Remote Sensing and GIS

Aerial Photography

An aerial photograph, in broad terms, is any photograph taken from the air. Normally, air photos are taken vertically from an aircraft using a highly-accurate camera. There are several things you can look for to determine what makes one photograph different from another of the same area, including type of film, scale, and overlap. Other important concepts used in aerial photography are stereoscopic coverage, fiducial marks, focal length, roll and frame numbers, and flight lines and index maps. The following material will help you understand the fundamentals of aerial photography by explaining these basic technical concepts.

Basic Concepts of Aerial Photography

Film: most air photo missions are flown using black and white film, however colour, infrared, and false-colour infrared film are sometimes used for special projects.

Focal length: the distance from the middle of the camera lens to the focal plane (i.e. the film). As focal length increases, image distortion decreases. The focal length is precisely measured when the camera is calibrated.

Scale: the ratio of the distance between two points on a photo to the actual distance between the same two points on the ground (i.e. 1 unit on the photo equals "x" units on the ground). If a 1 km stretch of highway covers 4 cm on an air photo, the scale is calculated as follows:

Another method used to determine the scale of a photo is to find the ratio between the camera's focal length and the plane's altitude above the ground being photographed.

If a camera's focal length is 152 mm, and the plane's altitude Above Ground Level (AGL) is 7 600 m, using the same equation as above, the scale would be:

Scale may be expressed three ways:

- Unit Equivalent
- Representative Fraction
- Ratio

A photographic scale of 1 millimetre on the photograph represents 25 metres on the ground would be expressed as follows:

- Unit Equivalent - 1 mm = 25 m
- Representative Fraction - 1/25 000
- Ratio - 1:25 000

Two terms that are normally mentioned when discussing scale are:

- Large Scale - Larger-scale photos (e.g. 1:25 000) cover small areas in greater detail. A large scale photo simply means that ground features are at a larger, more detailed size. The area of ground coverage that is seen on the photo is less than at smaller scales.
- Small Scale - Smaller-scale photos (e.g. 1:50 000) cover large areas in less detail. A small scale photo simply means that ground features are at a smaller, less detailed size. The area of ground coverage that is seen on the photo is greater than at larger scales.

The National Air Photo Library has a variety of photographic scales available, such as 1:3 000 (large scale) of selected areas, and 1:50 000 (small scale).

Fiducial marks: small registration marks exposed on the edges of a photograph. The distances between fiducial marks are precisely measured when a camera is calibrated, and this information is used by cartographers when compiling a topographic map.

Overlap: is the amount by which one photograph includes the area covered by another photograph, and is expressed as a percentage. The photo survey is designed to acquire 60 per cent forward overlap (between photos along the same flight line) and 30 per cent lateral overlap (between photos on adjacent flight lines).

Stereoscopic Coverage: the three-dimensional view which results when two overlapping photos (called a stereo pair), are viewed using a stereoscope. Each photograph of the stereo pair provides a slightly different view of the same area, which the brain combines and interprets as a 3-D view.

Roll and Photo Numbers: each aerial photo is assigned a unique index number according to the photo's roll and frame. For example, photo A23822-35 is the 35th annotated photo on roll A23822. This identifying number allows you to find the photo in NAPL's archive, along with metadata information such as the date it was taken, the plane's altitude (above sea level), the focal length of the camera, and the weather conditions.

Flight Lines and Index Maps: at the end of a photo mission, the aerial survey contractor plots the location of the first, last, and every fifth photo centre, along with its roll and frame number, on a National Topographic System

(NTS) map. Photo centres are represented by small circles, and straight lines are drawn connecting the circles to show photos on the same flight line.

This graphical representation is called an air photo index map, and it allows you to relate the photos to their geographical location. Small-scale photographs are indexed on 1:250,000 scale NTS map sheets, and larger-scale photographs are indexed on 1:50,000 scale NTS maps.

Remote Sensing

Introduction and History

The technology of modern remote sensing began with the invention of the camera more than 150 years ago. Although the first, rather primitive photographs were taken as "stills" on the ground, the idea and practice of looking down at the Earth's surface emerged in the 1840s when pictures were taken from cameras secured to tethered balloons for purposes of topographic mapping. Perhaps the most novel platform at the end of the last century is the famed pigeon fleet that operated as a novelty in Europe. By the first World War, cameras mounted on airplanes provided aerial views of fairly large surface areas that proved invaluable in military reconnaissance. From then until the early 1960s, the aerial photograph remained the single standard tool for depicting the surface from a vertical or oblique perspective.

