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REMOTE SENSING

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Remote Sensing: is the collection of information relating to objects without being in physical contact with them. Thus our eyes and ears are remote sensors, and the same is true for cameras and microphones and for many instruments used for all kinds of applications

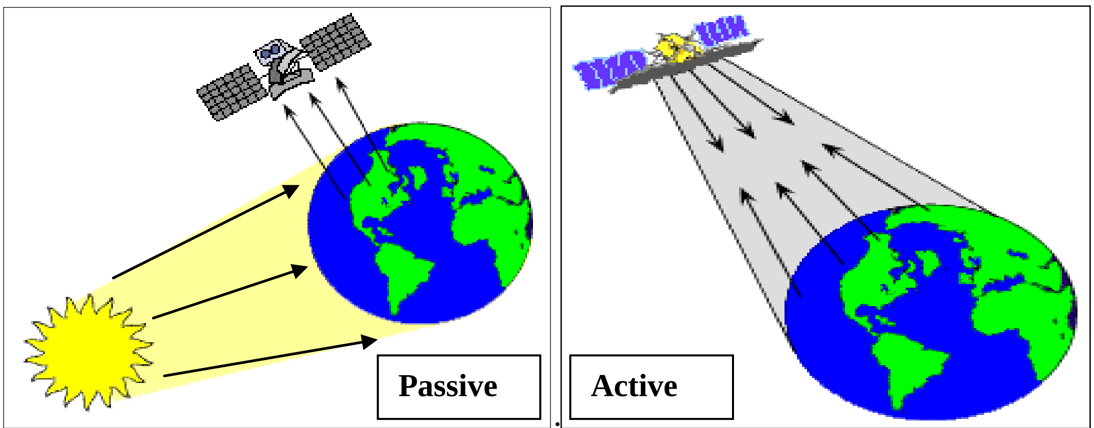
Or, said another way:

Remote sensing is the process of acquiring data/information about objects/substances not in direct contact with the sensor, by gathering its inputs using electromagnetic radiation or acoustical waves that emanate from the targets of interest. An aerial photograph is a common example of a remotely sensed (by camera and film, or now digital) product.

Introduction

The sun is a source of energy or radiation, which 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.

There are two main types of remote sensing: Passive remote sensing and Active remote sensing.



1-Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding area being observed. Reflected sunlight is the most

common source of radiation measured by passive sensors. Examples of passive remote sensors include film photography, infrared, and radiometers.

2-Active remote sensing, on the other hand, emits energy in order to scan objects and areas whereupon a sensor then detects and measures the radiation that is reflected or backscattered from the target. RADAR is an example of active remote sensing where the time delay between emission and return is measured, establishing the location, height, speeds and direction of an object.

Overview

Remote sensing makes it possible to collect data on dangerous or inaccessible areas. Remote sensing applications include monitoring deforestation in areas such as the Amazon Basin, the effects of climate change on glaciers and Arctic and Antarctic regions, and depth sounding of coastal and ocean depths. Military collection during the cold war made use of stand-off collection of data about dangerous border areas. Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed.

Applications of Remote Sensing

There are probably hundreds of applications - these are typical:

Meteorology - Study of atmospheric temperature, pressure, water vapour, and wind velocity.

Oceanography: Measuring sea surface temperature, mapping ocean currents, and wave energy spectra and depth sounding of coastal and ocean depths

Glaciology- Measuring ice cap volumes, ice stream velocity, and sea ice distribution. **(Glacial)**

Geology- Identification of rock type, mapping faults and structure.

Geodesy- Measuring the figure of the Earth and its gravity field.

Topography and cartography - Improving digital elevation models.

Agriculture Monitoring the biomass of land vegetation

Forest- monitoring the health of crops, mapping soil moisture

Botany- forecasting crop yields.

Hydrology- Assessing water resources from snow, rainfall and underground aquifers.

Disaster warning and assessment - Monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters.

Planning applications - Mapping ecological zones, monitoring deforestation, monitoring urban land use.

Oil and mineral exploration- Locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.

Military- developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements

Urban- determining the status of a growing crop

Climate- the effects of climate change on glaciers and Arctic and Antarctic regions

Sea- Monitoring the extent of flooding

Rock- Recognizing rock types

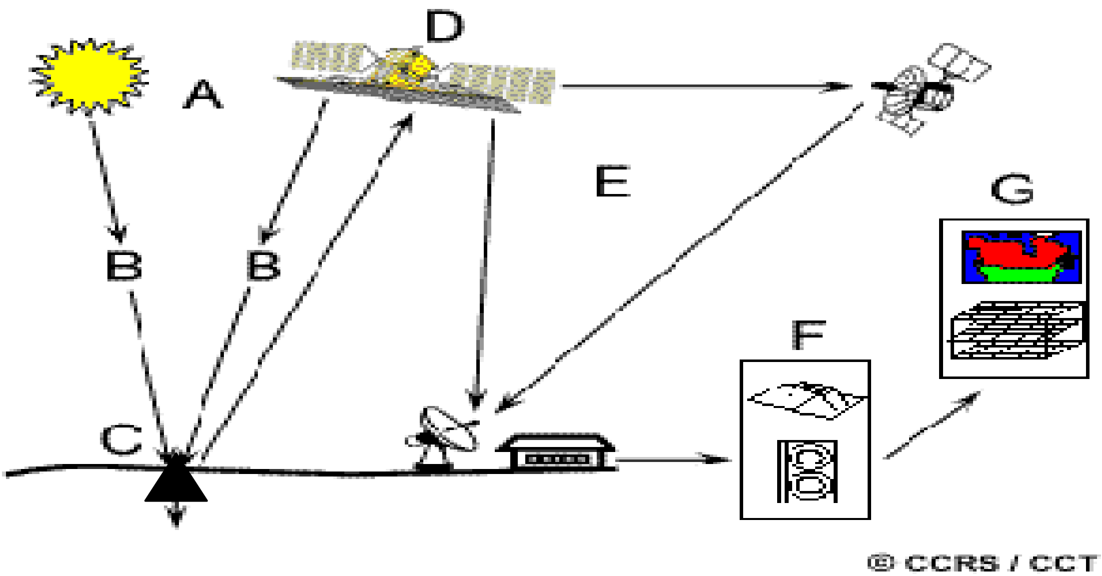
Space program- is the backbone of the space program

Seismology: as a premonition.

Principles and Process of Remote Sensing

Remote sensing actually done from satellites as Landsat or airplane or on the ground. To repeat the essence of the definition above, remote sensing uses instruments that house sensors to view the spectral, spatial and radiometric relations of observable objects and materials at a distance. Most sensing modes are based on sampling of photons corresponding frequency in the electromagnetic (EM) spectrum.

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-emitted sensors.



i. 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.

ii. 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.

iii. 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.

iv. 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.

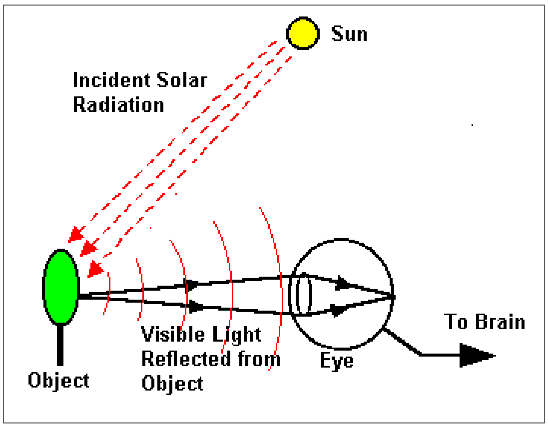
v. Transmission, Reception, and Processing (E) - The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed.

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

vii. 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.

Types of Remote Sensing System

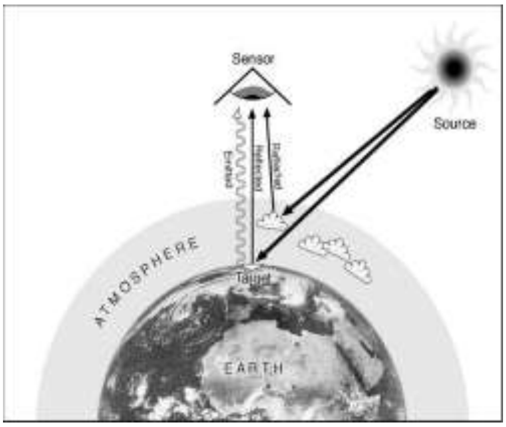
1- Visual remote sensing system



The human visual system is an example of a remote sensing system in the general sense. The **sensors** in this example are the two types of photosensitive cells, known as the **cones** and the **rods**, at the retina of the eyes. The cones are responsible for colour vision. There are three types of cones, each being sensitive to one of the red, green, and blue regions of the visible spectrum. Thus, it is not coincidental that the modern computer display monitors make use of the same three primary colours to generate a multitude of colours for displaying colour images. The cones are insensitive

under low light illumination condition, when their jobs are taken over by the rods. The rods are sensitive only to the total light intensity. Hence, everything appears in shades of grey when there is insufficient light. As the objects/events being observed are located far away from the eyes, the information needs a carrier to travel from the object to the eyes. In this case, the information carrier is the visible light, a part of the electromagnetic spectrum. The objects reflect/scatter the ambient light falling onto them. Part of the scattered light is intercepted by the eyes, forming an image on the retina after passing through the optical system of the eyes. The signals generated at the retina are carried via the nerve fibres to the brain, the central processing unit (CPU) of the visual system. These signals are processed and interpreted at the brain, with the aid of previous experiences. The visual system is an example of a "***Passive Remote Sensing***" system which depends on an external source of energy to operate. We all know that this system won't work in darkness.

