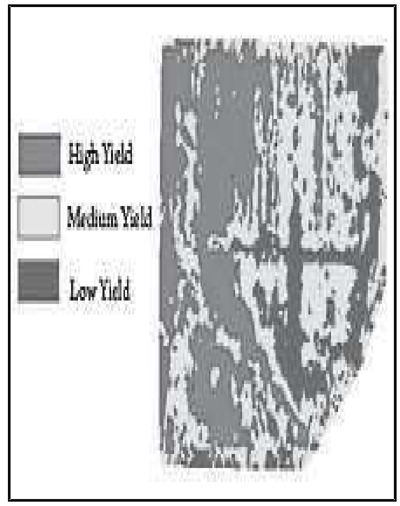
In reality, to achieve a high level of accuracy, this process is a bit more complicated since it is important to know, within a centimeter or so, where the plane is as it flies at 150 to 200 miles perhour, bumping up and down, while keeping track of 150,000 Lidar pulses per second. Fortunately several technologies-especially the Global Positioning System (GPS) and precision gyroscopes-came together to make it possible

Major advancements in Inertial Measuring Units (IMU) or Inertial Navigation Systems (INS) have been instrumental in making the exact positioning of the plane possible. These systems are Capable of measuring movement in all directions and parlaying these measurements into aposition. They are, however, not perfect and lose precision after a short time (e.g., 1 second). Avery high level GPS, which records several types of signals from the GPS satellites, is used to"update or reset" the INS or IMU every half of a second or so. The GPS positions are recordedby the plane and also at a ground station with a known position. The ground station provides a“correction” factor to the GPS position recorded by the plane.

2.12.4 Application

2.12.4.1Agriculture

LIDAR can be used to help farmers determine which areas of their fields to apply costly fertilizer. LIDAR can create a topographical map of the fields and reveals the slopes and sun exposure of the farm land. Researchers at the Agricultural Research Service blended this topographical information with the farm land’s yield results from previous years. From this information, researchers categorized the farm land into high-, medium-, or low-yield zones. This technology is valuable to farmers because it indicates which areas to apply the expensive fertilizers to achieve the highest crop yield.



2.12.4.2 Archaeology

LIDAR can also provide archaeologists with the ability to create high-resolution digital elevation models (DEMs) of archaeological sites that can reveal micro-topography that are otherwise hidden by vegetation. LiDAR-derived products can be easily integrated into a Geographic Information System (GIS) for analysis and interpretation.

2.12.4.3Geology and soil science

High-resolution digital elevation maps generated by airborne and stationary LIDAR have led to significant advances in geomorphology, the branch of geosciences concerned with the origin and evolution of Earth's surface topography. LIDAR's abilities to detect subtle topographic features such as river terraces and river channel banks, measure the land surface elevation beneath the vegetation canopy, better resolve spatial derivatives of elevation, and detect elevation changes between repeat surveys have enabled many novel studies of the physical and chemical processes that shape landscapes.

2.12.4.4 Forest and Tree Studies

A very costly and time-consuming aspect of timber management is the effort spent in the field measuring trees (Figure 1-6). Typically a sample of trees is measured for a number of parameters and the results are statistically extrapolated throughout the harvest area. Trees must be measured to determine how much wood is present, when it is most appropriate to harvest, and how much to harvest.

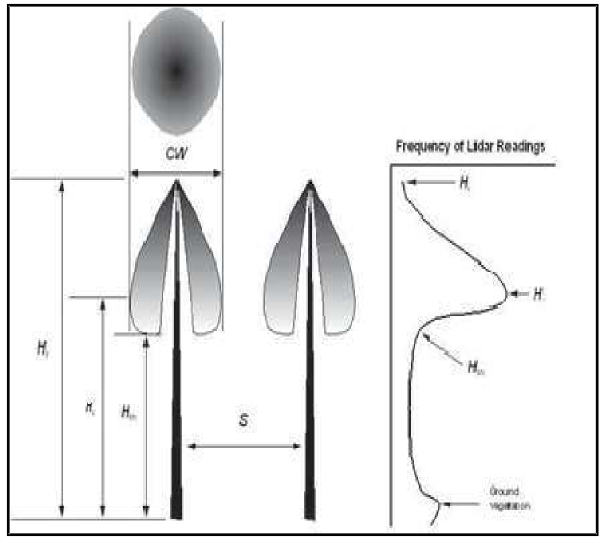


Figure 2.28 Tree Canopy Information (H = Height, CW = Crown Width, S = Spacing)
Gathered from Lidar (from Mississippi State University)

Check your Progress

Q.9. what is Lidar?

Q.8 Fill in the blank.

a) Lidar instruments can rapidly measure the Earth’s surface, at sampling rates greater than …………… kilohertz

b)…………… have been instrumental in making the exact positioning of the plane possible

c)LIDAR can create a …………….map of the fields and reveals the slopes and sun exposure of the farm land

5. Summary

This unit covered different techniques of Advance remote sensing, in which explain all basic concept ofthermal, microwave, Hyperspectral and lider remote sensing's techniques and their applications

6. Glossary

- **Across Track**-An across-track sensor is one that uses a mirror system that moves from side to side in the range to obtain remote sensing data.
- **Along-Track: -**An along-track sensor is made up of a linear detector array of CCDs (Charge Coupled Device) that obtains data in the platform's direction of motion
- **Beam: -**A focused pulse of energy. The antenna beam of a side-looking radar (SLAR) is directed perpendicular to the flight path and illuminates a swath parallel to the platform ground track
- **Circularly Polarized Antenna:-**An antenna that is designed to radiate a left-hand or right-hand circularly polarized electromagnetic wave in its far field.
- **Co-Polarization Maxima** The antenna polarization state for which maximum backscattered power is received from a particular target. For co-polarization, transmit and receive antennas are the same.
- **Radar Angles: -** A radar echo from a region where there are no visible targets; may be caused by insects, birds, or refractive index variations in the atmosphere.

Answer to check your progress/Possible Answers to SAQ

Ans 1. Two surfaces may have very similar reflected characteristics within in visible and infrared part of E.M. spectrum and may not be distinguishable, but they may be distinguished in thermal infrared spectrum. Objects radiate energy as a function of their temperature in thermal infrared wavelength. This emitted energy may be remote sensed using thermal sensor in the wavelength range from 3 to 14 µm. its generally record broad spectral bands typically 8.0 to 14 µm for image from aircraft and 10.5to 12.0 µm for image from satellites.

Ans .2kinetic heat is the kinetic energy of particles of matter in random motion, which causes the particles to collide resulting in change of energy state and emission of E.M. radiation. The kinetic heat energy of the object thus converted in to radiant energy

Ans 3.(a). 0.7 to 1000 µm , **(b)** Path radiance , **(c)** 6

Ans4. **(a)** True **(b)** False

Ans5. **(a).** Dark, **(b)** . Corner-reflector

Ans 6. **(a). True** **(b)** True

Ans.7.A multispectral sensor may have manyBands covering the spectrum from the visible to the long wave infrared Multispectral images do not produce the "spectrum" of an object. Landsat is an excellent example.

Hyperspectral deals with imaging narrow spectral bands over a continuous spectral range, and produce the spectra of all pixels in the scene. So a sensor with only 20 bands can also be Hyperspectral when it covers the range from 500 to 700 nm with 20 bands each 10 nm wide. (While a sensor with 20 discrete bands covering the VIS, NIR, SWIR, MWIR, and LWIR would be considered multispectral.)

Ans.8.(a).100 to 200 **(b)** ATRM **(c)**Minimum Noise Fraction

Ans9. Lidar (light detection and ranging) has become an established method for collecting very dense and accurate elevation values. This active remote sensing technique is similar to radar but uses light pulses instead of radio waves. Lidar is typically “flown” or collected from planes and produces a rapid collection of points (more than 70,000 per second) over a large collection area.

Ans10. **(a)** 150**(b)**Inertial Navigation Systems **(c)**Topographical

7. Suggested Readings

1. Thermal Remote Sensing in Land Surface Processes (Dale A. Quattrochi, Jeffrey C. Luvall)

2. Hyperspectral Remote Sensing: Principles and Applications (Marcus Borengasser , William S. Hungate , Russell L. Watkins

3. Microwave Remote Sensing: From theory to applications (Fawwaz Tayssir Ulaby, Richard K. Moore, and Adrian K. Fung)

8. References

1. Remote sensing of the environment [John R. Jensen]

2. Remote sensing Geology [Ravi P. Gupta]

3. Remote sensing and image interpretation [Lillsand and Kiefer]

4. Remote sensing principles and interpretation [Floyd F. Sabins]

5.http://www.csr.utexas.edu/projects/rs/hrs/hyper.html#background

6. http://www.csc.noaa.gov/digitalcoast/data/coastallidar/_pdf/What_is_Lidar.pdf

7. http://www.ferris.edu/faculty/burtchr/papers/lidar_principles.pdf

8.http://www.nps.edu/academics/centers/remotesensing/Presentations/Lidar%20Presentations/IntroductiontoLIDAR.pdf

9. http://www.sarusersmanual.com/ManualPDF/NOAASARManual_CH01_pg001-024.pdf

10.http://www.jars1974.net/pdf/04_Chapter03.pdf

8. TerminalQuestions

Q1. Explain energy exchange theory

Q2.How Stefan boltzman n law work?

Q3. What happen when thermal radiation interacts with earth surface?

Q4.Write down the SAR satellites name

Q5 what is speckle noise

Q6.Differences between Hyperspectral and multispectral imaging

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Digital Image Processing

3.1. INTRODUCTION

In today's world of advanced technology where most remote sensing data are recorded indigital format, virtually all image interpretation and analysis involves some element of digitalprocessing. Digital image processing may involve numerous procedures including formattingand correcting of the data, digital enhancement to facilitate better visual interpretation, or evenautomated classification of targets and features entirely by computer. In order to processremote sensing imagery digitally, the data must be recorded and available in a digital formsuitable for storage on a computer tape or disk. Obviously, the other requirement for digitalimage processing is a computer system, sometimes referred to as an **image analysissystem**, with the appropriate hardware and software to process the data. Severalcommercially available software systems have been developed specifically for remote sensingimage processing and analysis.

For discussion purposes, most of the common image processing functions available in imageAnalysis systems can be categorized into the following four categories:

- Preprocessing
- Image Enhancement
- Image Transformation
- Image Classification and Analysis

In first Semester (unit-1) already discuss on Image Transformation and Image classification, so in this Unit-2 we will cover Image Enhancement Techniques

3.2Objective

After going through this unit the learner will able to learn:

- Understand Image Enhancement Techniques
- Radiometric correction , Atmospheric correction

- Advance Technique of spectral Ratioing

3.3. Image Enhancement

Enhancements are used to make it easier for visual interpretation and understanding ofimagery. The advantage of digital imagery is that it allows us to manipulate the digital pixelvalues in an image. The contraststretch, density slicing, edge enhancement, and spatial filtering are the more commonly usedtechniques. Image enhancement is attempted after the image is corrected for geometricand radiometric distortions. Image enhancement methods are applied separately to eachband of a multispectral image. Digital techniques have been found to be most satisfactorythan the photographic technique for image enhancement, because of the precision and wideVariety of digital processes

3.3.1Contrast Enhancement

Contrast generally refers to the difference in luminance or grey level values in animage and is an important characteristic. It can be defined as the ratio of the maximumintensity to the minimum intensity over an image.

$$C = \frac{I_{max}}{I_{mix}}$$

Contrast ratio has strong bearing on the resolving power and delectability of an image .Larger this ratio, more easily it is to interpret the image

Contrast enhancement techniques expand the range of brightness values in an imageso that the image can be efficiently displayed in a manner desired by the analyst. Thedensity values in a scene are literally pulled farther apart, that is, expanded over a greaterrange. The effect is to increase the visual contrast between two areas of differentuniform densities. This enables the analyst to discriminate easily between areas initiallyhaving a small difference in density

Contrast enhancement can be effected by a linear or non linear transformation.

3.3.1.1. Linear Contrast Stretch

This is the simplest contrast stretch algorithm. The grey values in the originalimage and the modified image follow a linear relation in this algorithm. A density number inthe low range of the original histogram is assigned to extremely black, and a value at thehigh end is assigned to extremely white. The remaining pixel values are distributed linearlybetween these extremes. The features or details that were obscure on the original imagewill be clear in the contrast stretched image.In exchange for the greatly enhanced contrast of most original brightness values,there is a trade off in the loss of contrast at the extreme high and low density numbervalues. However, when compared to the overall contrast improvement, the contrast lossesat the brightness extremes are acceptable trade off, unless one was specificallyinterested in these elements of the scene.

The equation Y = ax+b performs the linear transformation in a linear contraststretch method. The values of 'a' and 'b' are computed from the equations

a = (Ymax - Ymin)/Xmax - Xmin

b = (Xmax Ymin - Xmin Ymax)/Xmax - Ymin

Where X = Input Pixel valueY = Output pixel value

X max,Xmin are the maximum and minimum in the input data values. Y max, Ymin are the maximum and minimum values in the output data values X max, Xmin values can be obtained from the scence histogram. Histograms are commonly used to display the frequency of occurrence of brightness values. Ymax, ymin are usually fixed at 0 and 255 respectively.