Satellite remote sensing can be traced to the early days of the space age (both Russian and American programs) and actually began as a dual approach to imaging surfaces using several types of sensors from spacecraft. In 1946, V-2 rockets acquired from Germany after World War II were launched to high altitudes from White Sands, New Mexico. These rockets, while never attaining orbit, contained automated still or movie cameras that took pictures as the vehicle ascended. Then, with the emergence of the space program in the 1960s, Earth-orbiting cosmonauts and astronauts acted much like tourists by taking photos out the window of their spacecraft.

The term "remote sensing," first used in the United States in the 1950s by Ms. Evelyn Pruitt of the U.S. Office of Naval Research, is now commonly used to describe the science—and art—of identifying, observing, and measuring an object without coming into direct contact with it. This process involves the detection and measurement of radiation of different wavelengths reflected or emitted from distant objects or materials, by which they may be identified and categorized by class/type, substance, and spatial distribution.

Radiation

Unless it has a temperature of absolute zero (-273°C) an object reflects, absorbs, and emits energy in a unique way, and at all times. This energy, called electromagnetic radiation, is emitted in waves that are able to transmit energy from one place to another. For example, this computer, trees, air, the Sun, the Earth, and all the stars and planets are reflecting and emitting a wide range of electromagnetic waves. These waves originate from billions of vibrating electrons, atoms, and molecules, which emit and absorb electromagnetic radiation in unique combinations of wavelengths.

The amount of electromagnetic radiation an object emits depends primarily on its temperature. The higher the temperature of an object, the faster its electrons vibrate and the shorter its peak wavelength of emitted radiation. Conversely, the lower the temperature of an object, the slower its electrons vibrate, and the longer its peak wavelength of emitted radiation. This concept can be shown by gripping the end of a long rope and shaking it. Rapidly shaking the rope (high temperature) results in a series of short waves travelling along it, while shaking it slowly (low temperature) results in a series of longer waves.

Electromagnetic Spectrum

The fundamental unit of electromagnetic phenomena is the photon, the smallest possible amount of electromagnetic energy of a particular wavelength. Photons, which are without mass, move at the speed of light—300,000 km/sec (186,000 miles/sec) in the form of waves analogous to the way waves propagate through the oceans. The energy of a photon determines the frequency (and wavelength) of light that is associated with it. The greater the energy of the photon, the greater the frequency of light and vice versa.

The entire array of electromagnetic waves comprises the electromagnetic (EM) spectrum. The waves are called electromagnetic because they consist of combined electric and magnetic waves that result when a charged particle (electron) accelerates. The EM spectrum has been arbitrarily divided into regions or intervals to which descriptive names have been applied. At the very energetic (high frequency; short wavelength) end are gamma rays and x-rays. Radiation in the ultraviolet region extends from about 1 nanometer to about 0.36 micrometers. It is convenient to measure the mid-regions of the spectrum in these two units: micrometers (µm), a unit of length equivalent to one-millionth of a meter, or nanometers (nm), a unit of length equivalent to one-billionith of a meter. The visible region occupies the range between 0.4 and 0.7 µm, or its equivalents of 400 to 700 nm. The infrared (IR) region, spans between 0.7 and 100 µm. At shorter wavelengths (near .7 µm) infrared radiation can be detected by special film, while at longer wavelengths it is felt as heat.

Longer wavelength intervals are measured in units ranging from millimeters (mm) through meters (m). The microwave region spreads across 1 mm to 1 m; this includes all of the intervals used by man-made radar systems, which generate their own active radiation directed towards (and reflected from) targets of interest. The lowest frequency (longest wavelength) region—beyond 1 m—is associated with radio waves.

Absorption Bands and Atmospheric Windows

Some types of electromagnetic radiation easily pass through the atmosphere, while other types do not. The ability of the atmosphere to allow radiation to pass through it is referred to as its transmissivity, and varies with the wavelength/type of the radiation. The gases that comprise our atmosphere absorb radiation in certain wavelengths while allowing radiation with differing wavelengths to pass through.