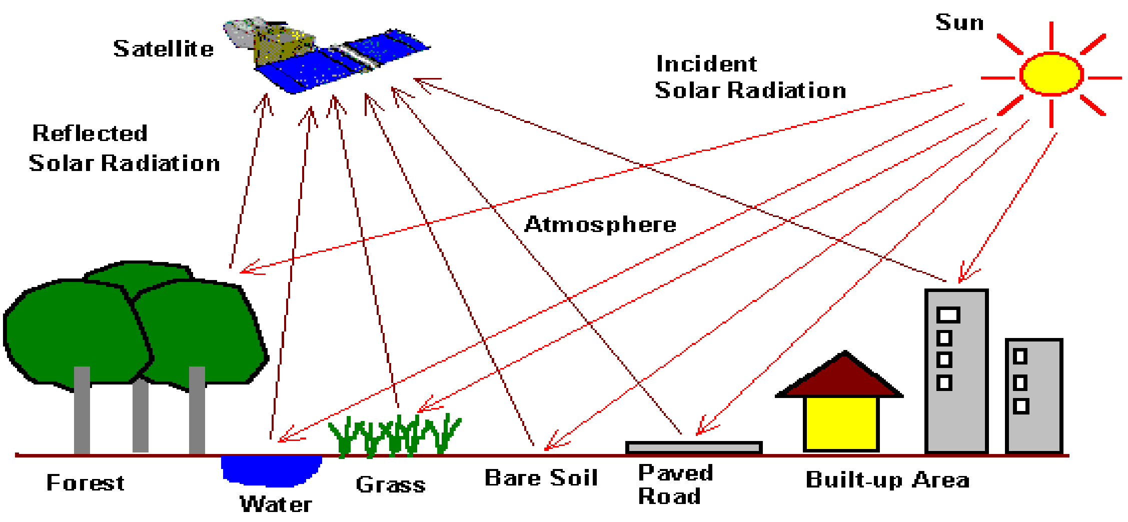
2- Optical Remote Sensing



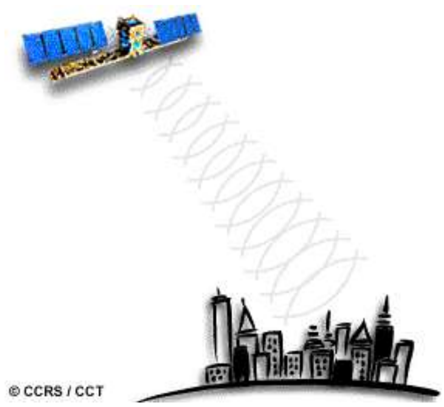
In Optical Remote Sensing, optical sensors detect solar radiation reflected or scattered from the earth, forming images resembling photographs taken by a camera high up in space. The wavelength region usually extends from the visible and near infrared VNIR to the short-wave infrared SWIR. Different materials such as water, soil, vegetation, buildings and roads reflect visible and infrared light in different ways. They have different colours and brightness when seen under the sun. The interpretations of optical images requires the knowledge of the ***spectral reflectance signatures*** of the various materials (natural or man-made) covering the surface of the earth.

3-Infrared Remote Sensing

Infrared remote sensing makes use of infrared sensors to detect infrared radiation emitted from the Earth's surface. The middle-wave infrared (MWIR) and long-wave infrared (LWIR) are within the thermal infrared region. These radiations are emitted from warm objects such as the Earth's surface. They are used in satellite remote sensing for measurements of the earth's land and sea surface temperature. Thermal infrared remote sensing is also often used for detection of forest fires, volcanoes, oil fires.



4-Microwave Remote Sensing



There are some remote sensing satellites which carry passive or active microwave sensors. The active sensors emit pulses of microwave radiation to illuminate the areas to be imaged. Images of the earth surface are formed by measuring the microwave energy scattered by the ground or sea back to the sensors. These satellites carry their own "flashlight" emitting microwaves to illuminate their targets. ***The images can thus be acquired day***

and night. Microwaves have an additional advantage as they can ***penetrate clouds***. Images can be acquired even when there are clouds covering the earth surface. A microwave imaging system which can produce high resolution image of the Earth is the ***synthetic aperture radar*** **(SAR)**. Electromagnetic radiation in the microwave wavelength region is used in remote sensing to provide useful information about the Earth's atmosphere, land and ocean. When microwaves strike a surface, the proportion of energy scattered back to the sensor depends on many factors:

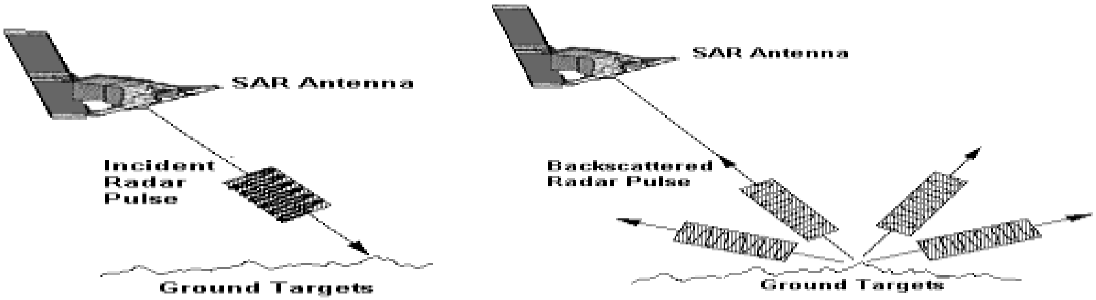
- Physical factors such as the ***dielectric constant*** of the surface materials which also depends strongly on the moisture content;
- Geometric factors such as surface ***roughness, slopes, orientation*** of the objects relative to the radar beam direction;
- The types of ***landcover*** (soil, vegetation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

5-Radar Remote Sensing

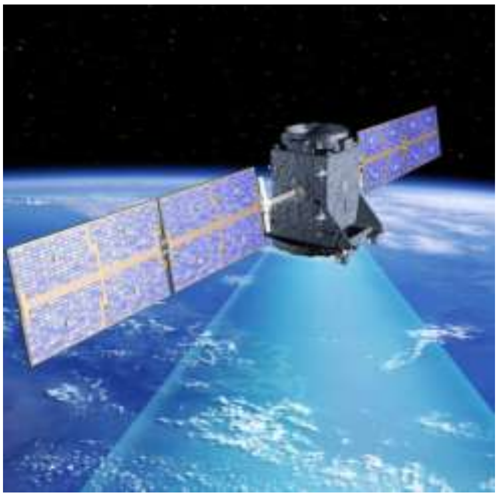
Using radar, geographers can effectively map out the terrain of a territory. Radar works by sending out radio signals, and then waiting for them to bounce off the ground and return. By measuring the amount of time it takes for the signals to return, it is possible to create a very accurate topographic map. An important advantage to using radar is that it can ***penetrate thick clouds and moisture***. This allows scientists to accurately map areas such as rain forests, which are otherwise too obscured by clouds and rain. Imaging radar systems are versatile sources of remotely sensed images, providing daynight, all-weather imaging capability. Radar images are used to map landforms and geologic structure, soil types, vegetation and crops, and ice and oil slicks on the ocean surface.

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 utilising the time delay of the backscattered signals. In real aperture radar imaging, the ground resolution is limited by the size of the microwave beam sent out from the antenna.