When y_{max},y_{min} take the values 0 and 255, the above equation reduces to

X - Xmin

Y =------------. 255

Xmax – Xmin

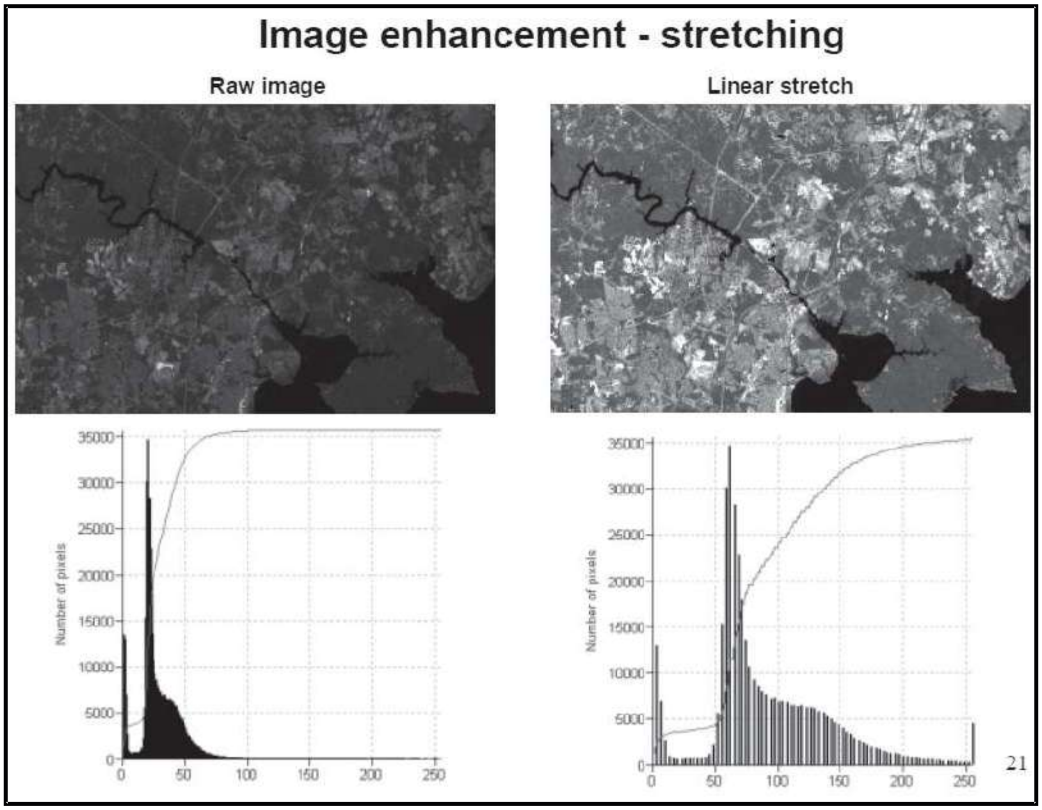


Figure 3.1Linear Contrast Stretch Operation

3.3.1.2. Non-Linear Contrast Enhancement

In these methods, the input and output data values follow a non-lineartransformation. The general form of the non-linear contrast enhancement is defined by y =f (x), where x is the input data value and y is the output data value. The non-linear contrastenhancement techniques have been found to be useful for enhancing the color contrastbetween the nearly classes and subclasses of a main class.The use of non-linear contrast enhancement is restricted by the type ofapplication. Good judgment by the analyst and several iterations through the computer areusually required to produce the desired results.

A type of non linear contrast stretch involves scaling the input data logarithmically. This enhancement has greatest impact on the brightness values found in the darker part ofhistogram. It could be reversed to enhance values in brighter part of histogram by scalingthe input data using an inverse log function. (Refer figure3.2).

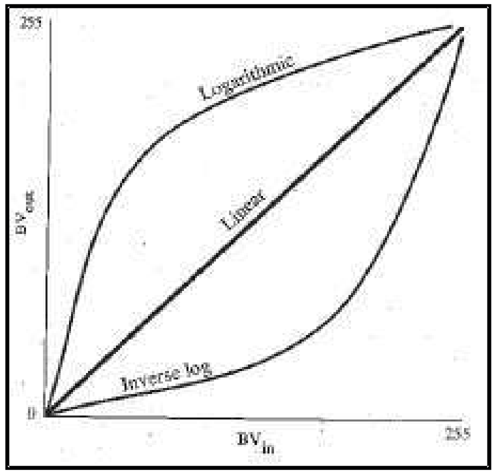


Figure 3.2 Non –Linear Logarithmic and Inverse Log Contrast Stretch Algorithms

3.3.1.3. HistogramEqualization

This is another non-linear contrast enhancement technique. In this technique,histogram of the original image is redistributed to produce a uniform population density.This is obtained by grouping certain adjacent grey values. Thus the number of grey levels inthe enhanced image is less than the number of grey levels in the original image

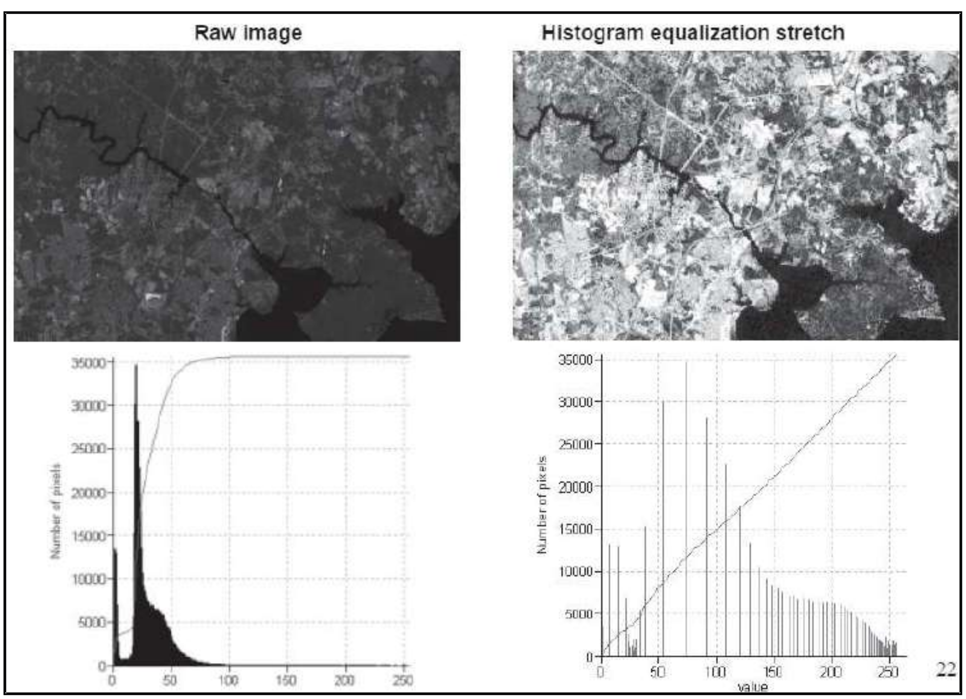


Figure 3.3 Image Enhancement-Histogram Equalization -Stretch

3.4. SpatialFiltering

Encompassesanother set ofdigital processingfunctions whichare used toenhance theappearance of animage. Spatial filters are designed to highlight or suppress specific features in an image basedon their **spatial frequency**. Spatial frequency is related to the concept of image texture. It refers to the frequency of the variations in tone that appear inan image. "Rough" textured areas of an image, where the changes in tone are abrupt over asmall area, have high spatial frequencies, while "smooth" areas with little variation in toneover several pixels, have low spatial frequencies.

3.4.1. SpatialFiltering Convolution

In convolution Procedure**,**moving a 'window' of a few pixels in dimension (e.g. 3x3, 5x5, etc.) over each pixel in theimage, applying a mathematical calculation using the pixel values under that window, andreplacing the central pixel with the new value (figure3.4) The window is moved along in both the row andcolumn dimensions one pixel at a time and the calculation is repeated until the entire imagehas been filtered and a "new" image has been generated.

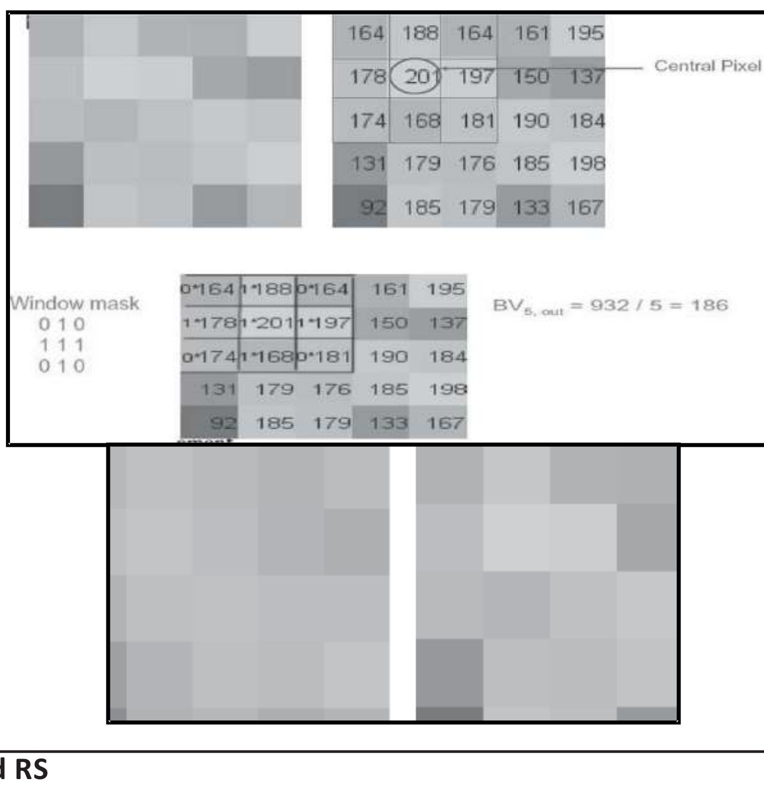


Figure 3.4Spatial Filtering Convolution Functions

3.4.2 Low-Pass Filter

A Low-pass filteris designed to emphasize larger, homogeneous areas of similar tone and reduce the smaller detail in an image. Thus, low-pass filters generally serve to smooth the appearance of an image. Average and median filters, often used for radar imagery, are examples of low-pass filters

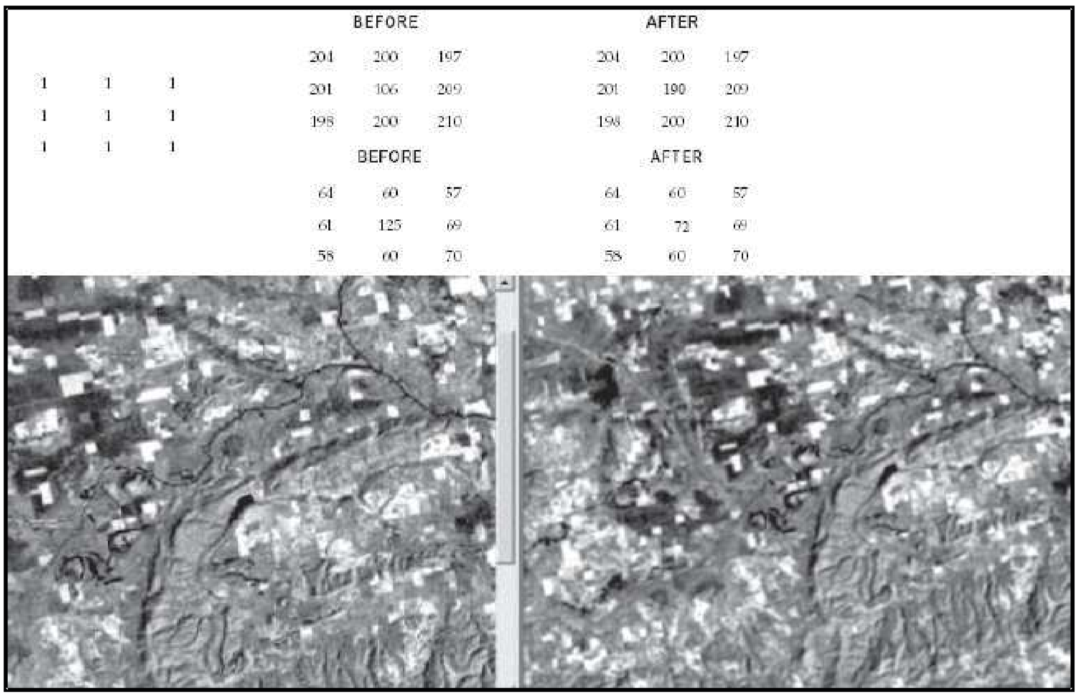


Figure 3.5.Low Pass Filter- Image Smoothing

3.4.3. High-Pass Filter

In high-pass filtersdo the opposite and serve to sharpen the appearance of fine detail in an image. One implementation of a high-pass filter first applies a low-pass filter to an image and then subtracts the result from the original, leaving behind only the high spatial frequency information. Directional, or edgedetection filters are designed to highlight linear features, such as roads or field boundaries. These filters can also be designed to enhance features which are oriented in specific directions. These filters are useful in applications such as geology, for the detection of linear geologic structures.