The areas of the EM spectrum that are absorbed by atmospheric gases such as water vapor, carbon dioxide, and ozone are known as absorption bands. In the figure, absorption bands are represented by a low transmission value that is associated with a specific range of wavelengths.

In contrast to the absorption bands, there are areas of the electromagnetic spectrum where the atmosphere is transparent (little or no absorption of radiation) to specific wavelengths. These wavelength bands are known as atmospheric "windows" since they allow the radiation to easily pass through the atmosphere to Earth's surface.

Most remote sensing instruments on aircraft or space-based platforms operate in one or more of these windows by making their measurements with detectors tuned to specific frequencies (wavelengths) that pass through the atmosphere. When a remote sensing instrument has a line-of-sight with an object that is reflecting sunlight or emitting heat, the instrument collects and records the radiant energy.While most remote sensing systems are designed to collect reflected radiation, some sensors, especially those on meteorological satellites, directly measure absorption phenomena, such as those associated with carbon dioxide (CO_2) and other gases. The atmosphere is nearly opaque to EM radiation in part of the mid-IR and all of the far-IR regions. In the microwave region, by contrast, most of this radiation moves through unimpeded, so radar waves reach the surface (although weather radars are able to detect clouds and precipitation because they are tuned to observe backscattered radiation from liquid and ice particles).

Spectral Signatures

A primary use of remote sensing data is in classifying the myriad features in a scene (usually presented as an image) into meaningful categories or classes. The image then becomes a thematic map (the theme is selectable e.g., land use, geology, vegetation types, rainfall). A farmer may use thematic maps to monitor the health of his crops without going out to the field. A geologist may use the images to study the types of minerals or rock structure found in a certain area. A biologist may want to study the variety of plants in a certain location.

For example, at certain wavelengths, sand reflects more energy than green vegetation while at other wavelengths it absorbs more (reflects less) energy. Therefore, in principle, various kinds of surface materials can be distinguished 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 of the amount of radiation reaching the surface). Using reflectance differences, the four most common surface materials (GL = grasslands; PW = pinewoods; RS = red sand; SW = silty water) can be easily distinguished, as shown in the next figure.

When more than two wavelengths are used, the resulting images tend to show more separation among the objects. Imagine looking at different objects through red lenses, or only blue or green lenses. In a similar manner, certain satellite sensors can record reflected energy in the red, green, blue, or infrared bands of the spectrum, a process called multispectral remote sensing. The improved ability of multispectral sensors provides a basic remote sensing data resource for quantitative thematic information, such as the type of land cover. Resource managers use information from multispectral data to monitor fragile lands and other natural resources, including vegetated areas, wetlands, and forests. These data provide unique identification characteristics leading to a quantitative assessment of the Earth's features.

Pixels and Bits

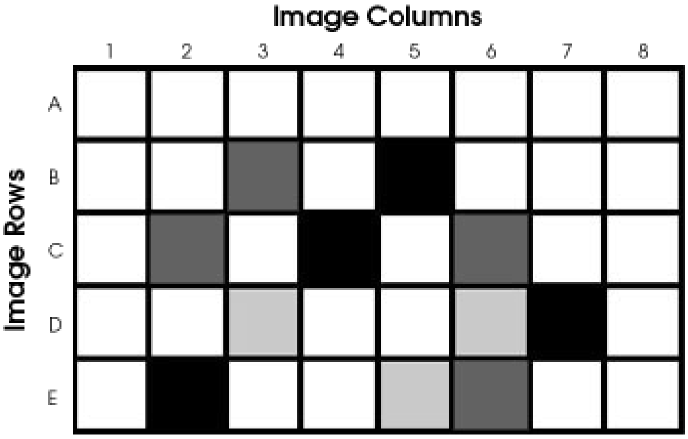
Using radio waves, data from Earth-orbiting satellites are transmitted on a regular basis to properly equipped ground stations. As the data are received they are translated into a digital image that can be displayed on a computer screen. Just like the pictures on your television set, satellite imagery is made up of tiny squares, each of a different gray shade or color. These squares are called pixels—short for picture elements—and represent the relative reflected light energy recorded for that part of the image.