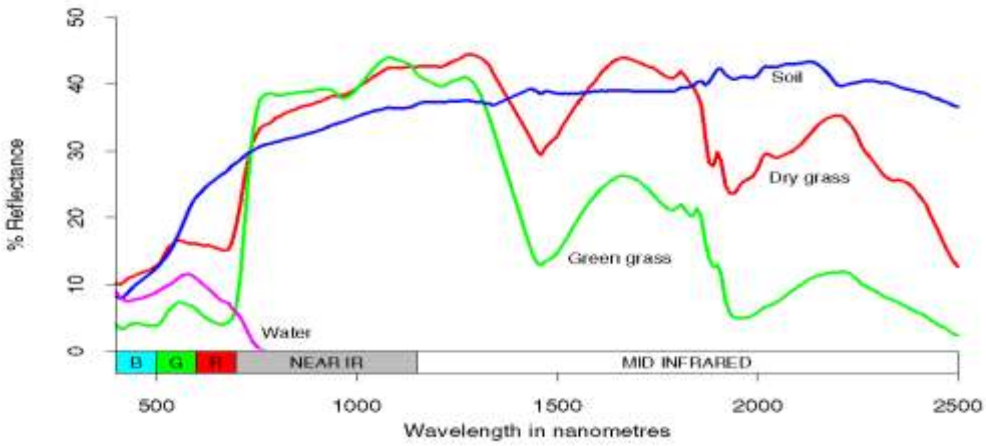
6-Satellite Remote Sensing



In this, you will see many remote sensing images acquired by earth observation satellites. These remote sensing satellites are equipped with sensors looking down to the earth. They are the "eyes in the sky" constantly observing the earth as they go round in predictable orbits. Orbital platforms collect and transmit data from different parts of the electromagnetic spectrum, which in conjunction with larger scale aerial or ground-based sensing and analysis provides researchers with enough information to monitor trends. Other uses include different areas of the earth sciences such as natural resource management, agricultural fields such as land usage and conservation, and national security and overhead, ground-based and stand-off collection on border areas.

How Satellites Acquire Images

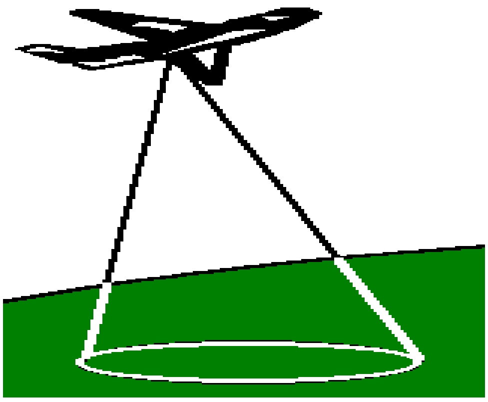
Satellite sensors record the intensity of electromagnetic radiation (sunlight) reflected from the earth at different wavelengths. Energy that is not reflected by an object is absorbed. Each object has its own unique 'spectrum', some of which are shown in the diagram below.



Remote sensing relies on the fact that particular features of the landscape such as bush, crop, salt-affected land and water reflect light differently in different wavelengths. Grass looks green, for example, because it reflects green light and absorbs other visible wavelengths. This can be seen as a peak in the green band in the reflectance spectrum for green grass above. The spectrum also shows that grass reflects even more strongly in the infrared part of the spectrum. While this can't be detected by the human eye, it can be detected by an infrared sensor.

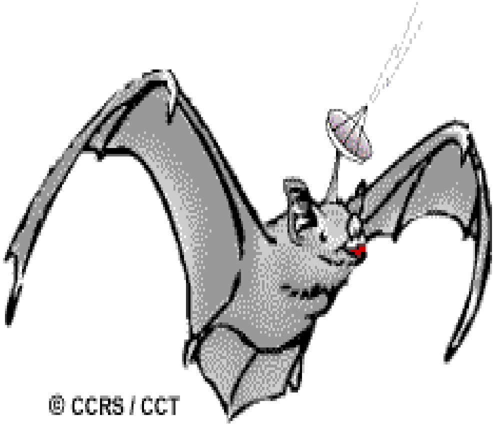
Instruments mounted on satellites detect and record the energy that has been reflected. The detectors are sensitive to particular ranges of wavelengths, called 'bands'. The satellite systems are characterised by the bands at which they measure the reflected energy. The Landsat TM satellite, which provides the data used in this project, has bands at the blue, green and red wavelengths in the visible part of the spectrum and at three bands in the near and mid infrared part of the spectrum and one band in the thermal infrared part of the spectrum. The satellite detectors measure the intensity of the reflected energy and record it.

7- Airborne Remote Sensing



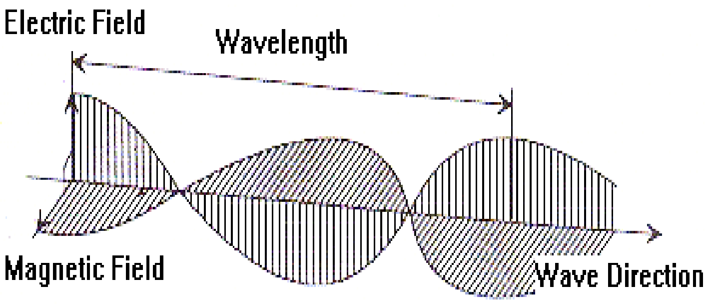
In airborne remote sensing, downward or sideward looking sensors are mounted on an aircraft to obtain images of the earth's surface. An advantage of airborne remote sensing, compared to satellite remote sensing, is the capability of offering very ***high spatial resolution*** images (20 cm or less). The disadvantages are ***low coverage area and high cost per unit area of ground coverage***. It is not cost-effective to map a large area using an airborne remote sensing system. Airborne remote sensing missions are often carried out as one-time operations, whereas earth observation satellites offer the possibility of continuous monitoring of the earth.

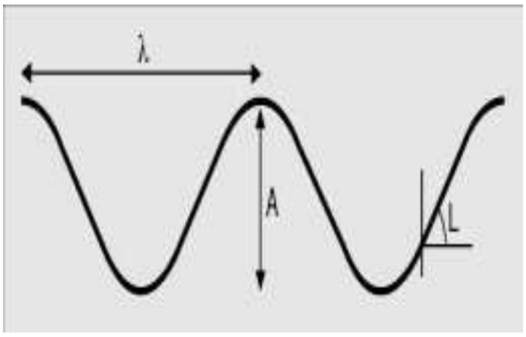
8-Acoustic and near-acoustic remote sensing



- Sonar: passive sonar, listening for the sound made by another object (a vessel, a whale etc); active sonar, emitting pulses of sounds and listening for echoes, used for detecting, ranging and measurements of underwater objects and terrain.
- Seismograms taken at different locations can locate and measure earthquakes (after they occur) by comparing the relative intensity and precise timing.

Electromagnetic Waves





Electromagnetic waves are energy transported through space in the form of periodic disturbances of electric and magnetic fields. All electromagnetic waves travel through space at the same speed, c = 2.99792458 x 10^8 m/s, commonly known as the **speed of light**. An electromagnetic wave is characterized by a **frequency** and a **wavelength**.

Photons

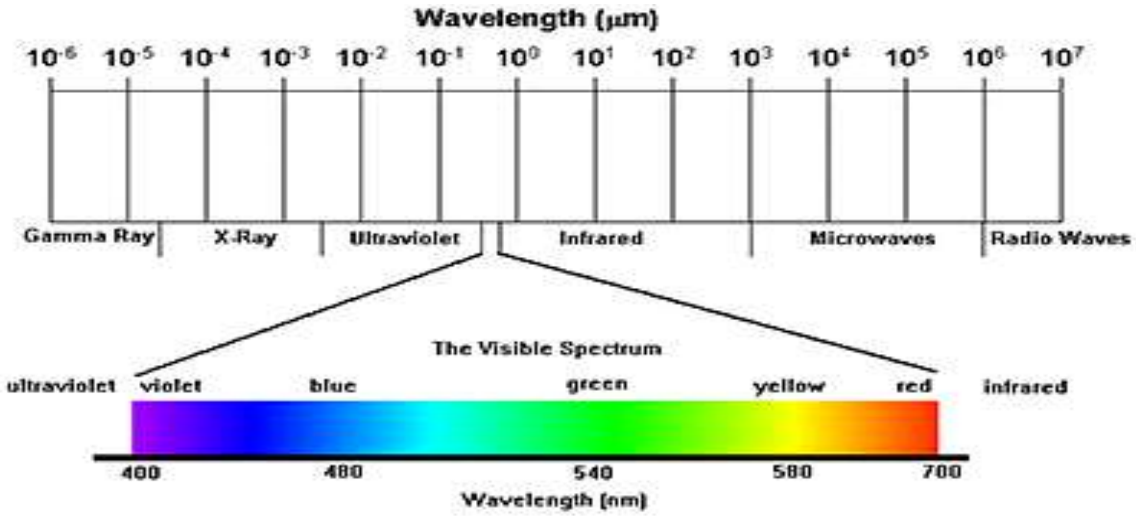
According to quantum physics, the energy of an electromagnetic wave is quantized, i.e. it can only exist in discrete amount. The basic unit of energy for an electromagnetic wave is called a **photon**. The energy E of a photon is proportional to the wave frequency γ,

$$E = h\gamma = \frac{hc}{\lambda}$$

Where the constant h is the **Planck's Constant**, h = 6.626 x 10^{-34} J s.