-1	-1	-1
-1	16	-1
-1	-1	-1

BEFORE			AFTER		
204	200	197	204	200	197
201	106	209	201	9	209
198	200	210	198	200	210

BEFORE			AFTER		
64	60	57	64	60	57
61	125	69	61	187	69
58	60	70	58	60	70

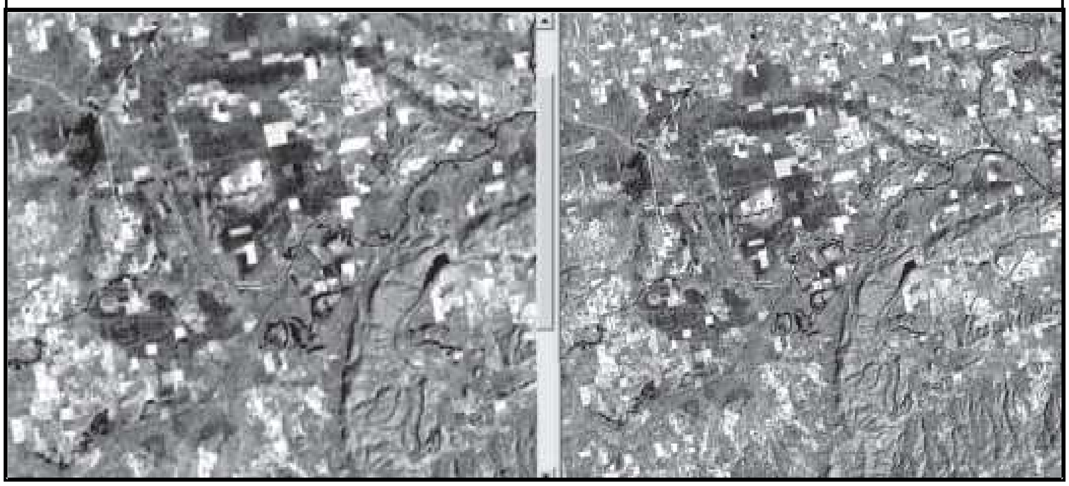


Figure 3.6(a).High Pass Kernel-ImageSharpening

-1 2 -1
-1 2 -1
-1 2 -1

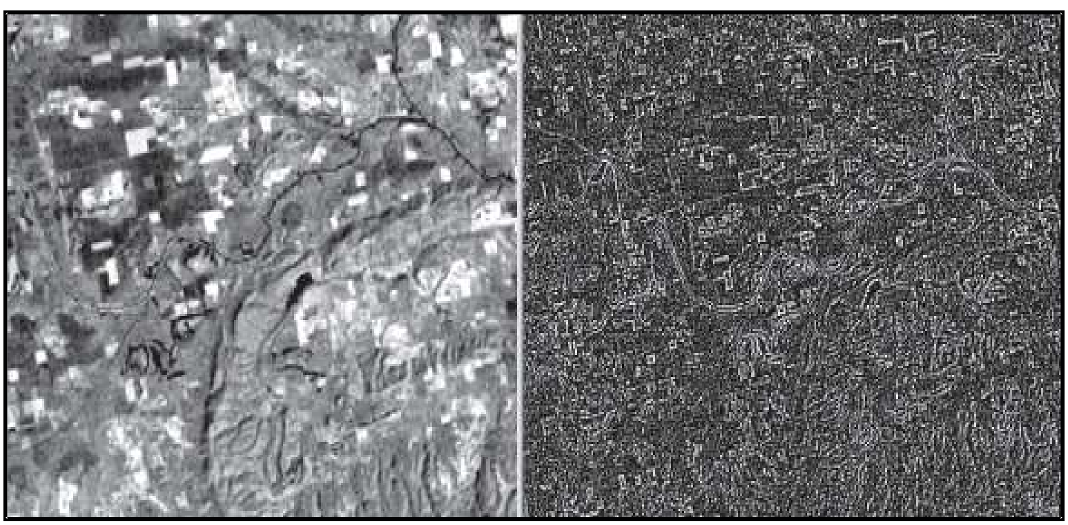


Figure 3.6(b).High Pass Kernel-Edge Detection

Check Your Progress

Q.1 What is ImageEnhancements?

Q.2 What isLow-pass filter?

Q.3 Fill in the blank.

a)Spatial filters are designed to highlight or suppress specific features in an image basedon their **…………………..**

b)In Histogram Equalizationthe original image is redistributed to produce a uniform population **…………………**

Q. 4 True false against the following:

a)Contrast generally refers to the difference in luminance or grey level values in animage and is an important characteristic.

b)A type of linear contrast stretch involves scaling the input data logarithmically

3.5. Radiometric Correction

Radiometric errors are caused by detector imbalance and atmospheric deficiencies. Radiometric corrections are transformations on the data in order to remove errors, which are geometry independent. Radiometric corrections are also called as cosmetic corrections and are done to improve the visual appearance of the image. Multiple detectors are used in the sensor system to simultaneously sense several image lines during each sweep of the mirror. This configuration requires an array of 24 detectors (6 lines x 4 bands) in case of MSS. As the detectors are not precisely equivalent in their output characteristics, their output changes gradually over time. Due to these variations there will be different output for the same ground radiance

To accomplish this, the scanner views an electrically illuminated step wedge filter during each mirror sweep. Once per orbit, the scanner views the sun to provide a more absolute calibration. These calibration values are used to develop radiometric correction functions for each detector. The correction functions yield digital numbers that correspond linearly with radiance and are applied to all data prior to dissemination. Some of the radiometric distortions are as follows

(1) Correction for missing lines (2) correction for periodic line striping (3) random noise correction (4) atmospheric correction

3.5.1.CorrectionforMissing Scan Lines (ScanLine Drop Out)

Although detectors onboard orbiting satellites are well tested and calibrated before launch,breakdown of any of the detectors may take place. Such defects are due to errors in thescanning or sampling equipment, in the transmission or recording of image data or inreproduction of CCT's. The missing scan lines are seen as horizontal black (pixel value 0) orwhite (pixel value 255) lines on the image. Techniques are available to locate these bad linesby selecting unusually large(**Figure3.7 Example of missing**

scanline)discrepancies in image values for sequential lines. The first stepin the restoration process is to calculate the average DN value per scan line for entirescene. The average DN value for each scan line is then compared with scene average. Anyscan line deviating from the average bymore than a designated threshold value is identifiedas defective. Once detected, they may be cosmetically corrected in three ways:

3.5.1.1.Replacement by Preceding or Succeeding Line

This is the simplest method for estimating the pixel value along a dropped scan line, itInvolves replacement of the value of the missing scan line by the value of the correspondingPixel on immediately preceding or succeeding scan line

$V_{i,j} = V_{i,j-1}$ or $V_{i,j} = V_{i,j+1}$

Where $V_{i,j}$ = missing pixel value of pixel i scan line j

$V_{i,j-1}$ = pixel value of pixel i and scan line j-1 (preceding), and

$V_{i,j+1}$ = pixel value of pixel i and scan line j+1 (succeeding)

3.5.1.2.Averaging Method

The missing scan line is replaced by the average value of the corresponding pixel on Immediately preceding and succeeding line.

$V_{i,j}=V_{i,j-1} + V_{i,j+1} / 2$

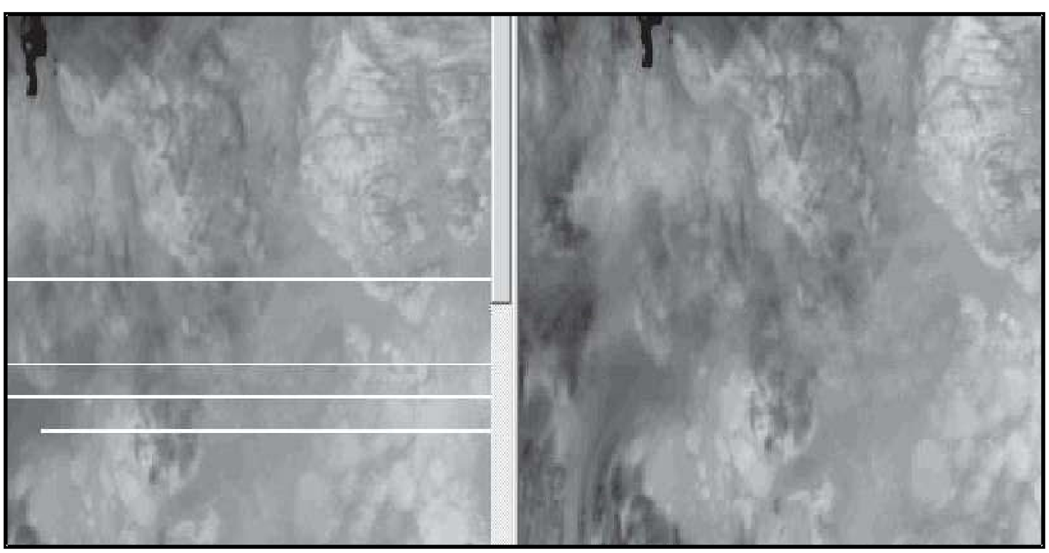


Figure3.8.DNs of Bad Lines Are Obtained As Average ofthe Neighbouring DN

3.5.1.3. Replacement with Correlated Band

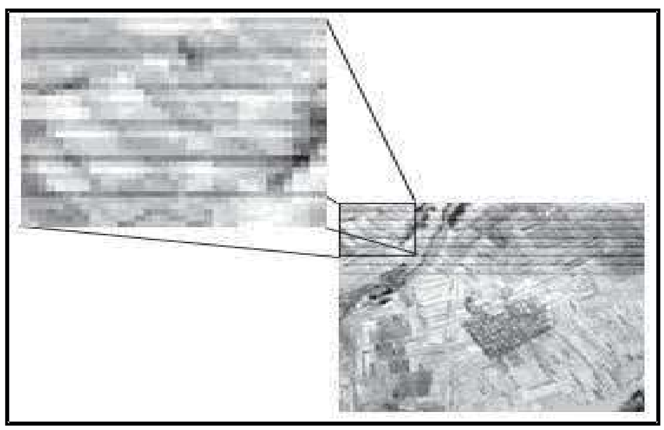
This method relies on the fact that spectral bands in the same region of the spectrum arehighly correlated. For e.g. Landsat-3 MSS band 4[green] and band 5[red] are highlycorrelated. The missing pixels in band k is estimated by considering contributions from theequivalent pixels in the same band in another highly correlated band and neighbouring pixelsin the same band. If highly correlated band were denoted by subscript r then algorithm canbe represented by

$$V_{i,j,k} = M [V_{i,j,r} - (V_{i,j+1,r} + V_{i,j-1,r}) /2 + (V_{i,j+1,k} - V_{i,j-1,k}) /2]$$

Where M =□k /□r

3.5.2. Correctionfor Line Striping (De-Stripping)

A sensor is called ideal when there is a linear relationship between input and the output. Although all the detectors are well calibrated prior to the launch, the response of some ofthe detectors may shift towards lower or higher end. The presence of a systematichorizontal banding pattern is frequently seen on images produced by electronic scannerssuch as MSS sixth line banding and on TM sixteenth line banding.**(Figure3.9 Example of Line stripping)** Banding is a cosmeticdefect and it interferes with the visual appreciation of the patterns and features on theimage. Hence corrections for these bandings are to be applied to improve the visualappearance and interpretability of the image. Two methods of de-stripping are considered,both these methods are based upon the shape of the histograms of pixel values generatedby the individual detectors in a particular band



3.5.2.1. Linear Method

This method uses a linear expression to model the relationship between input and outputvalues. It assumes that mean and standard deviation of data from each detector should besame. Detector imbalance is the only factor producing the differences in means andstandard deviations. To get rid of this effect due to detector imbalance, the means andstandard deviations of the six (MSS) histograms are equalized i.e. forced to equal thestandard deviation of the whole image

The overall standard deviation is given by

$$\sigma = \sqrt{\frac{\Sigma n_i (\bar{x}_i^2 + v_i)}{\Sigma n_i} - \bar{x}^2}$$

Where

$\bar{x}$ = overall mean ($\Sigma \bar{x}_i / 6$)

$\bar{x}_i$ = mean of detector i

v_i = variance of detector i

n_i = no. of pixels processed by detector i

3.5.2.2. Histogram Matching (Non Linear)

In some images it appears that different gain and offsets are appropriate for different scene radiance images i.e. the sensor transfer curves are non linear. If the relationship between the input and output values is non-linear then histogram matching method should be applied. This method uses the shape of the cumulative frequency histogram of each detector to find an estimate of the non-linear transfer function. The cumulative frequency histogram of each detector and one target are computed. Then the shape of the individual cumulative histogram is matched to the target histogram as closely as possible. The first values in the target histogram to equal or exceed the values in detector histogram are taken as output reference and the corresponding input value is taken as output value.