This weather satellite image of hurricane Floyd from September 15, 1999, has been magnified to show the individual picture elements (pixels) that form most remote sensing images. (Image derived from NOAA GOES DATA)

Each pixel represents a square area on an image that is a measure of the sensor's ability to resolve (see) objects of different sizes. For example, the Enhanced Thematic Mapper (ETM+) on the Landsat 7 satellite has a maximum resolution of 15 meters; therefore, each pixel represents an area 15 m x 15 m, or 225 m^2. Higher resolution (smaller pixel area) means that the sensor is able to discern smaller objects. By adding up the number of pixels in an image, you can calculate the area of a scene. For example, if you count the number of green pixels in a false color image, you can calculate the total area covered with vegetation.

How does the computer know which parts of the image should be dark and which one should be bright? Computers understand the numeric language of binary numbers, which are sets of numbers consisting of 0s and 1s that act as an "on-off" switch. Converting from our decimal system to binary numbers, 00 = 0, 01 = 1, 10 = 2, 11 = 3. Note that we cannot use decimal numbers since all computers are fussy—they only like "on" and "off."

For example, consider an image that is made up of 8 columns by 5 rows of pixels. In this figure, four shades are present: black, dark gray, light gray and white. The darkest point is assigned the binary number 00, dark gray as 01, light gray as 10, and the brightest part the binary number 11. We therefore have four pixels (B5, C4, D7 and E2) that the spacecraft says are 00. There are three dark gray pixels (B3, C2, C6 and E6) assigned the binary number 01, three light gray pixels (D3, D6 and E5) that are binary number 10, and 29 white pixels are assigned the binary number 11.



Colour Images

Four shades between white and black would produce images with too much contrast, so instead of using binary numbers between 00 and 11, spacecraft use a string of 8 binary numbers (called "8-bit data"), which can range from 00000000 to 11111111. These numbers correspond from 0 to 255 in the decimal system. With 8-bit data, we can assign the darkest point in an image to the number 00000000, and the brightest point in the image to 11111111. This produces 256 shades of gray between black and white. It is these binary numbers between 0 and 255 that the spacecraft sends back for each pixel in every row and column—and it takes a computer to keep track of every number for every pixel!

Another essential ingredient in most remote sensing images is color. While variations in black and white imagery can be very informative, the number of different gray tones that the eye can separate is limited to about 20 to 30 steps (out of a maximum of about 200) on a contrast scale. On the other hand, the eye can distinguish 20,000 or more color tints, enabling small but often important variations within the target materials or classes to be discerned.

Since different bands (or wavelengths) have a different contrast, computers can be used to produce a color image from a black and white remote sensing data set. Remember, satellites record the reflected and emitted brightness in the different parts of the spectrum, as is demonstrated in the figure above.

Similar to the screen on a color television set, computer screens can display three different images using blue light, green light and red light. The combination of these three wavelengths of light will generate the color image that our eyes can see. This is accomplished by displaying black and white satellite images corresponding to various bands in either blue, green, or red light to achieve the relative contrast between the bands. Finally, when these three colors are combined, a color image—called a "false color image"—is produced (it's called "false color" because colors are assigned that we can see and easily interpret with our eyes).

In order to understand what the colors mean in the satellite image, we must know which band (or wavelength) is used for each of the blue, green and red parts of the computer display. Without detailed knowledge of how each band has been changed for contrast and brightness, we cannot be sure why the colors are what they are.

Remote Sensing Methods

There are two types of remote sensing instruments—passive and active. Passive instruments detect natural energy that is reflected or emitted from the observed scene. Passive instruments sense only radiation emitted by the object being viewed or reflected by the object from a source other than the instrument. Reflected sunlight is the most common external source of radiation sensed by passive instruments. Scientists use a variety of passive remote sensors.

Radiometer

An instrument that quantitatively measures the intensity of electromagnetic radiation in some band of wavelengths in the spectrum. Usually a radiometer is further identified by the portion of the spectrum it covers; for example, visible, infrared, or microwave.

Imaging Radiometer

A radiometer that includes a scanning capability to provide a two-dimensional array of pixels from which an image may be produced is called an imaging radiometer. Scanning can be performed mechanically or electronically by using an array of detectors.

Spectrometer

A device designed to detect, measure, and analyze the spectral content of the incident electromagnetic radiation is called a spectrometer. Conventional, imaging spectrometers use gratings or prisms to disperse the radiation for spectral discrimination.

Spectroradiometer

A radiometer that can measure the intensity of radiation in multiple wavelength bands (i.e., multispectral). Oftentimes the bands are of a high spectral resolution—designed for the remote sensing of specific parameters such as sea surface temperature, cloud characteristics, ocean color, vegetation, trace chemical species in the atmosphere, etc.