The frequency (and hence, the wavelength) of an electromagnetic wave depends on its source. There is a wide range of frequency encountered in our physical world, ranging from the low frequency of the electric waves generated by the power transmission lines to the very high frequency of the gamma rays originating from the atomic nuclei. These wide frequency ranges of electromagnetic waves constitute the **Electromagnetic Spectrum**. The electromagnetic spectrum can be divided into several wavelength (frequency)

regions, among which only a narrow band from about 400 to 700 nm is visible to the human eyes. Note that there is no sharp boundary between these regions. The boundaries shown in the figures are approximate and there are overlaps between two adjacent regions. **Wavelength units: 1mm = 1000 µm; 1µm=1000 nm.**



1-Gamma Rays <0.30 nm: This range is completely absorbed by the upper atmosphere and not available for remote sensing.

2-X-Rays 0.03—30.0 nm: This range is completely absorbed by the atmosphere and not employed in remote sensing.

3-Ultraviolet: **0.03—0.40 µm**

i-Hard UV 0.03—0.3 µm: This range is completely absorbed by the atmosphere and not employed in remote sensing.

ii-Photographic UV 0.30—0.40 µm: This range is not absorbed by the atmosphere and detectable with film and photo detectors but with severe atmospheric scattering.

4-Visible Light: This narrow band of electromagnetic radiation extends from about 400 nm (violet) to about 700 nm (red). It's Available for remote sensing the Earth, can be imaged with photographic film.

Violet: 400 - 430 nm

Indigo: 430 - 450 nm

Blue: 450 - 500 nm: Because water increasingly absorbs electromagnetic (EM) radiation at longer wavelengths, band 1 provides the best data for mapping depth-

detail of water-covered areas. It is also used for soil-vegetation discrimination, forest mapping, and distinguishing cultural features

Green: 500 - 570 nm: The blue-green region of the spectrum corresponds to the chlorophyll absorption of healthy vegetation and is useful for mapping detail such as depth or sediment in water bodies. Cultural features such as roads and buildings also show up well in this band.

Yellow: 570 - 590 nm

Orange: 590 - 610 nm

Red: 610 - 700 nm: Chlorophyll absorbs these wavelengths in healthy vegetation. Hence, this band is useful for distinguishing plant species, as well as soil and geologic boundaries

5-Infrared: 0.7 to 300 µm wavelength. This region is sensitive to plant water content, which is a useful measure in studies of vegetation health. This band is also used for distinguishing clouds, snow, and ice, mapping geologic formations and soil boundaries. It is also responsive to plant and soil moisture content. This region is further divided into the following bands:

a-Near Infrared (NIR): 0.7 to 1.5 µm.

b-Short Wavelength Infrared (SWIR): 1.5 to 3 µm.

d-Mid Wavelength Infrared (MWIR): 3 to 8 µm.

e-Long Wavelength Infrared (LWIR): 8 to 15 µm.

f-Far Infrared (FIR): longer than 15 µm.

The NIR and SWIR are also known as the ***Reflected Infrared***, referring to the main infrared component of the solar radiation reflected from the earth's surface. The MWIR and LWIR are the ***Thermal Infrared***.

6-Microwaves (Radar) 1 mm to 1 m wavelength. Microwaves can penetrate clouds, fog, and rain. Images can be acquired in the active or passive mode. Radar is the active form of microwave remote sensing. Radar images are acquired at various wavelength bands

7-Radio and TV Waves: 10 cm to 10 km wavelength. The longest-wavelength portion of the electromagnetic spectrum.

1.3 Interactions between Matter and Electro-magnetic Radiation

All matter reflects, absorbs, penetrates and emits electro-magnetic radiation in a unique way. For example, the reason why a leaf looks green is that the chlorophyll absorbs blue and red spectra and reflects the green spectrum . The unique characteristics of matter are called **spectral characteristics** .

Why does an object have a peculiar characteristic of reflection, **absorption** or emission? In order to answer the question, one has to study the relation between molecular, atomic and electro-magnetic radiation. In this section, the interaction between hydrogen atom and absorption of electro-magnetic radiation is explained for simplification.

A hydrogen atom has a nucleus and an electron as shown in Figure .1. The inner state of an atom depends on the inherent and discrete energy level. The electron's orbit is determined by the energy level. If electro-magnetic radiation is incident on an atom of H with a lower **energy level** (E_1), a part of the energy is absorbed, and an electron is induced by **excitation** to rise to the energy level (E_2) resulting in the upper orbit.

The electro-magnetic energy E is given as follow.

$$E = hc / \lambda$$

where h : Plank's constant c : velocity of light λ : wavelength

The difference of energy level

$\Delta E = E_2 - E_1 = hc / \lambda_H$ is absorbed.

In other words, the change of the inner state in an H-atom is only realized when electro-magnetic radiation at the peculiar wavelength λ_H is absorbed in an H-atom. Conversely electro-magnetic radiation at the wavelength λ_H is **radiated** from an H-atom when the energy level changes from E_2 to E_1.

All matter is composed of atoms and molecules with a particular composition. Therefore, matter will emit or absorb electro-magnetic radiation at a particular wavelength with respect to the inner state.

The types of inner state are classified into several classes, such as ionization, excitation, molecular vibration, molecular rotation etc. as shown in Figure .2 and Table .1, which will radiate the associated electro-magnetic radiation. For example, visible light is radiated by excitation of valence electrons, while infrared is radiated by molecular vibration or lattice vibration.

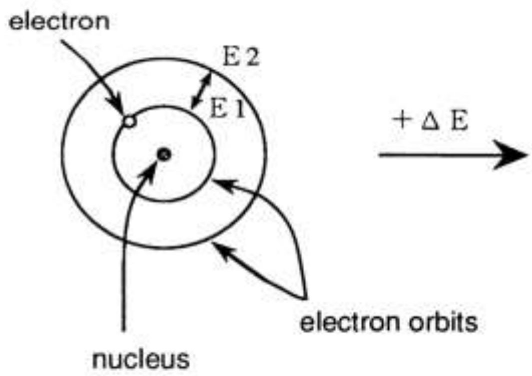


Figure .1 Change in energy level of the electron of a H atom according to absorption of electromagnetic radiation wavelength λ H

Table. .1 Relation between characteristic state and electromagnetic radiation

Characteristic state	energy (eV)	associated electromagnetic wave
Nuclear transmission and disintegrations	$10^7 \sim 10^5$	γ - ray
Ionization by inner electron removal	$10^4 \sim 10^2$	X - ray
Ionization by outer electron removal	$10^2 \sim 4$	Ultra - violet
Excitation of valence electrons	$4 \sim 1$	Visible
Molecular vibration, Lattice vibration	$10 \sim 10^{-5}$	Infrared
Molecular rotations, electron spin resonance	$10^{-4} \sim 10^{-5}$	Microwave
Nuclear spin resonance	10^{-7}	Meter wave

[unit] energy of 1eV = 1.60219×10^{-19} Joule   wavelength of 1eV light = 1.23985 μm

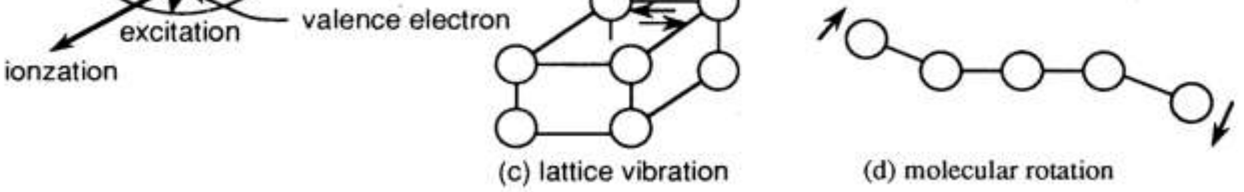


Figure ' ".2 Schematics of characteristic states associated with electromagnetic radiation

Energy interaction with targets

Where EM energy is incident upon any object there are three fundamental energy interactions that are possible. Various fractions of the incident energy are reflected, absorbed and/or transmitted.