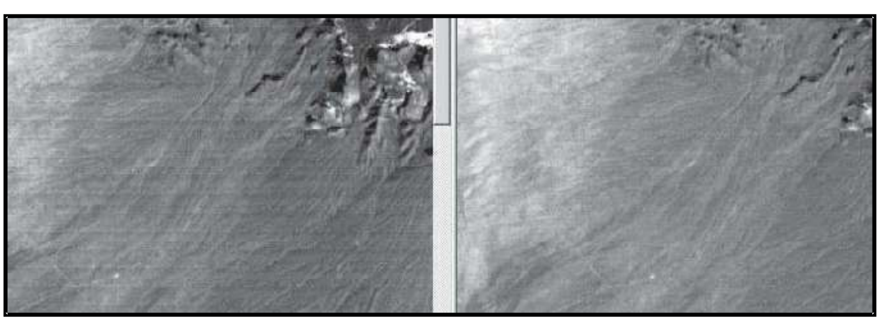


Figure3.10DNs of bad lines are adjusted so as histogram of the bad line matches that of the good lines

3.5.3.Random Noise Correction

Random noise means pixels having offset values from the normal. It can be easily corrected By means of a smoothing filter on the data

Figure3.11Noise Arise Mean Filter

3.5.4. Atmospheric Correction

The value recorded at any pixel location on the remotely sensed image is not a record of the true ground-leaving radiance at that point; for the signal is attenuated due to absorption and its directional properties are altered by scattering. Figure3.13 depicts the effects the atmosphere has

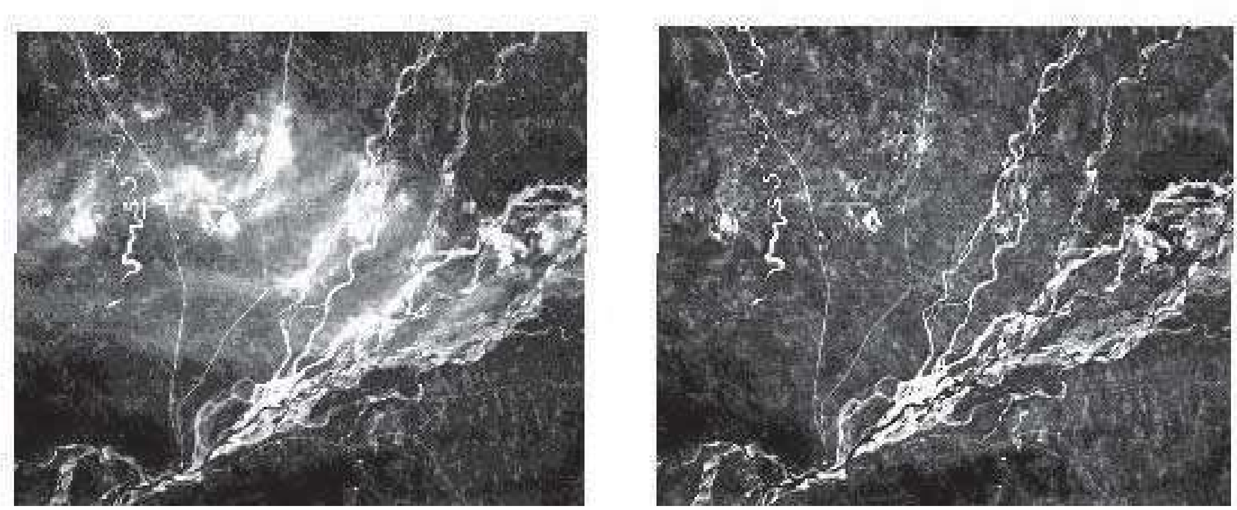


Figure 3.12Before Correction After Correction

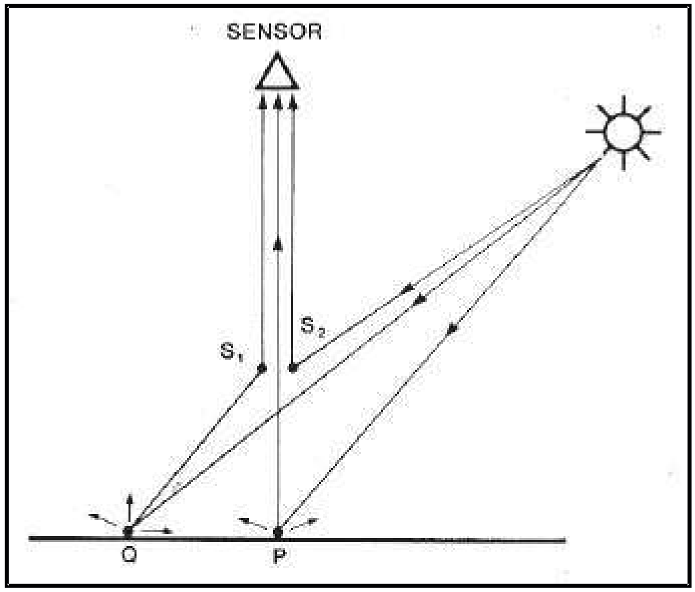


Figure3.13 Components of the signal received by satellite mounted sensor

Scattering at S2 redirects some of the incident radiance within the atmosphere in the field of view of the sensor (the atmospheric path radiance) and some of the energy reflected from point Q is scattered at S1 so that it is seen as coming from P. To add to these effects the radiance from P and Q is attenuated as it passes through the atmosphere. Other difficulties are caused by the variations in the illumination geometry (Sun's elevation and azimuth angles).

The relationship between radiance received at a sensor above the atmosphere and the Radiance leaving the ground surface can be given as

$$L_s = H_{tot} \rho T + L_p$$

H_{tot} = total downwelling radiance in a specified spectral band
ρ = reflectance of the target
T = atmospheric transmittance
L_p = atmospheric path radiance

The path radiance Lp varies in magnitude inversely with wavelength for scattering increasesas wavelength decreases. Atmospheric path radiance introduces haze in the imagerywhereby decreasing the contrast of the data. In order to remove the haze component twosimple techniques are discussed here

3.5.4.1.Histogram Minimum Method (Dark Pixel Subtraction Technique)

In this method an assumption is made that there is a high probability that there are someareas in the image with low reflectance (clear water, deep shadow etc). These pixels willhave values very close to zero in the short wave infrared band. Any values greater than zerois assumed to be a haze contributionthe histograms of all the bands in the image arecomputed for the full image. The lowest pixel values in the histograms of all the bands aretaken as the first approximation of the atmospheric path radiance and these minimumvalues are subtracted from the respective images.

The atmospheric effects correction - algorithms is

$I^{\circ}(i,j) = I(i,j) - Bias$

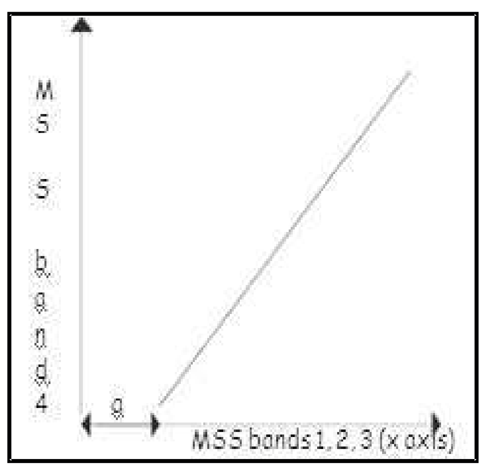
Where, I (i,j) = input pixel value at line i and sample j

I° (i.j) = Enhanced pixel value at same location (i,j)

The bias is the amount of offset for each spectral band

3.5.4.2. Regression Method

In this method the pixel values corresponding to regions having low reflectance (water,deep shadow) in the short-wave infrared regions are plotted against the pixel values of theother spectral bands in turns and a best fit (least squares) straight line is computed usingstandard regression methods. The offset a on the x-axis in



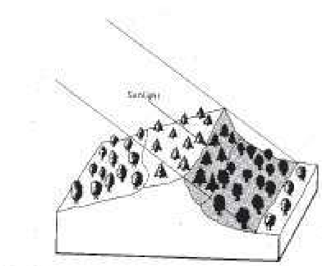
different bands is theatmospheric path radiance and hence has to be subtracted from the respective images

Figure 3.14

3.6. Spectral Ratioing

Image division or **spectral ratioing** is one of the most common transforms applied to image data. Image Ratioing serves to highlight subtle variations in the spectral responses of various surface covers. Ratio images are enhancements resulting from the division of DN values in one spectral band by the corresponding values in another band. A major advantage of ratio image is that they convey the spectral or color characteristics of image features, regardless of variations in scene illumination conditions. This concept is illustrated in figure ….. Which depicts two different land cover types (deciduous and coniferous trees) occurring on both the sunlit and shadowed sides of a ridge line. DNs observed for each cover types are substantially lower in the shadowed area than in the sunlit area. However, the ratio values for each cover types are nearly identical, irrespective of the illumination condition. Hence, a radioed image of the scene effectively compensates for the brightness variation caused by the varying topography and emphasizes the color content of the data

Ratios for Elimination of Topographic Effect

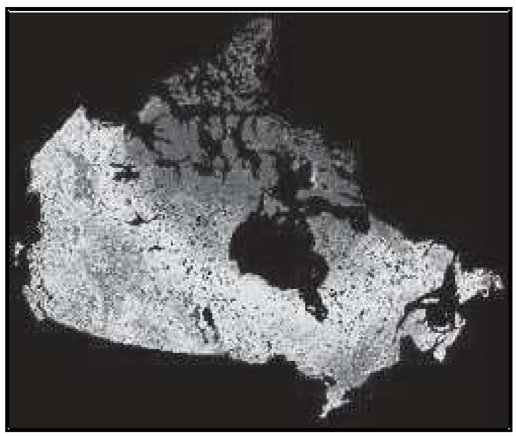


Landcover/ Illumination	Digital Number		Ratio
	Band A	Band B	
Decidous			
Sunlit	48	50	.96
Shadow	18	19	.95
Coniferous			
Sunlit	31	45	.69
Shadow	11	16	.69

- Same cover type
- Radiance at shodow is only 50% of radiance at sunlit
- Ratio nearly identical

Figure 3.15.Reduction of Scene Illumination Effects through Spectral Ratioing (Adapted From Sabins, 1997)

Another example illustrates the concept of spectral ratioing. Healthy vegetation reflects strongly in the near-infrared portion of the spectrum while absorbing strongly in the visible red. Other surface types, such as soil and water, show near equal reflectances in both the near-infrared and red portions. Thus, a ratio image of Landsat MSS Band 7 (Near-Infrared - 0.8 to 1.1 mm) divided by Band 5 (Red - 0.6 to 0.7 mm) would result in ratios much greater than 1.0 for vegetation, and ratios around 1.0 for soil and water. Thus the discrimination of vegetation from other surface cover types is significantly enhanced. Also, we may be better able to identify areas of unhealthy or stressed vegetation, which show low near-infrared reflectance, as the ratios would be lower than for healthy green vegetation



Another benefit of spectral Ratioing is that, because we are looking at relative values (i.e. ratios) instead of absolute brightness values, variations in scene illumination as a result oftopographic effects are reduced. Thus, although the absolute reflectances for forest coveredslopes may vary depending on their orientation relative to the sun's illumination, the ratio oftheir reflectances between the two bands should always be very similar. More complex ratiosinvolving the sums of and differences between spectral bands for various sensors have beendeveloped for monitoring vegetation conditions.