Active instruments provide their own energy (electromagnetic radiation) to illuminate the object or scene they observe. They send a pulse of energy from the sensor to the object and then receive the radiation that is reflected or backscattered from that object. Scientists use many different types of active remote sensors.

Radar (Radio Detection and Ranging)

A radar uses a transmitter operating at either radio or microwave frequencies to emit electromagnetic radiation and a directional antenna or receiver to measure the time of arrival of reflected or backscattred pulses of radiation from distant objects. Distance to the object can be determined since electromagnetic radiation propagates at the speed of light.

Scatterometer

A scatterometer is a high frequency microwave radar designed specifically to measure backscattered radiation. Over ocean surfaces, measurements of backscattered radiation in the microwave spectral region can be used to derive maps of surface wind speed and direction.

Lidar (Light Detection and Ranging)

A lidar uses a laser (light amplification by stimulated emission of radiation) to transmit a light pulse and a receiver with sensitive detectors to measure the backscattered or reflected light. Distance to the object is determined by recording the time between the transmitted and backscattered pulses and using the speed of light to calculate the distance traveled. Lidars can determine atmospheric profiles of aerosols, clouds, and other constituents of the atmosphere.

Laser Altimeter

A laser altimeter uses a lidar (see above) to measure the height of the instrument platform above the surface. By independently knowing the height of the platform with respect to the mean Earth's surface, the topography of the underlying surface can be determined.

Image analysis

In order to take advantage of and make good use of remote sensing data, we must be able to extract meaningful information from the imagery.

Much interpretation and identification of targets in remote sensing imagery is performed manually or visually, i.e. by a human interpreter. Recognizing targets is the key to interpretation and information extraction. Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of **tone, shape, size, pattern, texture, shadow, and association**.

If a two-dimensional image can be viewed **stereoscopically** so as to simulate the third dimension of height, visual interpretation will be much easier.

When remote sensing data are available in digital format, **digital processing and analysis** may be performed using a computer. Digital processing may be used to enhance data as a prelude to visual interpretation. Digital processing and analysis may also be carried out to automatically identify targets and extract information completely without manual intervention by a human interpreter.

Digital image processing may involve numerous procedures including formatting and correcting of the data, digital enhancement to facilitate better visual interpretation, or even automated classification of targets and features entirely by computer. In order to process remote sensing imagery digitally, the data must be recorded and available in a digital form suitable for storage on a computer tape or disk.

At last but not least, an important element in the image analysis is the integration of data. In the early days of analog remote sensing when the only remote sensing data source was aerial photography, the capability for integration of data from different sources was limited. Today, with most data available in digital format from a wide array of sensors, data integration is a common method used for interpretation and analysis. Data integration fundamentally involves the combining or merging of data from multiple sources in an effort to extract better and/or more information. This may include data that are multitemporal, multiresolution, multisensor, or multi-data type in nature.

Remote sensing application

Agriculture - Satellite and airborne images are used as mapping tools to classify crops, examine their health and viability, and monitor farming practices. Agricultural applications of remote sensing include the following:

- crop type classification
- crop condition assessment
- crop yield estimation
- mapping of soil characteristics
- mapping of soil management practices
- compliance monitoring (farming practices)

Forestry - Forestry applications of remote sensing include the following:

Reconnaissance mapping: Objectives to be met by national forest/environment agencies include forest cover updating, depletion monitoring, and measuring biophysical properties of

- forest stands.
- forest cover type discrimination
- agroforestry mapping

Commercial forestry: Of importance to commercial forestry companies and to resource management agencies are inventory and mapping applications: collecting harvest information, updating of inventory information for timber supply, broad forest

- type, vegetation density, and biomass measurements.
- clear cut mapping / regeneration assessment
- burn delineation
- infrastructure mapping / operations support
- forest inventory
- biomass estimation
- species inventory

Environmental monitoring: Conservation authorities are concerned with monitoring the quantity, health and diversity of the Earth's forests.