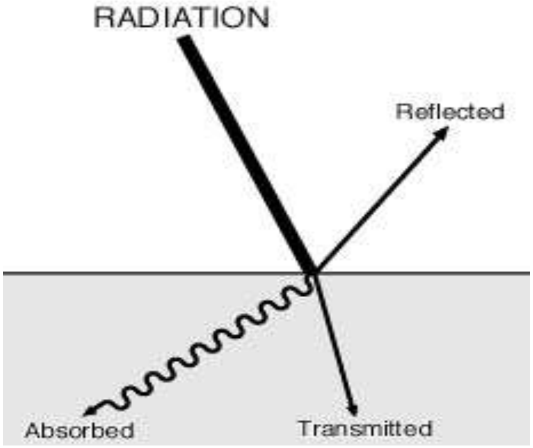
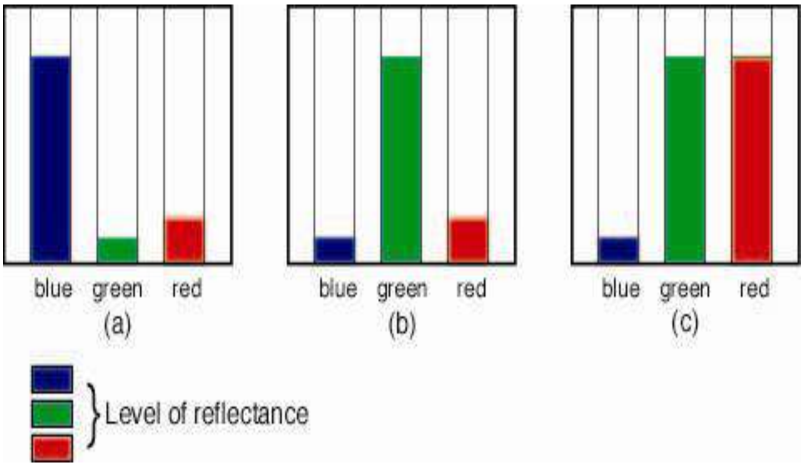
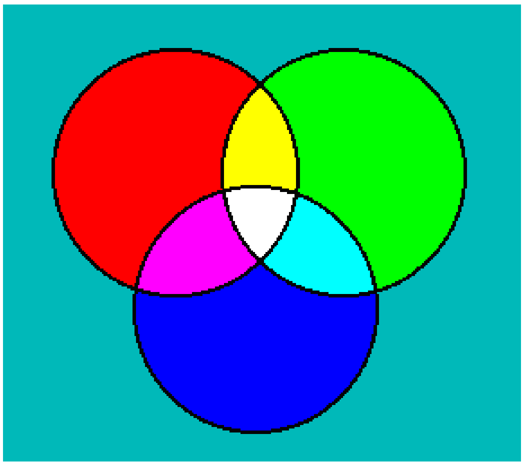


Figure show Interaction of electromagnetic energy with a target

By applying the principle of conservation of energy we can state the interrelationship between these interactions as: $\mathbf{E_I = E_R + E_A + ET}$

Where $\mathbf{E_I}$ denotes the incident energy, $\mathbf{E_R}$ denotes the reflected energy, $\mathbf{E_A}$ denotes the absorbed energy and $\mathbf{E_T}$ denotes the transmitted energy, and with all energy components being a function of wavelength. Three points concerning this relationship should be noted: **First**, the proportions of energy reflected, absorbed and transmitted will vary for different targets depending on their material type and condition. These differences permit us to distinguish between objects in an image; bright objects, such as sand, have higher reflectance than dull objects, such as tarmac. **Second**, the proportion of reflected, absorbed and transmitted energy for a target will vary with wavelength, For example, an object with high absorption at 'green' and 'red' wavelengths and high reflectance at `blue' wavelengths will appear with a 'blue' colour to the human eye (Figure a). Green objects such as grass have higher reflectance at green wavelengths than at blue or red wavelengths (Figure b). Finally, let us consider the relative reflectance from a yellow object. Yellow is the product of EM energy at red and green wavelengths, hence a yellow object will have high reflectance at these wavelengths and relatively high absorption at blue wavelengths (Figure c). This is the principle of **multispectral reflectance**. (Figure-Right) illustrates combinations of primary (visible) wavelengths.

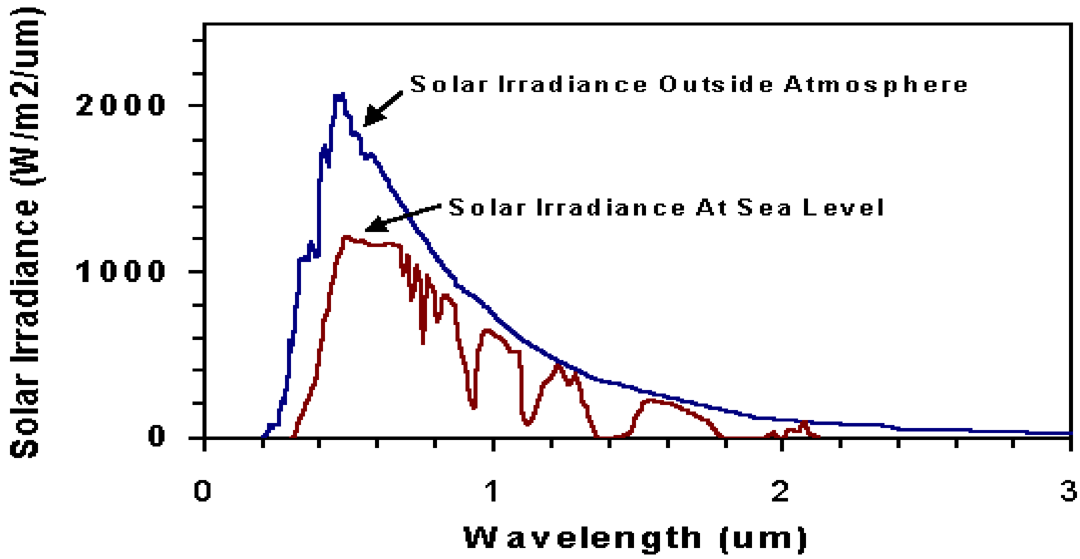




All remote sensing systems measure the fraction of reflected energy for specific illumination and view angles. The full term for a measurement at a specified geometry is the ***bidirectional reflectance***, such that the set of measurements at all geometries describes the bidirectional reflectance distribution function **BRDF**. However, in this topic we will use the term 'reflectance' for simplicity and, unless otherwise stated, we will assume sensor viewing a target at nadir. Before getting too carried away with the amazing powers of human eyesight you should remember that your vision is restricted to the visible part of the spectrum. You are unable to exploit differences in the reflectance of targets at other wavelengths such as infrared or ultraviolet. The principle of conservation of energy applies at all wavelengths, however, and therefore by building instruments that record the level of reflected radiation we are able to exploit the information content across the entire EM spectrum. **Third**, note that in order to interpret multispectral images we need to understand the reflectance, absorption and transmittance properties of typical Earth surfaces, such as soil, water and vegetated surfaces, at these wavelengths.

Solar Irradiation

Optical remote sensing depends on the sun as the sole source of illumination. The solar irradiation spectrum above the atmosphere can be modelled by a black body radiation spectrum having a source temperature of 5900 K, with a peak irradiation located at about 500 nm wavelength. Physical measurement of the solar irradiance has also been performed using ground based and spaceborne sensors. After passing through the atmosphere, the solar irradiation spectrum at the ground is modulated by the ***atmospheric transmission windows***. Significant energy remains only within the wavelength range from about 0.25 to 3 µm as shown in figure.

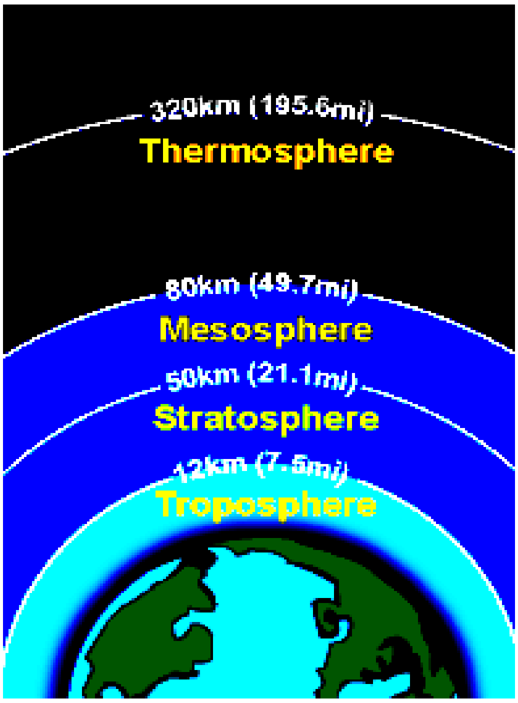


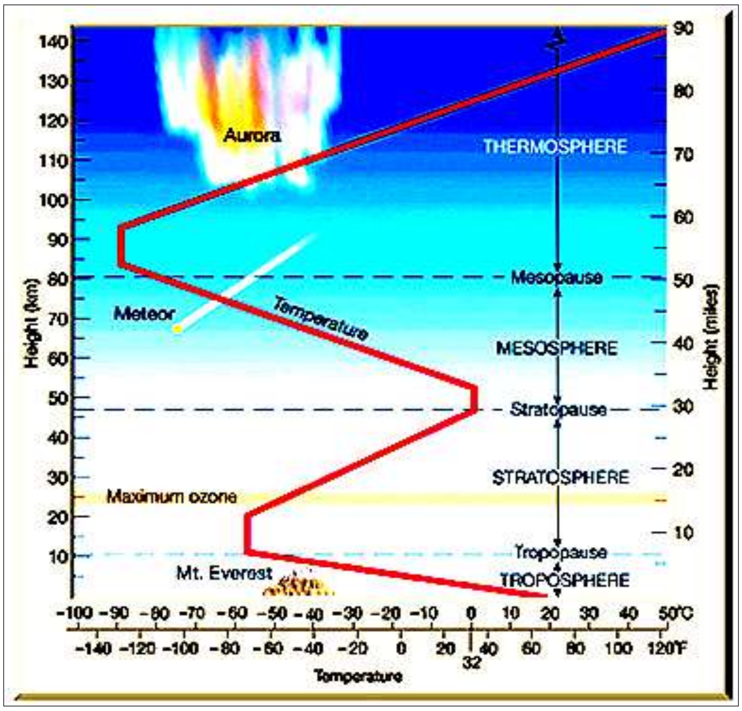
The Earth's Atmosphere

The earth's surface is covered by a layer of atmosphere consisting of a mixture of gases and other solid and liquid particles. The gaseous materials extend to several hundred kilometres in altitude, though there is no well defined boundary for the upper limit of the atmosphere. The first 80 km of the atmosphere contains more than 99% of the total mass of the earth's atmosphere. The vertical profile of the atmosphere is divided into four layers: **troposphere**, **stratosphere**, **mesosphere** and **thermosphere**. The tops of these layers are

known as the **tropopause**, **stratopause**, **mesopause** and **thermopause**, respectively.