Commonly used Vegetation Indices

- Vegetation Index or Ratio Vegetation

Index (RVI) = IR / R

- Normalized Differential Vegetation Index

(NDVI) = (IR - R)/(IR + R)

- Transformed Vegetation Index (TVI)

= {(IR - R)/(IR + R) + 0.5}1/2 x 100

But one of the widely used image transform is the NDVI

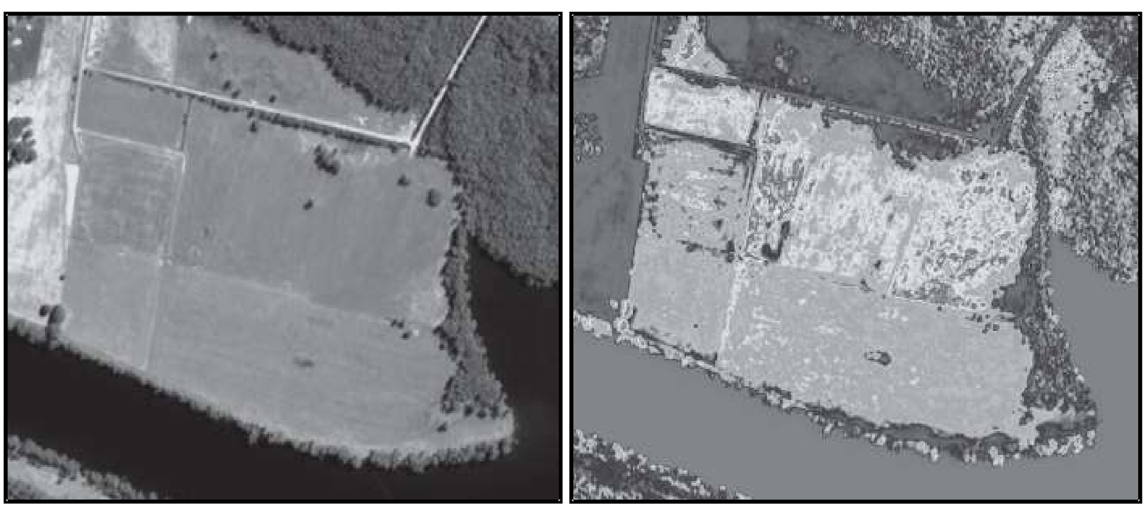
3.6.1. Normalized Difference Vegetation Index (NDVI)

The most popular method of vegetation analysis uses the Normalized Difference Vegetation Index (NDVI) algorithm to measure plant material. NDVI is used to measure and monitor plant growth, vegetation cover and biomass production using any multispectral sensor which has both a Visible Red and Near Infra-Red bands.

$$\text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}$$

Where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively

Figure 3.16



False color processed image Here, the brighter highlight more vigorous and healthy plant

NDVI processed image of the same area shows not reds only the extant of vegetation health ,but also densitygrowth

3.6.2. Principal Component Analysis

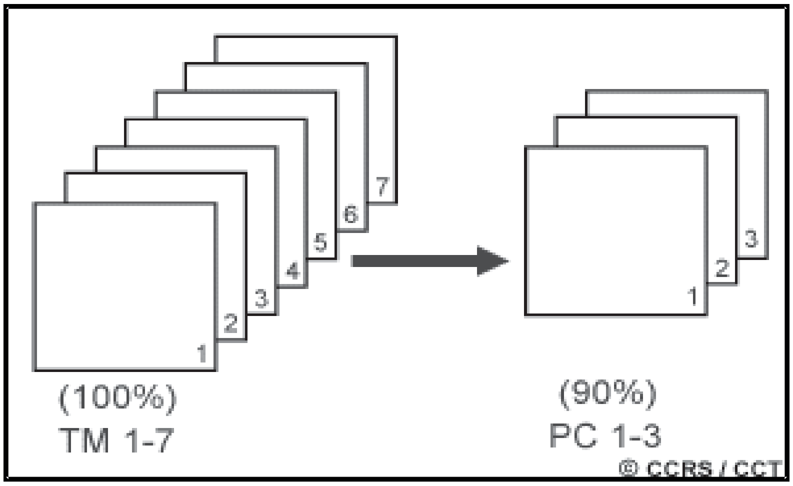


Figure 3.17

Image transformation techniques based on complex processing of the statistical characteristic of multi-band data sets can be used to reduce this data redundancy and correlation between bands One such transform is called principal components analysis. The objective of this transformation is to reduce the dimensionality (i.e. the number of bands) in the data, and compress as much of the information in the original bands into fewer bands. The "new" bands that result from this statistical procedure are called components. This process attempts to maximize (statistically) the amount of information (or variance) from the original data into the least number of new components. As an example of the use of principal components analysis, a seven band Thematic Mapper (TM) data set may be transformed such that the first three principal components contain over 90 percent of the information in the original seven bands. Interpretation and analysis of these three bands of data, combining them either visually or digitally, is simpler and more efficient than trying to use all of the original seven bands. Principal components analysis, and other complex transforms, can be used either as an enhancement technique to improve visual interpretation or to reduce the number of bands to be used as input to digital classification procedures

3.7. Summary

This unit discuss on Digital image processingin which we introduce various image enhancement techniques, before use satellite image for analysis, we have to correct image through differentmethods like radiometric, atmospheric corrections, some time data quality not good (line strip,dropline) then we use spatial correction method spectral ratioing very effective transforms method . How ndvi extract vegetation information through satellite image

3.8Gloassary

- **Calibration-**Process of comparing an instrument's measurements with a standard.
- **Contrast Enhancement-**Image-processing procedure that improves the contrast ratio of images. The original narrow range of digital values is expanded to utilize the full range of available digital values.
- **Electromagnetic Radiation-**Energy propagated in the form of and advancing interaction between electric and magnetic fields. All electromagnetic radiation moves at the speed of light.
- **Image Striping-**A defect produced in line scanner and push broom imaging devices produced by the non-uniform response of a single detector, or amongst a bank of detectors. In a line-scan image the stripes are perpendicular to flight direction, but parallel to it in a push broom image.
- **Noise**-Random or repetitive events that obscure or interfere with the desired information.
- **Non-directional Filter**-Mathematical filter that treats all orientations of linear features equally.
- **Periodic Line Dropout-**Defect on Landsat MSS or TM images in which no data are recorded for every sixth or sixteenth scan line, causing a black line on the image.
- **Polarization-**The direction of orientation in which the electrical field vector of electromagnetic radiation vibrates.
- **Principal Component Analysis-**The analysis of covariance in a multiple data set so that the data can be projected as additive combinations on to new axes, which express different kinds of correlation among the data.

3.9. Answer to check your progress/Possible Answers to SAQ

Ans.1 Enhancements are used to make it easier for visual interpretation and understanding ofimagery Image enhancement is attempted after the image is corrected for geometricand radiometric distortions. Image enhancement methods are applied separately to eachband of a multispectral image

Ans.2.A Low-pass filter is designed to emphasize larger, homogeneous areas of similar tone and reduce the smaller detail in an image. Thus, low-pass filters generally serve to smooth the appearance of an image.

Ans.3 Fill in the blank.

(a)Frequency(b)Density

Ans. 4 True false against the following:

(a) True **(b)** False

3.10. References

1. faculty.ksu.edu.sa/74534/.../11-radiometric%20correction.ppt

3. Http://xweb.geos.ed.ac.uk/~rharwood/teaching/msc/adv_ip/princcpt.pdf

4. http://www.stats.org.uk/pca/pca.pdf

5. www.una.edu/.../remote_sensing/...

6. http://giswin.geo.tsukuba.ac.jp/sis/tutorial/gisseminar_Kondwani_manual_2010July1.pdf

7. http://remotesensing.schools.officelive.com/spectralrationing.aspx

8-fundamentals-of-remote-sensing.-by Noam Levin ,November 1999

3.11. Suggested Readings

1. Introductory digital image processing (John R. Jensen)

2. Introductory Remote Sensing Digital Image Processing and Application (Paul Jude Gibson, Clare H. Power

3.12.Terminal Questions

Q1.How Non-Linear Contrast Enhancement

Q2Different between Low Pass Filter and High Pass Filter

Q3.What Is Radiometric Correction

Q4. Explain Regression Method (Atmospheric Correction)

Q5 For What Purpose NDVI Method Is Use?

UNIT 4: FUTURE GEOINFORMATICS

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OPEN GIS

4.1. INTRODUCTION

Open GIS is the full integration of geospatial data into mainstream information technology. What this means is that GIS users would be able to freely exchange data over a range of GIS software systems and networks without having to worry about format conversion or proprietary data types.

Open GIS seeks to facilitate the exchange of information not only between individual GIS systems but also to other systems, such as statistical analysis, image processing, document management, or visualization. Especially with the proliferation of geo-based websites, the networking component of GIS systems with other data processes is becoming more important.

4.2 Objectives

After going through this unit the learner will able to learn:

What is Open Gis?

Uses of Open Gis Software

How NDSI Work

How to use free Web Gis

4.3.1 Difference between Open Gis and Licence (Commercial)GIS Software

- Open source software is free; you don't have to purchase it and you can freely distribute it to anyone else, as opposed to proprietary software which you must purchase and typically cannot share with anyone (since it's copyrighted).
- The source code, or actual computer programming, that was used to create the software is transparent, as opposed to proprietary software where the code is hidden and encrypted.
- Under the open source model the programming code is transparent and you are free to change and make improvements to it; this is strictly prohibited with proprietary software.

4.3.2. Open GIS Consortium (OGC)

The OGC is a consensus-based association of public and private sector organizations to meet these three objectives. Its purpose is to create and manage an industry-wide architecture for interoperable geoprocessing. OGC was founded in 1994 as a not-for-profit membership organization for the purpose of addressing the lack on interoperability among GIS systems and between these systems and mainstream computing systems.

By engaging key players in the GIS Industry such as software companies, governmental agencies, private businesses and academia , the OGC is bringing standardization of geographic data as is already found in other information systems. The end goal is to adopt widespread technology standards and business processes in an effort to support georeferenced data throughout the global community.

Other groups have joined the effort for an Open GIS system. GIPSIE is one such effort. An acronym for GIS Interoperability Project Stimulating the Industry in Europe, the project's goals are to stimulate European GI communities' involvement in the worldwide Open GIS specification process and thus increase the European GIS industry's competitiveness.

4.3.3Open GIS Programming Languages

Open source projects typically are worked on by a community of volunteer programmers. Open source GIS programs are based on different base programming languages. Three main groups of open source GIS (outside of web GIS) in terms of programming languages are: **"C" languages, Java, and .NET**.

The first group would be the group that uses **"C"** language for its implementation. This is the more mature of the groups of open source GIS, probably for the simple reason that is the group that has been working on GIS software applications the longest and has a long history of reuse of code. The libraries in the "C" group, from the base infrastructure, and include some capabilities like coordinate reprojection that make them very useful and popular. Popular "C" based open source GIS software applications include GRASS, a project started in 1982 by the US Army but is now open source, and QGIS (otherwise known as Quantum GIS).

The second group of Open Source GIS would be the ones that use **JAVA** as the implementation language. JTS, central library for the Java GIS development, offers some geospatial functions that allow to compare objects and return a Boolean true/false result indicating the existence (or absence) of any questioned spatial relationship. GeoTools, Geoserve, and OpenMap, are among the most popular open source GIS in this group of JAVA tools.

The third most influential group of Open Source GIS would be the one that integrates applications that use "**.NET"** as the implementation language. SharpMap and Worldwind are the most popular of these applications.

Outside of the three major language groups, open source web mapping is another group. Population open source web mapping includes OpenLayers and MapBuilder, widely used due to their simplicity and accessibility.

- Listed here are available open source GIS based applications you can download written for a variety of platforms and in various languages

4.3.4Different Tribes Use Different Tools

- **C/C++ Tribe**

  MAPSEVER, GRASS, MAPGUIDE, QGIS, POSTGIS, OGR/GDAL, PROJ4, FDOTERRALIB
- **Java Tribe**

GeoTools, Geoserver, uDig, DeeGree jump, gvSIG

- **Web tribe**

MapBender, Open Layers, Ka-map

- **.Net Tribe**

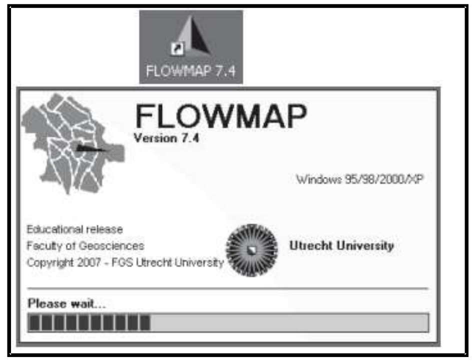
SharpMap, Worldwind, Mapwindow

4.3.5. Open Source Desktop GIS Software

4.3.5.1 Flow Map

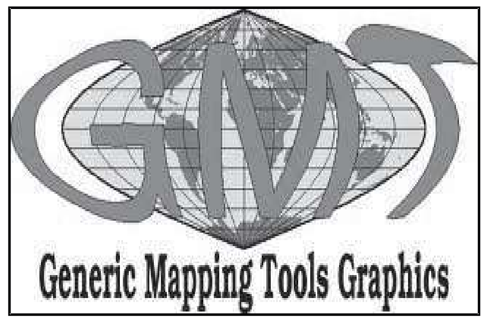
Flow map is a freeware application designed to analyze and display flow data. This application was developed at the Faculty of Geographical science of the Utrecht University in the Netherlands

Platforms: Window OS



4.3.5.2. GMT MAPPING TOOLS

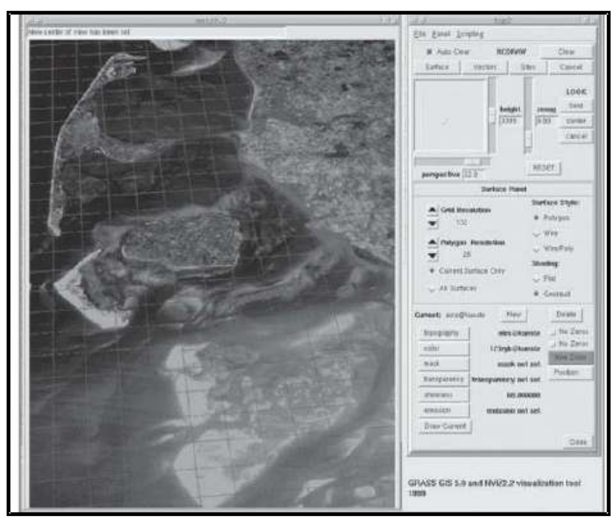
GMT**Generic mapping tool** is a free, public-domain collection of ~60 UNIX tools that allow users to manipulate (x,y) and (x,y,z) data sets (including filtering, trend fitting, gridding, projecting, etc.) and produce Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots through contour maps to artificially illuminated surfaces and 3-D perspective views in black and white, gray tone, hachure patterns, and 24-bit color.