- deforestation (rainforest, mangrove colonies)
- species inventory
- watershed protection (riparian strips)
- coastal protection (mangrove forests)
- forest health and vigor

Geology - Remote sensing is used as a tool to extract information about the land surface structure, composition or subsurface, but is often combined with other data sources providing complementary measurements. Multispectral data can provide information on lithology or rock composition based on spectral reflectance. Radar provides an expression of surface topography and roughness, and thus is extremely valuable, especially when integrated with another data source to provide detailed relief.

Geological applications of remote sensing include the following:

- surficial deposit / bedrock mapping
- lithological mapping
- structural mapping

- sand and gravel (aggregate) exploration/ exploitation
- mineral exploration
- hydrocarbon exploration
- environmental geology
- geobotany
- baseline infrastructure
- sedimentation mapping and monitoring
- event mapping and monitoring
- geo-hazard mapping
- planetary mapping

Hydrology - Remote sensing offers a synoptic view of the spatial distribution and dynamics of hydrological phenomena, often unattainable by traditional ground surveys. Radar has brought a new dimension to hydrological studies with its active sensing capabilities, allowing the time window of image acquisition to include inclement weather conditions or seasonal or diurnal darkness.

Hydrological applications of remote sensing include the following:

- wetlands mapping and monitoring,
- snow pack monitoring / delineation of extent,
- determining snow-water equivalent,
- flood mapping and monitoring,
- river /delta change detection
- irrigation canal leakage detection
- soil moisture estimation,
- measuring snow thickness,
- river and lake ice monitoring,
- glacier dynamics monitoring (surges, ablation)
- drainage basin mapping and watershed modeling
- irrigation scheduling

Sea ice - Remote sensing data can be used to identify and map different ice types, locate leads (large navigable cracks in the ice), and monitor ice movement. With current technology, this information can be passed to the client in a very short timeframe from acquisition. Users of this type of information include the Coast Guard, port authorities, commercial shipping and fishing industries, ship builders, resource managers (oil and gas / mining), infrastructure construction companies and environmental consultants, marine insurance agents, scientists, and commercial tour operators.

Examples of sea ice information and applications:

- ice concentration
- iceberg detection and tracking
- tactical identification of leads: navigation: safe shipping routes/rescue
- ice condition (state of decay)
- pollution monitoring
- ice type / age /motion
- surface topography
- historical ice and iceberg conditions and dynamics for planning purposes
- wildlife habitat
- meteorological / global change research

Land cover and Land use - Resource managers involved in parks, oil, timber, and mining companies, are concerned with both land use and land cover, as are local resource inventory or natural resource agencies. Changes in land cover will be examined by environmental monitoring researchers, conservation authorities, and departments of municipal affairs, with interests varying from tax assessment to reconnaissance vegetation mapping. Governments are also concerned with the general protection of national resources, and become involved in publicly sensitive activities involving land use conflicts.

Land use applications of remote sensing include the following:

- natural resource management
- baseline mapping for GIS input
- routing and logistics planning for seismic / exploration / resource extraction activities
- legal boundaries for tax and property evaluation
- wildlife habitat protection
- urban condition and expansion / encroachment
- target detection - identification of landing strips, roads, clearings, bridges, land/water interface
- damage delineation (tornadoes, flooding, volcanic, seismic, fire)

Oceans & Coastal Monitoring - Coastlines are environmentally sensitive interfaces between the ocean and land and respond to changes brought about by economic development and changing land-use patterns. Often coastlines are also biologically diverse inter-tidal zones, and can also be highly urbanized. With over 60% of the world's population living close to the ocean, the coastal zone is a region subject to increasing stress from human activity. Government agencies concerned with the impact of human activities in this region need new data sources with which to monitor such diverse changes as coastal erosion, loss of natural habitat, urbanization, effluents and offshore pollution. Many of the dynamics of the open ocean and changes in the coastal region can be mapped and monitored using remote sensing techniques.