- **Troposphere**: This layer is characterized by a decrease in temperature with respect to height, at a rate of about 6.5ºC per kilometer, up to a height of about 10 km. All the weather activities (water vapour, clouds, precipitation) are confined to this layer. A layer of aerosol particles normally exists near to the earth surface. The aerosol concentration decreases nearly exponentially with height, with a characteristic height of about 2 km. The term **upper atmosphere** usually refers to the region of the atmosphere above the troposphere.
- **Stratosphere**: The temperature at the lower 20 km of the stratosphere is approximately constant, after which the temperature increases with height, up to an altitude of about 50 km. **Ozone** exists mainly at the stratopause. The troposphere and the stratosphere together account for more than 99% of the total mass of the atmosphere.
- **Mesosphere**: The temperature decreases in this layer from an altitude of about 50 km to 85 km.





meteor

- **Thermosphere**: This layer extends from about 85 km upward to several hundred kilometres. The temperature may range from 500 K to 2000 K. The gases exist mainly in the form of thin plasma, i.e. they are ionized due to bombardment by solar ultraviolet radiation and energetic cosmic rays. Many remote sensing satellites follow the near polar **sun-synchronous orbits** at a height around 800 km, which is well above the thermopause.

Atmospheric Constituents

When electromagnetic radiation travels through the atmosphere, it may be absorbed or scattered by the constituent particles of the atmosphere. Molecular absorption converts the radiation energy into excitation energy of the molecules. Scattering redistributes the energy of the incident beam to all directions. The overall effect is the removal of energy from the incident radiation. The various effects of absorption and scattering are outlined in the following sections. The atmosphere consists of the following components:

- **Permanent Gases:** They are gases present in nearly constant concentration, with little spatial variation. About 78% by volume of the atmosphere is nitrogen while the life- sustaining oxygen occupies 21%. The remaining one percent consists of the inert gases, carbon dioxide and other gases.
- **Gases with Variable Concentration:** The concentration of these gases may vary greatly over space and time. They consist of water vapour, ozone, nitrogenous and sulphurous compounds.

- **Solid and liquid particulates:** Other than the gases, the atmosphere also contains solid and liquid particles such as aerosols, water droplets and ice crystals. These particles may congregate to form clouds and haze.
- **Ozone Layers:** Ozone in the stratosphere absorbs about 99% of the harmful solar UV radiation shorter than 320 nm. It is formed in three-body collisions of atomic oxygen (O) with molecular oxygen (O_2) in the presence of a third atom or molecule. The ozone molecules also undergo photochemical dissociation to atomic O and molecular O_2. When the formation and dissociation processes are in equilibrium, ozone exists at a constant concentration level. However, existence of certain atoms (such as atomic chlorine) will catalyse the dissociation of O_3 back to O_2 and the ozone concentration will decrease. It has been observed by measurement from space platforms that the ozone layers are depleting over time, causing a small increase in solar ultraviolet radiation reaching the earth. In recent years, increasing use of the fluorocarbon compounds in aerosol sprays and refrigerant results in the release of atomic chlorine into the upper atmosphere due to photochemical dissociation of the fluorocarbon compounds, contributing to the depletion of the ozone layers.

Absorption by Gaseous Molecules

The energy of a gaseous molecule can exist in various forms:

- **Translational Energy**: Energy due to translational motion of the centre of mass of the molecule. The average translational kinetic energy of a molecule is equal to kT/2 where k is the Boltzmann's constant and T is the absolute temperature of the gas.
- **Rotational Energy**: Energy due to rotation of the molecule about an axis through its centre of mass.

- **Vibrational Energy**: Energy due to vibration of the component atoms of a molecule about their equilibrium positions. This vibration is associated with stretching of chemical bonds between the atoms.
- **Electronic Energy**: Energy due to the energy states of the electrons of the molecule.

The last three forms are **quantized**, i.e. the energy can change only in discrete amount, known as the **transitional energy**. A **photon** of electromagnetic radiation can be absorbed by a molecule when its frequency matches one of the available transitional energies.

Solar Radiation in the Atmosphere

In satellite remote sensing of the earth, the sensors are looking through a layer of atmosphere separating the sensors from the Earth's surface being observed. Hence, it is essential to understand the effects of atmosphere on the electromagnetic radiation travelling from the Earth to the sensor through the atmosphere. The atmospheric constituents cause wavelength dependent **absorption** and **scattering** of radiation. These **effects** degrade the quality of images. Some of the atmospheric effects can be corrected before the images are subjected to further analysis and interpretation.

A consequence of atmospheric absorption is that certain wavelength bands in the electromagnetic spectrum are strongly absorbed and effectively blocked by the atmosphere. The wavelength regions in the electromagnetic spectrum usable for remote sensing are determined by their ability to penetrate atmosphere. These regions are known as the **atmospheric transmission windows**. Remote sensing systems are often designed to operate within one or more of the atmospheric windows. These windows exist in the microwave region, some wavelength bands in the infrared, the entire visible region and part of the near ultraviolet regions.

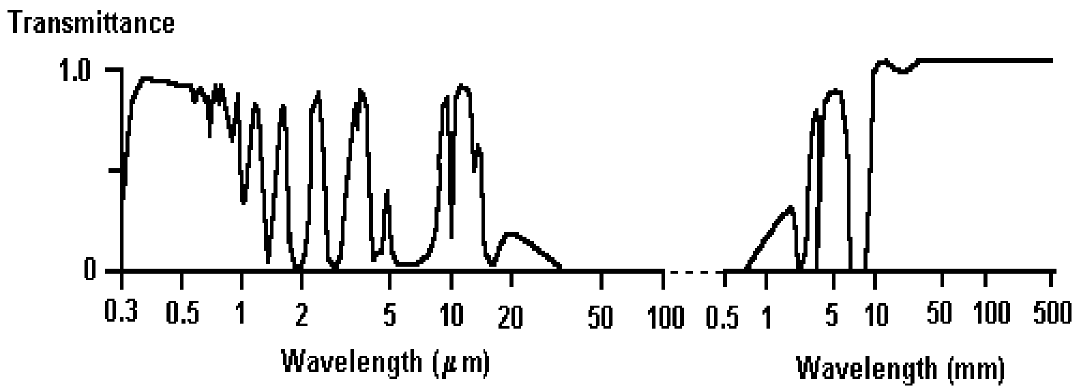
Atmosphere Effects

Our eyes inform us that the atmosphere is essentially transparent to light, and we tend to assume that this condition exists for all Electromagnetic radiation. In fact, however, the gases of the atmosphere selectively scatter light of different wavelengths. The gases also absorb Electromagnetic energy at specific wavelength intervals called absorption bands. The intervening regions of high energy transmittance are called atmospheric transmission bands, or windows. The transmission and absorption bands are shown in the following figure, together with the gases responsible for the absorption bands. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of**, Transmittance, Scattering** and **Absorption**.

1. Transmittance-Some radiation penetrates through atmosphere, water, or other materials.

Atmospheric Transmission Windows

Each type of molecule has its own set of absorption bands in various parts of the electromagnetic spectrum. As a result, only the wavelength regions outside the main absorption bands of the atmospheric gases can be used for remote sensing. These regions are known as the **Atmospheric Transmission Windows**. The wavelength bands used in remote sensing systems are usually designed to fall within these windows to minimize the atmospheric absorption effects. These windows are found in the visible, near-infrared, certain bands in thermal infrared and the microwave regions.



2. Scattering: 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 types of scattering which take place **Rayleigh**, **Mie**, and **non-selective scattering**, which absorbance and re-emittance of EM energy by particles without changing wavelength.

i-Rayleigh scattering: occurs when particles are very small compared to the wavelength of the radiation. 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 (thus the sky is “painted” in red).

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

iii- 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).