Platforms: UNIX, Macintosh

4.3.5.3. GRASS

Geographic Resources Analysis Support System (GRASS) is the public domain GIS software application originally developed by the US Government. GRASS is probably the most well-known open source and original GIS software applications. GRASS is a raster-based GIS, vector GIS, image processing system, graphics production system, data management system, and spatial modeling system. GRASS can be downloaded for free.

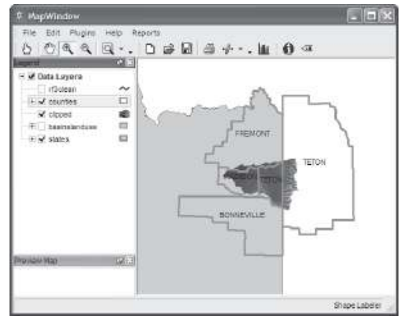


Platforms: Linux, Macintosh, Sun Solaris, Silicon Graphics Irix, HP-UX, DEC-Alpha, and Windows OS

4.3.5.4. MapWindow GIS

MapWindow GIS is open source GIS application that can be extended through plug-ins. The application is built using Microsoft's .NET

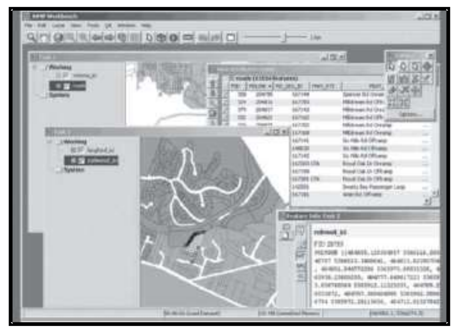
Platforms: Windows



4.3.5.5. Open JUMP GIS

Open JUMP GIS is an open source GIS written in Java through a collaborative effort by volunteers. Formerly known as JUMP GIS, the application can read Shapefiles and GML format files.

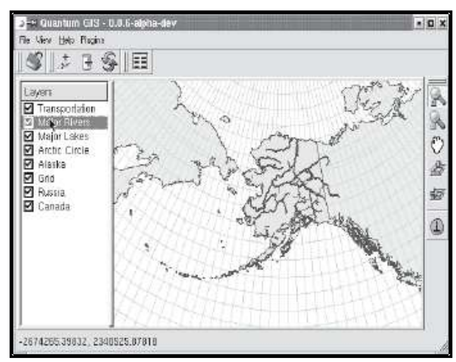
Platforms: Windows, Macintosh, Linux, UNIX



4.3.5.6. Quantum GIS

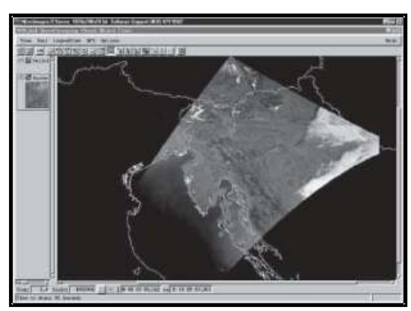
Also referred to as QGIS, Quantum GIS is an Open Source Geographic Information System (GIS). More: Getting Started With QGIS: Open Source GIS

Platforms: Linux, UNIX, Mac OSX, and Windows

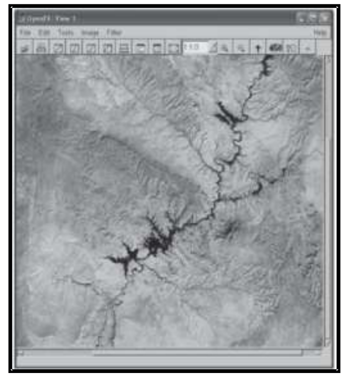


4.3.5.7. TNTLite

Tntlite Micro Images, Inc. Provides tntlite as a free version of tntmips, the professional software for geospatial data analysis The free tntlite product has all the features of the professional version, except tntlite limits the size of Project File objects, and tntlite enables data sharing only with other copies of tntlite (export processes are disabled). Can either be downloaded or ordered on CD.Platforms: Windows



4.3.5.8. OpenEV



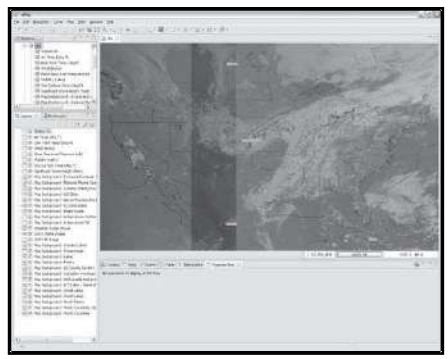
Openev is a software library and application for viewing and analysing raster and vector geospatial data is used by private companies, universities, governments and non-profit organizations around the world. Openev is both:

- An application for displaying and analysing geospatial data
- Developer library from creating new applications

Openev is released under the gnu lgpl license open source license

Platforms: for windows, linux, sun solaris, and sgi irix operating systems

4.3.5.9. UDig GIS



UDig GIS is a free, open source GIS desktop application that runs on Windows, Linux and Mac OS. UDig was designed to use OGC's OpenGIS standards such as WMS, WFS and more. One-click install allows you to view local Shapefiles, remote WMS services and even directly edit your own spatial database geometries.

Platforms: Windows, Linux, Macintosh

Check Your Progress:

Q 1: What is Open GISProgramming Languages?

Q 2: Full Forms

a.GRASS

b. GMT

c. OGC

NSDI

4.4. INTRODUCTION

An Indian NSDI was created by the Government of India via a resolution in June 2006. The NSDI is for the purpose of acquiring, processing, storing, distributing and improving utilization of spatial data which would be a gateway of spatial data being generated by various agencies of the Government of India; and where as the data producing agencies of the Government of India shall be initially the contributing agencies to the NSDI.

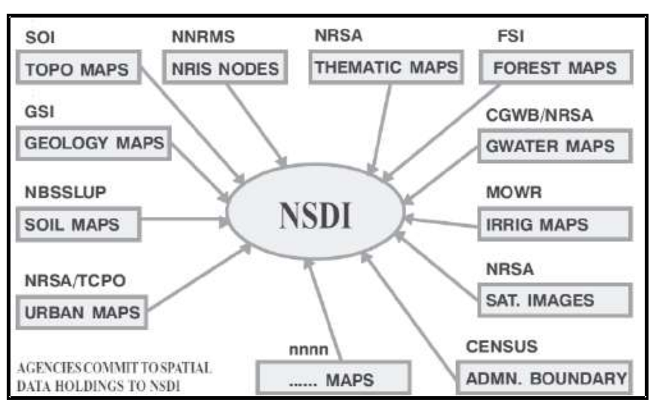
It is possible to combine spatial data and services from different sources across the Community in a consistent way and share them between several users and applications. It is possible for spatial data collected at one level of govt./public authority to be shared between all the different levels of govt./public authorities; and spatial data and services are made available under conditions that do not restrict their extensive use. It is easy to discover available spatial data, to evaluate their fitness for purpose and to know the conditions applicable to their use.

4.4.1 Proposed Framework of NSDI

- The NSDI would aim to have a de-centralized approach to:
- Develop and maintain Standard digital collections of spatial data
- Develop common solutions for discovery, access, and use of spatial data in response to the needs of diverse user groups
- Build relationships among organizations to support the continuing development of the NSDI
- Increase the awareness and understanding of the vision, concepts, and benefits of the NSDI

4.4.2. NSDI Contents

To start with, the rich collection of spatial data available in the countryshould form the foundation data for NSDI, as shown in Fig



1. National coverage of topographical maps on scales of 1:250000, 1:50000and 1:25000 and any other data of the Survey of India (SOI) toposheets

2. National coverage of geological maps on 1:50000 scales and other maps/data of the Geological Survey of India (GSI)

3. National coverage of soil maps on 1:250000 and 1:50000 scales and other maps/data of the National Bureau of Soil Survey and Land use Planning (NBSSLUP)

4. National coverage of forest maps on 1:50000 scale of the Forest Survey of India (FSI)

5. National coverage of the hydrology maps on all scales of the Central Ground Water Board (CGWB)

6. National coverage of land use maps on 1:50000 scale; wasteland maps on 1:50000 scale; urban maps on 1:50000 scale; ground water potential maps on 1:50000 scale and other thematic maps of National Remote Sensing Agency (NRSA);

7. NRIS Nodes of the NNRMS Programme involving District and State Natural Resources databases on 1:50000 scales;

8. Command area maps of Central Water Commission (CWC)

9. National coverage of coastal land use maps on 1:50000 and 1:25000scale of Ministry of Environment and Forests (MoEnF)

10 .Census maps and census data of the Census Department

11. NATMOs national atlases on 1:1000000 and other scales

12. National coverage of Satellite images of different resolutions

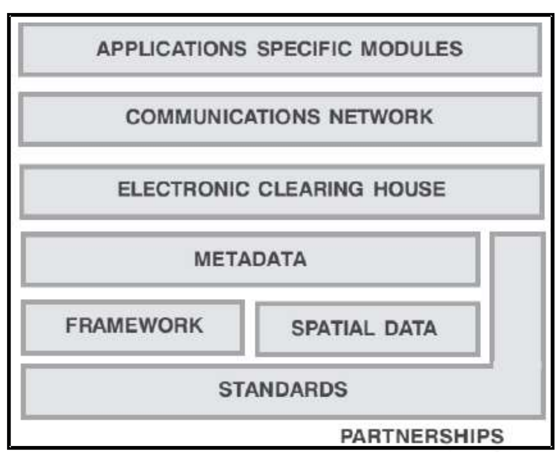
13.Hydro graphic data of the National Hydrographic Department

14. To this set of basic data, addition of India Meteorological Department's weather information and Department of Ocean Development's Ocean information (at smaller scales) could also beadded

15.Non-spatial data of the Bureau of Economics and Statistics, National Council for Applied Economic Research etc – which could be linked to the spatial features and become a part of the NSDI.

4.4.3. NSDI – Design Elements

The NSDI elements, as illustrated in **Fig**, would be:



4.4.3.1. NSDI Standard

NSDI standard defined and agreed to national agencies and defining content and schemas, design and process, network protocols, exchange and transfer. Standards are the crux of the NSDI and would be of relevance to database standardization - formats, exchange and interoperability; Networks-gateways and protocols Communication equipment, software standards, etc. Standards enable applications and technology to work together. Tools, applications, and data affect each other, and processes for developing standards must consider these interactions.

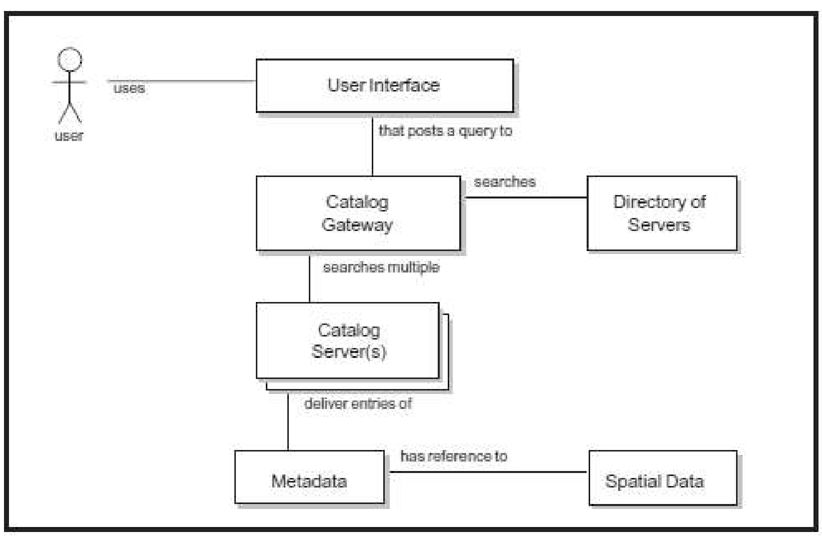
4.4.3.2. NSDI Servers

The NSDI would a network of servers that, in unison would the successful performance of NSDI goals objectives. The following 3 NSDI elements envisaged

NSDI Web-Server: The NSDI Web-Server would be the front-end interface to NSDI. The Web-Server would provide the open access to NSDI information and "secure" entry to NSDI Metadata and NSDI Agency Servers. The DNS for the NSDI web-server would bewww.nsdi.gov.in

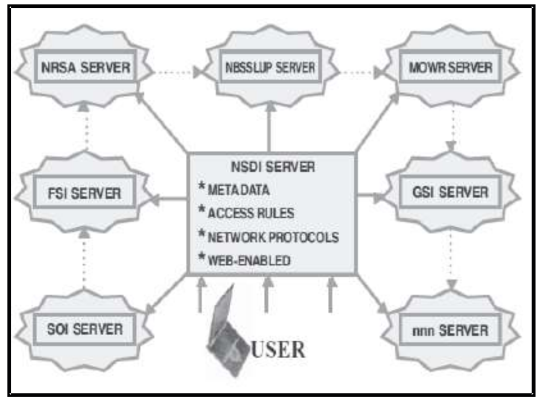
NSDI Metadata Server: The NSDI Metadata Server would maintain the NSDI metadata content. At a higher level, it would be linked to NSDI Web-Server and lower-level it would be linked through NSDI Server Catalogue to NSDI Agency Servers.