Ocean applications of remote sensing include the following:

- Ocean pattern identification:
  - currents, regional circulation patterns, shears frontal zones, internal waves, gravity waves, eddies, upwelling zones, shallow water
  - bathymetry
- Storm forecasting
  - wind and wave retrieval
- Fish stock and marine mammal assessment
  - water temperature monitoring
  - water quality
  - ocean productivity, phytoplankton concentration and drift
  - aquaculture inventory and monitoring
- Oil spills
  - mapping and predicting oil spill extent and drift
  - strategic support for oil spill emergency response decisions
  - identification of natural oil seepage areas for exploration
- Shipping
  - navigation routing
  - traffic density studies
  - operational fisheries surveillance
  - near-shore bathymetry mapping
- Intertidal zone
  - tidal and storm effects
  - delineation of the land /water interface
  - mapping shoreline features / beach dynamics
  - coastal vegetation mapping
  - human activity / impact

Atmosphere monitoring - Measurements and observations of the atmosphere (and especially the troposphere) are the most important pre-requisite to our understanding of weather and climate. Numerical models of the atmosphere have revolutionized the preparation of weather forecasts, although rather than reducing the need for observations such models have increased awareness of the importance of data through assimilation schemes. Indeed, the accuracy of forecasts relies crucially upon how well the initial state of the atmosphere can be described and this requires detailed measurements throughout the entire depth of the atmosphere.

Over the last half century, the increasing availability of low cost computers and sensors has enabled a move away from a reliance on the collection of weather data at traditional sites and enclosures. However, perhaps the greatest contribution to improving accuracy in weather prediction and monitoring is the advent of new observing systems based on satellite and airborne platforms. These technologies have completely revolutionized the networking of conventional meteorological instrumentation and have facilitated a colossal advance in both the spatial and temporal scale of weather measurement (Chapman et. al 2011).

Satellite systems provide a unique opportunity to monitor Earth-atmosphere system processes and parameters continuously. In view of the great benefit provided by spaceborne Earth-atmosphere remote sensing, there were strong efforts to construct Earth observing satellite systems in the past. Satellite based observations of the Earth and the atmosphere started with the first meteorological satellite, the Television InfraRed Observation Satellite (TIROS-1), launched in 1960. During the following decades several satellite systems with different sensors provided data for a wide range of atmospheric parameters that enhanced our understanding of Earth-atmosphere processes and dynamics. Nowadays, operational satellite systems provide invaluable measurements of atmospheric parameters at regular intervals on a global scale (Thies and Bendix, 2011).

Meteorological parameters measured by remote sensing

- Radiation: Radiation energy and its spatio-temporal distribution is the driver for atmospheric dynamics. To understand weather and climate, measurements of the radiation that enters and leaves the Earth-atmosphere system are necessary.

- Surface temperature: Retrievals of the sea surface temperature (SST) and land surface temperature (LST) from space provide information for interactions between ocean/land and atmosphere such as evaporation processes and boundary layer dynamics.
- Wind: Wind fields derived from satellites provide continuous area-wide information about atmospheric dynamics in a high spatial and temporal resolution. Such information is of great benefit as an input parameter for numerical weather prediction. Thus, atmospheric motion vectors, derived by tracking atmospheric features (e.g. clouds or water vapour) with satellites were one of the first satellite data products assimilated in global numerical weather prediction.
- Water vapor: Water vapour is the principal greenhouse gas in the atmosphere and a key compound of the global climate. It is important for many atmospheric processes, such as radiative transfer, circulation dynamics, cloud formation, precipitation and the greenhouse effect. Information about the distribution and variability of atmospheric water vapour is critical for understanding these processes controlling the Earth radiative budget and the hydrological cycle.
- Gasses: As a response on the increasing human impact on the evolution of the global climate and on the stratospheric ozone layer much effort has been made to understand the underlying chemical and physical processes and the role of anthropogenic gas emissions. To fulfill this objective there is a clear need for global observation of gas emissions and concentrations in the Earth atmosphere system.
- Aerosols: Aerosols in the troposphere are a major climate forcing parameter, due to the direct and indirect aerosol effect. Despite this importance there are still significant uncertainties concerning the physical and optical properties of tropospheric aerosols and their interaction with global climate. This is mainly due to the inadequate quantitative knowledge of global aerosol characteristics and their temporal variability. To evaluate the aerosol radiative effects together with the magnitude and the potential variability of the aerosol climate forcing it is therefore essential to monitor aerosols on the global scale.
- Clouds – identification and properties: identifying clouds in satellite imagery is an important first step in the retrieval of both surface and atmospheric properties. In the past, various cloud classification techniques have been developed for the different satellite systems and for a variety of purposes. Typical cloud parameters that can be derived from satellite data and that are useful for such investigations comprise cloud-top height, cloud optical thickness, cloud effective particle radius, cloud liquid water path and cloud phase.
- Precipitation: Precipitation is a key factor of the global water cycle and affects all aspects of human life. Because of its great importance and its high spatial and temporal variability, the correct spatio-temporal detection and quantification of precipitation has been one of the main goals of meteorological satellite missions. Precipitation retrieval from satellite data can provide area-wide information in regions for which data from rain gauge or radar networks are sparse or unavailable (Thies and Bendix, 2011).