3. Absorption

Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. Some radiation is absorbed through electron or molecular reactions within the medium encountered; a portion of the energy incorporated can then be re-emitted (as emittance), largely at longer wavelengths, so that some of the sun's radiant energy engages in heating the target giving rise then to a thermal response. In contrast to **scattering**, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents which absorb radiation. Any effort to measure the spectral properties of a material through a planetary atmosphere, must consider where the atmosphere absorbs.

I- X-Ray and Gama Ray Absorption

This range of X-Ray and Gama Ray is completely absorbed by the atmosphere and not receive the earth.

II-Ultraviolet Absorption

Absorption of ultraviolet (UV) in the atmosphere is chiefly due to electronic transitions of the atomic and molecular oxygen and nitrogen. Due to the

ultraviolet absorption, some of the oxygen and nitrogen molecules in the upper atmosphere undergo ***photochemical dissociation*** to become atomic oxygen and nitrogen. These atoms play an important role in the absorption of solar ultraviolet radiation in the ***thermosphere***. The photochemical dissociation of oxygen is also responsible for the formation of the ***ozone layer*** in the ***stratosphere***.

III-Visible Region Absorption

There is little absorption of the electromagnetic radiation in the visible part of the spectrum.

Iv-Infrared Absorption

The absorption in the infrared (IR) region is mainly due to rotational and vibrational transitions of the molecules. The main atmospheric constituents responsible for infrared absorption are water vapour (H_2O) and carbon dioxide (CO_2) molecules. The water and carbon dioxide molecules have ***absorption bands*** centred at the wavelengths from ***near to long wave infrared*** (0.7 to 15 μm). In the far infrared region, most of the radiation is absorbed by the atmosphere.

V-Microwave Region Absorption

The atmosphere is practically transparent to the microwave radiation.

Spectral Reflectance Signature

When solar radiation hits a target surface, it may be ***transmitted***, ***absorbed*** *or* ***reflected***. Different materials reflect and absorb differently at different wavelengths. Some radiation reflected away from the target at different angles (depending in part on surface "roughness" as well as on the angle of the sun's direct rays relative to surface inclination), and some being directed back on line with the observing sensor. Most remote sensing systems are designed to monitor reflected radiation. The reflectance spectrum of a material is a plot of the fraction of radiation reflected as a function of the incident wavelength and serves as a unique signature for the material. In principle, a material can be identified from its spectral reflectance signature if the sensing system has sufficient ***spectral resolution*** to distinguish its spectrum from those of other materials. This premise provides the basis for multispectral remote sensing.

The following graph shows the typical reflectance spectra of five materials: clear water, turbid water, bare soil and two types of vegetation.

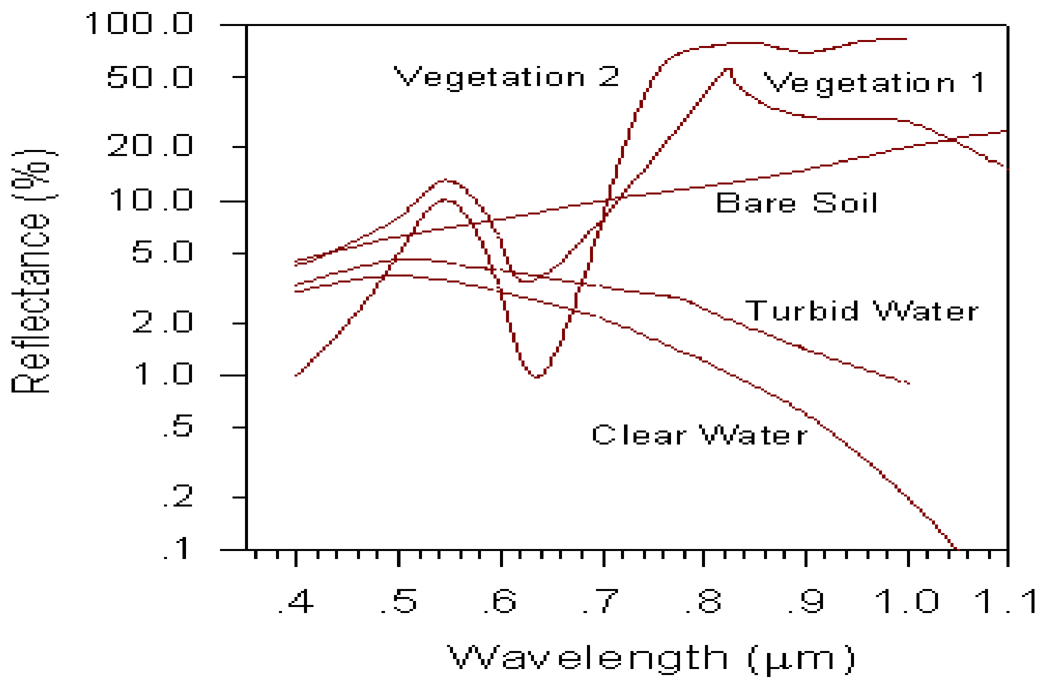


Fig. Reflectance Spectrum of Five Types of Landcover

The reflectance of ***clear water*** is generally low. However, the reflectance is maximum at the blue end of the spectrum and decreases as wavelength increases. Hence, clear water appears dark-bluish. ***Turbid water*** has some sediment suspension which increases the reflectance in the red end of the spectrum, accounting for its brownish appearance. The reflectance of ***bare soil*** generally depends on its composition. In the example shown, the reflectance increases monotonically with increasing wavelength. Hence, it should appear yellowish-red to the eye. ***Vegetation*** has a unique spectral signature which enables it to be distinguished readily from other types of land cover in an optical/near-infrared image. The reflectance is low in both the blue and red regions of the spectrum, due to absorption by chlorophyll for photosynthesis. It has a peak at the green region which gives rise to the green colour of vegetation. In the ***near infrared*** (NIR) region, the reflectance is much higher than that in the ***visible*** band due to the cellular structure in the leaves. Hence, vegetation can be identified by the high NIR but generally low visible reflectance. This property has been used in early reconnaissance missions during war times for "camouflage detection".

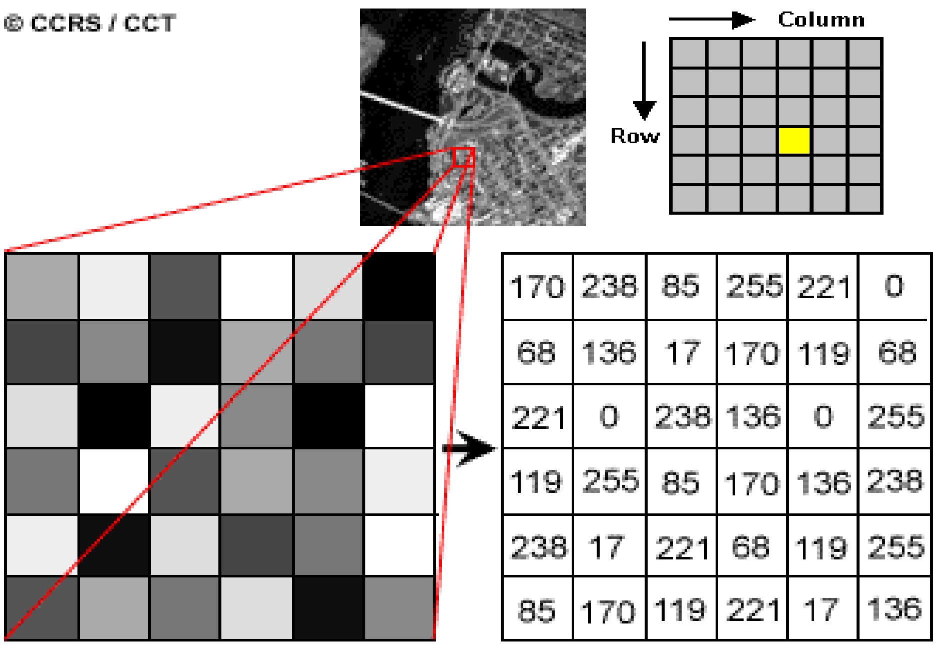
The shape of the reflectance spectrum can be used for ***identification of vegetation type***. For example, the reflectance spectra of vegetation 1 and 2 in the above figures can be distinguished although they exhibit the generally characteristics of high NIR but low visible reflectance's. Vegetation 1 has higher reflectance in the visible region but lower reflectance in the NIR region. For the same vegetation type, the reflectance spectrum also depends on other factors such as the leaf moisture content and health of the plants.

Image Processing

Pictures are the most common and convenient means of conveying or transmitting information. A picture is worth a thousand words. Pictures concisely convey information about positions, sizes and inter-relationships between objects. They portray spatial information that we can recognize as objects. Human beings are good at deriving information from such images, because of our innate visual and mental abilities.

Analog and Digital Images

An image is a two-dimensional representation of objects in a real scene. Remote sensing images are representations of parts of the earth surface as seen from space. The images may be analog or digital. Aerial photographs are examples of analog images while satellite images acquired using electronic sensors are examples of digital images**.** Digital image is a two-dimensional array of pixels. Each pixel has an intensity value (represented by a digital number) and a location address (referenced by its row and column numbers).