NSDI Agency Server: The NSDI Agency Server (or Servers) would hold the actual spatial data of the NSDI Agency



4.4.3.3. NSDI Gateway and Internet

The NSDI would evolve and expand with the participation of committing agencies and it is envisaged that SOI, NRSA, GSI, FSI, CGWB, NNRMS/NRIS, CWC, MoEnF, NATMO, NBSSLUP, CGWB, Census department, IMD,DOD, BES, NCAER etc would be the first committed agencies to the NSDI..Each agency would commit to establish a GIS database server as a NSDINode. The NSDI would enable development of new relationships that allow organizations and individuals from all sectors to work together to share spatial data. **Fig**shows the overall framework of NSDI

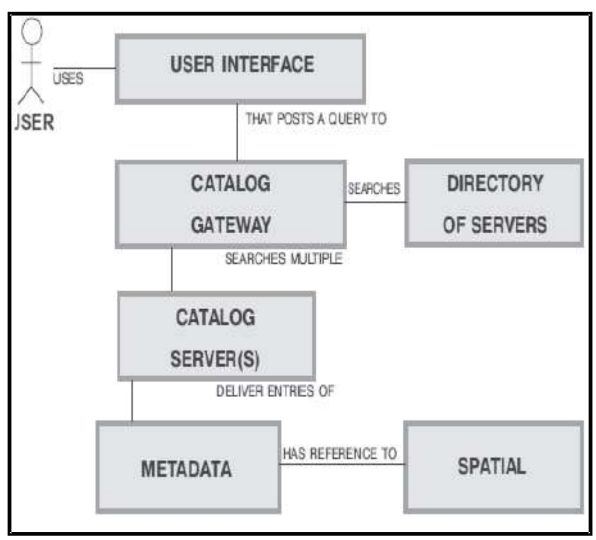


4.4.3.3.1. NSDI Nodes

NSDI nodes and GIS servers of the actual spatial information- in conformity of the NSDI Standard the NSDI Nodes would be mainlyGIS based spatial databases and development oriented information systems servers - all integrated and linked to basic spatial/geographic units. The value of NSDI would be to aid as a decisionmakingtool and more in the context of assisting planning fordevelopmental activities.

4.4.3.3.2. NSDI Search and Access Protocols

That would enable search and location of spatial information. The protocols would provide the gateway for users to access NSDI. The basic issue in the operation of the NSDI is the backbone on which the information travels from one point to another. The backbone carrier will be high-speed carrier capable of providing bandwidth on demand to intermediate levels of the NSDI and to users of the NSDI.



4.4.3.3.3NSDI Electronic ClearingHouse

The NSDI Clearinghouse would be the mechanism to provide access to the metadata and finally to the actual data sets. The clearinghouse has to have systems toauthenticate data requests and requests spatial data volumes are usually large and download through networks may not be feasible. In such cases, the system should be able to generate media bearingthe requested data for transmission by mail. The clearinghouse should also store information about the applications and availability of application specific modules that could be reused by other users. The clearinghouse would use the NSDI Search and access Protocols engines to look for and discover data and information.

4.4.3.3.4. NSDI User Interface

That would be the front-end interface for userqueries and access of spatial information. With regard to design ofNSDI much depends upon the level of penetration and upper-end levelof applications and services available on it. For a completely ubiquitous

NSDI, the penetration will have to reach public domain and thecapabilities will include online access of information applications.

4.4.3.3.5. NSDI Metadata

Metadata of the NSDI content and information availability The NSDI Metadata would get evolved from the NSDI Standard and as digital spatial information is populated. As a part of NSDI, one of the critical steps would be the development of a metadata standard and development of metadata files.There are different levels that metadata may be used for:

1. Search and Location - What data sets hold the sort of data of interest? This enables organizations to know and publicize what data holdings they have.

2. Analysis metadata - Do the identified data sets contain sufficient information to enable a sensible analysis to be made for my purposes? This is documentation to be provided with the data to ensure that others use the data correctly and wisely.

3. Access metadata – What is the process of obtaining and using the data that are required? This helps end users and provider organizations to effectively store, reuse, maintain and archive their Data holdings

Check Your Progress:

Q3: What is Meta Data?

Q 4: Full Forms

a.SOI __________

b. NSDI __________

c. GSI __________

NAVIGATIONS SYSTEMS

4.5 INTRODUCTION

A navigation system is a (usually electronic) system that aids in navigation. Navigation systems may be entirely on board a vehicle or vessel, or they may be located elsewhere and communicate via radio or other signals with a vehicle or vessel, or they may use a combination of these methods.

Navigation systems may be capable of:

- containing maps, which may be displayed in human readable format via text or in a graphical format
- determining a vehicle or vessel's location via sensors, maps, or information from external sources
- providing suggested directions to a human in charge of a vehicle or vessel via text or speech
- providing directions directly to an autonomous vehicle such as a robotic probe or guided missile
- providing information on nearby vehicles or vessels, or other hazards or obstacles
- providing information on traffic conditions and suggesting alternative directions

4.5.1 Types of Navigations Systems

4.5.1.1 Automotive Navigation System

An automotive navigation system is a satellite navigation system designed for use in automobiles. It typically uses a GPS navigation device to acquire position data to locate the user on a road in the unit's map database. Using the road database, the unit can give directions to other locations along roads also in its database. Dead reckoning using distance data from sensors attached to the drive train, a gyroscope and an accelerometer can be used for greater reliability, as GPS signal loss and/or multipath can occur due to urban canyons or tunnels.


4.5.1.2 Road Database

The road database is a vector map of some area of interest. Street names or numbers and house numbers are encoded as geographic coordinates so that the user can find some desired destination by street address (see map database management).

Points of interest (waypoints) will also be stored with their geographic coordinates. Point of interest specialties include speed cameras, fuel stations, public parking, and "parked here" (or "you parked here").

Contents can be produced by the user base as their cars drive along existing streets (Wi-Fi) and communicating via the internet, yielding a free and up-to-date map

.

4.5.1.3 Map Formats

Formats are almost uniformly proprietary; there is no industry standard for satellite navigation maps, although Navteq are currently trying to address this with S-Dal (see below).

The map data vendors such as Tele Atlas and Navteq create the base map in a standard format GDF, but each electronics manufacturer compiles it in an optimized, usually proprietary format. GDF is not a CD standard for car navigation systems. GDF is used and converted onto the CD-ROM in the internal format of the navigation system.

4.5.1.4 CARIN

CARIN Database Format (CDF) is a proprietary navigation map format created by Philips Car Systems (this branch was sold to Mannesman VDO, VDO/Dayton in 1998, to Siemens VDO in 2002, and Continental in 2007.) and is used in a number of navigation-equipped vehicles. The 'carin' portmanteau is derived from Car Information and Navigation.

4.5.1.5 SDAL

This is a proprietary map format published by Navteq, who released it royalty free in the hope that it would become an industry standard for digital navigation maps. Vendors currently using this format include:

(1) Microsoft**(2)**Magellan**(3)**Pioneer**(4)**Panasonic**(5)**Clarion**(6)** InfoGation

4.5.2GPS Navigation Device

A **GPS navigation device** is any device that receives Global Positioning System (GPS) signals for the purpose of determining the device's current location on Earth. GPS devices provide latitude and longitude information, and some may also calculate altitude, although this is not considered sufficiently accurate or continuously available enough (due to the possibility of signal blockage and other factors) to rely on exclusively to pilot aircraft. GPS devices are used in military, aviation, marine and consumer product applications.

GPS devices may also have additional capabilities such as:

- containing maps, which may be displayed in human readable format via text or in a graphical format
- providing suggested directions to a human in charge of a vehicle or vessel via text or speech
- providing directions directly to an autonomous vehicle such as a robotic probe
- providing information on traffic conditions (either via historical or real time data) and suggesting alternative directions
- Providing information on nearby amenities such as restaurants, fuelling stations, etc.

In other words, all GPS devices can answer the question "Where am I?", and may also be able to answer:

- Which roads or paths are available to me now?
- Which roads or paths should I take in order to get to my desired destination?

- If some roads are usually busy at this time or are busy right now, what would be a better route to take?
- Where can I get something to eat nearby or where can I get fuel for my vehicle?

4.5.2.1 Dedicated GPS navigation devices

Dedicated devices have various degrees of mobility. Hand-held, outdoor, or sport receivers have replaceable batteries that can run them for several hours, making them suitable for hiking, bicycle touring and other activities far from an electric power source. Their screens are small, and some do not show color, in part to save power. Cases are rugged and some are water resistant.

Other receivers, often called mobile are intended primarily for use in a car, but have a small rechargeable internal battery that can power them for an hour or two away from the car. Special purpose devices for use in a car may be permanently installed and depend entirely on the automotive electrical system.

Manufacturers include:

- Navman products
- TomTom products
- Garmin products
- Mio products
- Navigon products
- Magellan Navigation consumer products
- TeleType products

4.5.2.2 Mobile phones with GPS capability

Due in part to regulations encouraging mobile phone tracking, including the majority of GPS receivers are built into mobile telephones, with varying degrees of coverage and user accessibility. Commercial navigation software is available for most 21st century smart phones as well as some Java-enabled phones that allow them to use an internal or external GPS receiver. Some phones with GPS capability work by assisted GPS (A-GPS) only, and do not function when out of range of their carrier's cell towers. Others can navigate worldwide with satellite GPS signals as a dedicated portable GPS receiver does, upgrading their operation to A-GPS mode when in range. Still others have a hybrid positioning system that can use other signals when GPS signals are inadequate.

The system uses gps one technology to determine the location, and then uses the mobile phone's data connection to download maps and calculate navigational routes. Other products including iPhone are used to provide similar services. Nokia gives Ovi Maps free on its smart phones and maps can be preloaded. GPS navigation applications for mobile phones include Waze and Google Maps Navigation. Google Maps Navigation included with Android means most smart phone users only need their phone to have a personal navigation assistant.

4.5.3 Commercial Aviation

Commercial aviation applications include GPS devices that calculate location and feed that information to large multi-input navigational computers for autopilot, course information and correction displays to the pilots, and course tracking and recording devices.

4.5.4Radio Navigation

A radio direction finder or RDF is a device for finding the direction to a radio source. Due to radio's ability to travel very long distances "over the horizon", it makes a particularly good navigation system for ships and aircraft that might be flying at a distance from land.

Rdfs works by rotating a directional antenna and listening for the direction in which the signal from a known station comes through most strongly.

In navigational applications, RDF signals are provided in the form of radio beacons, the radio version of a lighthouse. The signal is typically a simple AM broadcast of a morse code series of letters, which the RDF can tune in to see if the beacon is "on the air". Most modern detectors can also tune in any commercial radio stations, which is particularly useful due to their high power and location near major cities.

Decca, OMEGA, and LORAN-C are three similar hyperbolic navigation systems.

Decca was a hyperbolic low frequency radio navigation system that was first deployed during World War II when the Allied forces needed a system which could be used to achieve accurate landings. As was the case with Loran C, its primary use was for ship navigation in coastal waters. Fishing vessels were major post-war users

The OMEGA Navigation System was the first truly global radio navigation system for aircraft, operated by the United States in cooperation with six partner nations. OMEGA was developed by the United States Navy for military aviation users. It was approved for development in 1968 and promised a true worldwide oceanic coverage capability with only eight transmitters and the ability to achieve a four mile (6 km) accuracy when fixing a position.. Later, it was found useful for submarines. .

LORAN is a terrestrial navigation system using low frequency radio transmitters that use the time interval between radio signals received from three or more stations to determine the position of a ship or aircraft. The current version of LORAN in common use is LORAN-C, which operates in the low frequency portion of the EM spectrum from 90 to 110 khz.

4.5.5 Radar Navigation

When a vessel is within radar range of land or special radar aids to navigation, the navigator can take distances and angular bearings to charted objects and use these to establish arcs of position and lines of position on a chart. A fix consisting of only radar information is called a radar fix.

Types of radar fixes include "range and bearing to a single object, two or more bearings, tangent bearings, and "two or more ranges.

Parallel indexing is a technique defined by William Burger in the 1957 book The Radar Observer's Handbook. This technique involves creating a line on the screen that is parallel to the ship's course, but offset to the left or right by some distance. This parallel line allows the navigator to maintain a given distance away from hazards.

Special technique, known as the Franklin Continuous Radar Plot Technique, involves drawing the path a radar object should follow on the radar display if the ship stays on its planned course. During the transit, the navigator can check that the ship is on track by checking that the pip lies on the drawn line.

4.5.6 Micro Computers

Microcomputer, an electronic device with a microprocessor as its central processing unit (CPU).Microcomputer was formerly a commonly used term for personal computers, particularly any of a class of small digital computers whose CPU is contained on a single integrated semiconductor chip. Thus, a microcomputer uses a single microprocessor for its CPU, which performs all logic and arithmetic. The system also contains a number of associated semiconductor chips that serve as the main memory for storing program instructions and data and as interfaces for exchanging data of this sort with peripheral equipment—namely, input/output devices (e.g., keyboard, video display, and printer) and auxiliary storage units. Smaller microcomputers first marketed in the 1970s contain a single chip on which all CPU, memory, and interface circuits are integrated.