Geographic Information System (GIS)

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displayingdata related to positions on Earth’s surface. GIS can show many different kinds of data on one map. This enables people to more easily see, analyze, and understand patterns and relationships.

With GIS technology, people can compare the locations of different things in order to discover how they relate to each other. For example, using GIS, the same map could include sites that produce pollution, such as gas stations, and sites that are sensitive to pollution, such as wetlands. Such a map would help people determine which wetlands are most at risk.

GIS can use any information that includes location. The location can be expressed in many different ways, such aslatitude and longitude, address, or ZIP code. Many different types of information can be compared and contrasted using GIS. The system can include data about people, such as population, income, or education level. It can include information about the land, such as the location of streams, different kinds of vegetation, and different kinds of soil. It can include information about the sites of factories, farms, and schools, or storm drains, roads, and electric power lines.

Data and GIS

Data in many different forms can be entered into GIS. Data that are already in map form can be included in GIS. This includes such information as the location of rivers and roads, hills and valleys. Digital, or computerized, data can also be entered into GIS. An example of this kind of information is data collected by satellites that show land use—the location of farms, towns, or forests. GIS can also include data in table form, such as population information. GIS technology allows all these different types of information, no matter their source or original format, to be overlaid on top of one another on a single map.

Putting information into GIS is called data capture. Data that are already in digital form, such as images taken by satellites and most tables, can simply be uploaded into GIS. Maps must be scanned, or converted into digital information.

GIS must make the information from all the various maps and sources align, so they fit together. One reason this is necessary is because maps have different scales. A scale is the relationship between the distance on a map and the actual distance on Earth. GIS combines the information from different sources in such a way that it all has the same scale.

Often, GIS must also manipulate the data because different maps have different projections. A projection is the method of transferring information from Earth's curved surface to a flat piece of paper or computer screen. No projection can copy the reality of Earth's curved surface perfectly. Different types of projections accomplish this task in different ways, but all result in some distortion. To transfer a curved, three-dimensional shape onto a flat surface inevitably requires stretching some parts and squeezing other parts. A world map can show either the correct sizes of countries or their correct shapes, but it can't do both. GIS takes data from maps that were made using different projections and combines them so all the information can be displayed using one common projection.

GIS Maps

Once all of the desired data have been entered into a GIS system, they can be combined to produce a wide variety of individual maps, depending on which data layers are included. For instance, using GIS technology, many kinds of information can be shown about a single city. Maps can be produced that relate such information as average income, book sales, and voting patterns. Any GIS data layer can be added or subtracted to the same map.

GIS maps can be used to show information about number and density. For example, GIS can be used to show how many doctors there are in different areas compared with the population. They can also show what is near what, such as which homes and businesses are in areas prone to flooding.

With GIS technology, researchers can also look at change over time. They can use satellite data to study topics such as how much of the polar regions is covered in ice. A police department can study changes in crime data to help determine where to assign officers.

GIS often contains a large variety of data that do not appear in an onscreen or printed map. GIS technology sometimes allows users to access this information. A person can point to a spot on a computerized map to find other information stored in the GIS about that location. For example, a user might click on a school to find how many students are enrolled, how many students there are per teacher, or what sports facilities the school has.

GIS systems are often used to produce three-dimensional images. This is useful, for example, to geologists studying faults.

GIS technology makes updating maps much easier. Updated data can simply be added to the existing GIS program. A new map can then be printed or displayed on screen. This skips the traditional process of drawing a map, which can be time-consuming and expensive.

People working in many different fields use GIS technology. Many businesses use GIS to help them determine where to locate a new store. Biologists use GIS to track animal migration patterns. City officials use GIS to help plan their response in the case of a natural disaster such as an earthquake or hurricane. GIS maps can show these officials what neighborhoods are most in danger, where to locate shelters, and what routes people should take to reach safety. Scientists use GIS to compare population growth to resources such as drinking water, or to try to determine a region's future needs for public services like parking, roads, and electricity. There is no limit to the kind of information that can be analyzed using GIS technology.