High-performance microcomputer systems are used widely in business, in engineering, in "smart" or intelligent machines employed in the factory and office, and in military electronics systems.

In the early 1990s, small computers that fit in a pocket yet provide the power of a desktop personal computer were introduced. These pocket, or palm-sized, computers, commonly known as personal digital assistants (pdas), are distinguished by their high portability, enhanced performance, and low cost. Similarly, microprocessors began finding their way into cellular telephones and portable MP3 music players.

As personal computers started including multiple processors in the 2000s,microcomputer began to be relegated to descriptions of small "embedded" computers found in various electronic devices.

There are many generations of particular design and technical specification from the start of this particular design

1. Super computer 2.Mainframes 3.Minicomputers

4. Microcomputer 5.Termials 6.Embedded computer

The ranking of a micro is as you can see on the low end of computing but very popular and easy to use

Notebooks

- Notebooks, among the smallest microcomputers, can weight less than a kilogram. These ultra-portable units allow for easy setup in a classroom; they connect to the Internet via a cable or integrated Wi-Fi terminal. Most notebooks, these days have built-in microphones and webcams for video conferences.

Laptops

- Laptops are slightly bigger and heavier than the notebooks. Although laptops and notebooks have similar performance, the laptops have larger screens and are more convenient for longer work. The advantage of the laptop comparing to other microcomputers is its portability and easy access to the Internet. Many companies have problems with their laptop batteries. Some are not durable and can overheat and sometimes even explode.

Desktops

- Desktops are bigger and can perform more complex operations than notebooks and laptops. These microcomputers have separate components -- the system unit, keyboard and monitor. Desktop microcomputers are generally cheaper than laptops or notebooks. The desktops tend to be reliable and easy to repair. If a component fails to work, you can replace it more easily than you could its counterpart in a laptop or notebook.

Tower Computers

- Tower minicomputers have their power supply, motherboard and mass storage device stacked on the top of each other in a cabinet. In contrast to desktop minicomputers, wherein components are packed into a more compact box, tower computers offer the main advantage of having fewer space constraints for easier additional installation. Mini-tower microcomputers have system units that stand beside the monitor, while full-tower microcomputers have higher and wider units.

Check Your Progress:

Q 5: What is GPS Navigation?

Q 6: Fill in the blanks:

a. ____________ is a terrestrial navigation system using low frequency radio transmitters

b. Garmin is the type of ________ Device

C. is a device for finding the direction to a radio source

Q 7: Full Forms

a. CDF __________

b. GPS __________

WEB ENABLED GIS & RS MAPPING

4.6.1INTRODUCTION

The integration of GIS and Internet technologies is allowing GIS professionals to solve one of the most important problems inhibiting information utility: How to provide access to information and data without burdening end users with complicated and expensive software.

Internet is a perfect means of GIS data accessing, analyzing and transmission.

The World Wide Web, FTP (file transfer protocol) and HTTP programs make it convenient to access and transfer data files across the Internet. The Internet provides GIS users easy access to acquire GIS data from diverse data source in distributed environment. GIS users can use and download the data by sending the request through web browser application.

Open source web mapping provides people to digital geospatial data and teach them how to collect, manage and analyse these data to produce useful information. Some understanding of geography or earth science is advantageous and basic computing skills are required. New knowledge gained will include how to process digital imagery of Earth's surface and how to operate a GIS efficiently.

4.6.2Internet/web Environment

The internet is a vast communications network that today links together more than 4 million computers all over the world. Krolcoined the term "Internet", to a global network of computers connected through communication devices to one another for information sharing;

All computers on the Internet communicate with one another using the Transmission Control Protocol/Internet Protocol suite, abbreviated to TCP/IP. Computers on the Internet use client/server architecture;

The World Wide Web (WWW) is a system of Internet servers, which was developed in 1989 by Tim Berners-Lee of the European Particle Physics Lab (CERN) in Switzerland

4.6.3Web GIS Can do....

The World Wide Web is fast becoming a standard platform for Geographic Information System (GIS). It is a means for GIS users to exchange GIS data, conduct GIS analysis and present GIS output in the form of maps.

Internet has facilitated three major changes in GIS:

- Access to data;
- Transmission of data; and
- GIS Data analysis.

The Internet GIS applications provide all or almost all functionalities of traditional GIS software. In addition, it has additional functions that take advantage of the Internet and its associated protocols. The user of Internet GIS application can use traditional GIS tools for

Analyzing their data without having any specific GIS software

4.6.4Components of web GIS mapping

A client/server application has three components:

- Client,
- Server, and
- Network

The client sends a request to the server, which processes the request and returns the result to the client, the client then manipulates the data and/or results and presents to the user. Internet GIS applies the client/server concept in performing GISanalysis tasks.

4.6.5Web GIS Basic Properties

- Web GIS technology is dynamic, for example, once any client (s) or database administrator updates the data or information at server end, it will available for all the clients on web at the same time.
- The Internet GIS can also link with real time information, such as satellite images, traffic movements and accident information by real time connection with the relevant information sources.
- The applications developed are cross-platform and accessible through any web browser.
- The Internet GIS applications can categorize into two major categories'.Server-side applications and client-side applications. Server-side applications rely on GIS server

(usually reside on a remote server) to perform all GIS analysis, while client-side applications perform GISanalysis and processing in the Web browser on the user's local machine.

4.6.6Types of Internet GIS Applications

- Data Sharing and disseminations; Raw GIS data, requires installed software & expertise to use
- Geospatial Information Sharing and publishing Often includes cartographic representations Can produce single purpose human-readable images
- Web Data Services Produce machine-readable geospatial information
- Distributed Analysis Functions (GIS Anywhere);
- Interoperable GIS Web Services (GIS Anyone Anywhere).

4.6.7Open Source Web Mapping

1) **OpenLayers**
JavaScript library that is open source for displaying GIS data within a browser environment. OpenstreetMap uses openlayers for its main map display (aka the "Slippy Map")

2) **TileMill**
Built on open source libraries (Mapnik, node.js, backbone.js,express and code mirror). The Chicago Tribune included tilemill in a series entitled *Making Maps* using postgis, Mapnik, tilemill, and Google Maps

3) **Geomajas**

Geomajas is an enterprise-ready open source GIS framework for the web. It has client-server integration for displaying and editing of geographic data.It is compliant with OGC standards such as WMS, WFS, etc and also supports spatial databases.

4) **Geoserver**

Geoserver is an open source software server written in Java that allows users to share and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards.
.GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high

performance certified compliant Web Map Service (WMS). GeoServer forms a core component of the Geospatial Web.

5) **MapGuide**

MapGuide Open Source is a web-based platform that enables users to develop and deploy web mapping applications and geospatial web services. MapGuide features an interactive viewer that includes support for feature selection, property inspection, map tips, and operations such as buffer, select within, and measure. MapGuide includes an XML database for managing content, and supports most popular geospatial file formats, databases, and standards. MapGuide can be deployed on Linux or Windows, supports Apache and IIS web servers, and offers extensive PHP, .NET, Java, and JavaScript APIs for application development. MapGuide Open Source is licensed under the LGPL.

6) **MapFish**

Mapfish is a flexible and complete framework for building rich web-mapping applications. It emphasizes high productivity, and high-quality development.

Mapfish is based on the **Pylons** Python web framework. Mapfish extends Pylons with geospatial-specific functionality. For example mapfish provides specific tools for creating web services that allows querying and editing geographic objects.

Mapfish is compliant with the **Open Geospatial Consortium** standards. This is achieved through openlayers or geoext supporting several OGC norms, like WMS, WFS, WMC, KML, GML etc...

7) **MapServer**

Map Server is an Open Source platform for publishing spatial data and interactive mapping applications to the web. Originally developed in the mid-1990 at the University of Minnesota, mapserver is released under an *MIT-style license*, and runs on all major platforms (Windows, Linux, *and Mac OS X*).

Check your progress:

Q 8: What is Map server?

Q 9: Fill in the blanks:

a.Geoserver is an open source software server written in ________

b. All computers on the Internet communicate with one another using the Transmission Controlsuite ______

c.includes an XML database for managing content, and supports most popular geospatial file formats,

4.7 Summary

This unit elaborate about Future Geoinformaticsand explain how in future Gis become total usersfriendly, you can download open source gis software even you can edit and update your database online , you don't need to create maps or database you can download free from internet.

4.8 Glossary

- **Data**-- Any collection of related facts arranged in a particular format; often, the basic elements of information that are
- **Database -- L**ogical collection of inter related information, managed and stored as a unit, usually on some form of mass storage system such as magnetic tape or disk. A GIS database includes data about the Spatial locations and shape of geographic features recorded as points, lines, pixels, grid cells or tins as well as their attributes.
- **Data element** -- a logically primitive item of data.
- **Metadata**-- Data about the content, quality, condition, and other characteristics of data.
- **Spatial --** An adjective applied to objects that vary in space in two or three dimensions.
- **Radiowaves**are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light.
- **XML** Extensible Markup Language (XML) is a markup language that defines a set of rules for encoding documents in a format that is bothhuman-readable and machine-readable
- **HTTP**The Hypertext Transfer Protocol (HTTP) is an application protocol for distributed, collaborative, hypermedia information systems.[1]HTTP is the foundation of data communication for the World Wide Web.
- **Linux**is a Unix-like operating system that was designed to provide personal computer users a free or very low-cost operating system comparable to traditional and usually more expensive Unix systems
- **Dot Net**The Microsoft .Net Framework is a platform that provides tools and technologies you need to build Networked Applications as well as Distributed Web Services and Web Applications.

4.9 Answer to check your progress/Possible Answers to SAQ.

Ans 1. Open source projects typically are worked on by a community of volunteer programmers. Open source GIS programs are based on different base programming languages. Three main groups of open source GIS (outside of web GIS) in terms of programming languages are: "C" languages, Java, and .NET

Ans 2.a. Geographic Resources Analysis Support System, **b.**Generic mapping tool , **c.**Open GIS Consortium

Ans 3. Metadata of the NSDI content and information availability The NSDI Metadata would get evolved from the NSDI Standard and as digital spatial information is populated

1. Search and Location - What data sets hold the sort of data of interest? This enables organizations to know and publicize what data holdings they have.

2. Analysis metadata - Do the identified data sets contain sufficient information to enable a sensible analysis to be made for my purposes? This is documentation to be provided with the data to ensure that others use the data correctly and wisely.

3. Access metadata – What is the process of obtaining and using the data that are required? This helps end users and provider organizations to effectively store, reuse, maintain and archive their Data holdings

There are different levels that metadata may be used for:

Ans 4a. Survey of India, **b**. National Spatial Data Infrastructure, **c**. Geological Survey of India

Ans 5.A navigation system is a (usually electronic) system that aids in navigation. Navigation systems may be entirely on board a vehicle or vessel, or they may be located elsewhere and communicate via radio or other signals with a vehicle or vessel, or they may use a combination of these methods.

Ans 6a. LORAN**, b**. GPS**, c.** RDF

Ans 7aCarin Database Format, b. Global positing system

Ans 8 . Map Server is an Open Source platform for publishing spatial data and interactive mapping applications to the web. Originally developed in the mid-1990 at the University of Minnesota, mapserver is released under an *MIT-style license*, and runs on all major platforms (Windows, Linux, *and Mac OS X*).

Ans 9 a. Java,**b**. Protocol/Internet Protocol,**c.** MapGuide

4.10Reference

1. http://www.nsdiindia.gov.in/nsdi/nsdiportal/questionnaire/THE.pdf

2. http://nsdiindia.gov.in/nsdi/nsdiportal/images/NSDI%20Metadata%20Standard%20Vern-2.0.pdf

3. http://en.wikipedia.org/wiki/Navigation_system

4. To learn GIS using open source software, read Sid Feygin's article *How to Go from GIS Novice to Pro without Spending a Dime* which provides tips and resources.

5. http://gislounge.com/open-gis/

6. http://gislounge.com/open-source-gis-applications/

7. http://www.geomajas.org/

8. http://geoserver.org/display/GEOS/Welcome

9. http://mapguide.osgeo.org/

10. http://mapfish.org/

11. http://mapserver.org

12. http://openlayers.org/

13. http://mapbox.com/tilemill/

14. http://www.isprs.org/proceedings/XXXVIII/part6/papers/Tuohy/ISPRS_CVI_Tuohy[1].pdf

4.11. Suggested Readings

1. Desktop GIS: mapping the planet with open source tools Gary E. Sherman - 2008

2. Encyclopedia of GIS Shashi Shekhar, Hui Xiong - 2007

3. GIS for everyone: exploring your neighborhood and your world with .David Edward Davis - 2003

4.12. Terminal Questions

Q1.Difference Between Open Gis And Licence (Commercial) Gis Software?

Q2.Open GIS Consortium?

Q3.Wright the name of opengis software coming under java tribes.

Q4.what is Grass?

Q5. Explain automobile navigation

Q6. What is NSDI Electronic ClearingHouse?