Pixels

A digital image comprises of a two dimensional array of individual picture elements called **pixels** arranged in columns and rows. Each pixel represents an area on the Earth's surface. A pixel has an **intensity** value and a **location address** in the two dimensional image.

The **intensity value** represents the measured physical quantity such as the solar radiance in a given wavelength band reflected from the ground, emitted infrared radiation or backscattered radar intensity. This value is normally the average value for the whole ground area covered by the pixel.

The **intensity** of a pixel is digitised and recorded as a digital number. Due to the finite storage capacity, a digital number is stored with a finite number of bits (binary digits). The number of bits determines the **radiometric resolution** of the image. For example, an 8-bit digital number ranges from 0 to 255 (i.e. $2^8 - 1$), while a 11-bit digital number ranges from 0 to 2047. The detected intensity value needs to be scaled and quantized to fit within this range of value. In a Radiometrically Calibrated Image, the actual intensity value can be derived from the pixel digital number.

Multilayer Image

Several types of measurement may be made from the ground area covered by a single pixel. Each type of measurement forms images which carry some specific information about the area. By "stacking" these images from the same area together, a multilayer image is formed. Each component image is a layer in the multilayer image. Multilayer images can also be formed by combining images obtained from different sensors, and other subsidiary data. For example, a multilayer image may consist of three layers from a SPOT multispectral image, a layer of synthetic aperture radar SAR image, and perhaps a layer consisting of the digital elevation map of the area being studied.

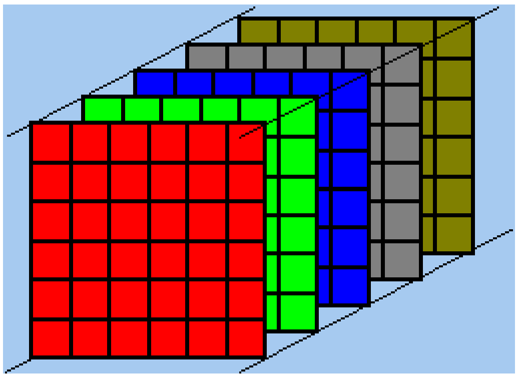
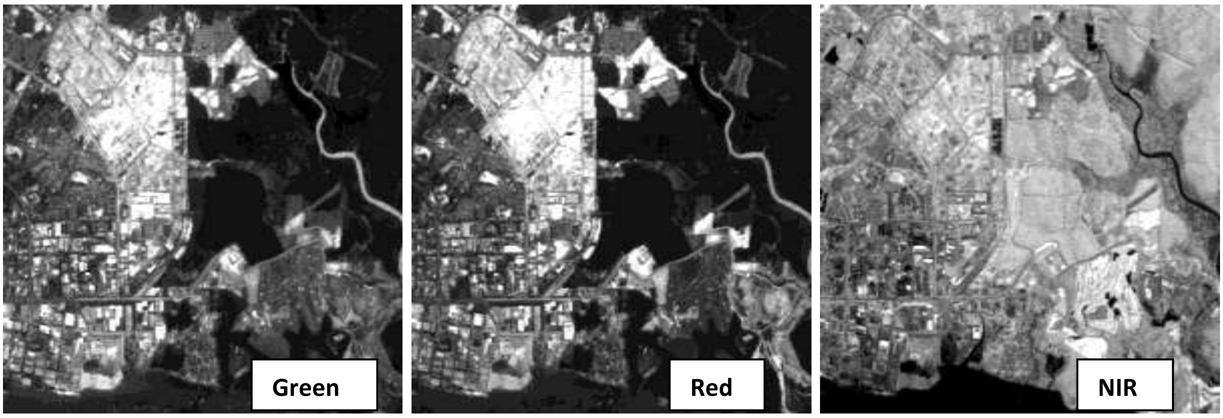


Fig:An illustration of a multilayer image consisting of five component layers.

Multispectral Images

A multispectral image consists of several bands of data. For visual display, each band of the image may be displayed one band at a time as a grey scale image, or in combination of three bands at a time as a colour composite image. Interpretation of a multispectral colour composite image will require the knowledge of the spectral reflectance signature of the targets in the scene. In this case, the spectral information content of the image is utilized in the interpretation. The following three images show the three bands of a multispectral image extracted from a **SPOT** multispectral scene at a ground resolution of 20 m. The area covered is the same as that shown in the above panchromatic image. Note that both the **XS1 (green) and XS2 (red)** bands look almost identical to the panchromatic image shown above. In contrast, the vegetated areas now appear bright in the **XS3 (NIR)** band due to high reflectance of leaves in the near infrared wavelength region. Several shades of grey can be identified for the vegetated areas, corresponding to different types of vegetation. Water mass (both the river and the sea) appear dark in the XS3 (near IR) band.

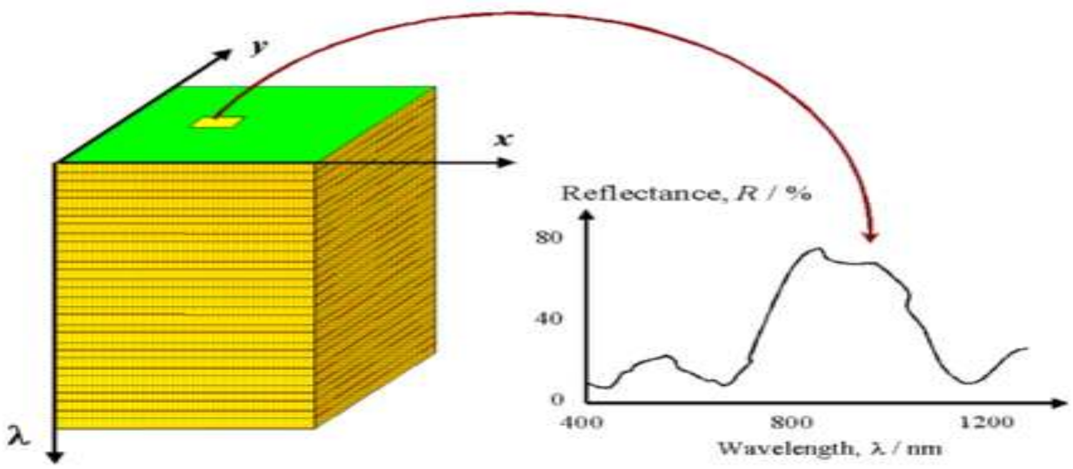


Superspectral Image

The more recent satellite sensors are capable of acquiring images at many more wavelength bands. For example, several satellites consist of 36 spectral bands, covering the wavelength regions ranging from the visible, near infrared, short-wave infrared to the thermal infrared. The bands have narrower bandwidths, enabling the finer spectral characteristics of the targets to be captured by the sensor. The term "superspectral" has been coined to describe such sensors.

Hyperspectral Image

A hyperspectral image consists of about a hundred or more contiguous spectral bands forming a three-dimensional (two spatial dimensions and one spectral dimension) image cube.. The characteristic spectrum of the target pixel is acquired in a hyperspectral image. The precise spectral information contained in a hyperspectral image enables better characterisation and identification of targets. Hyperspectral images have potential applications in such fields as precision agriculture (e.g. monitoring the types, health, moisture status and maturity of crops), coastal management (e.g. monitoring of phytoplanktons, pollution, bathymetry changes).



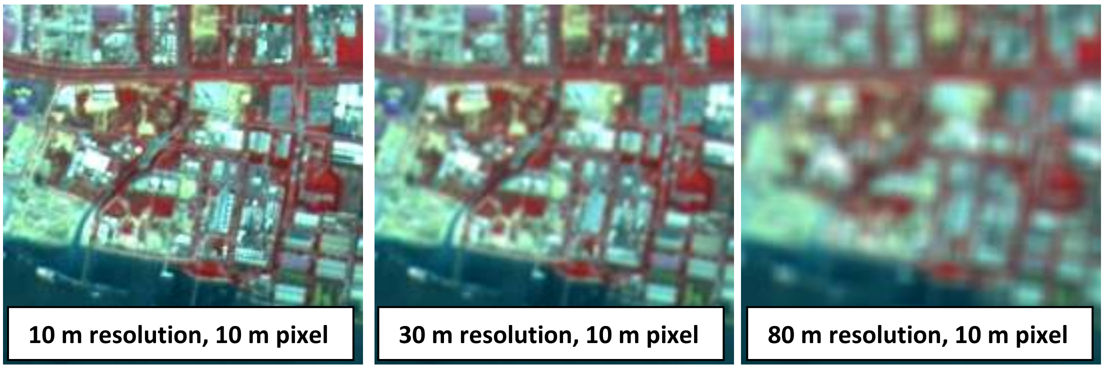
Images Resolutions

The quality of remote sensing data consists of its spectral, radiometric, spatial and temporal resolutions.

1-Spatial Resolution

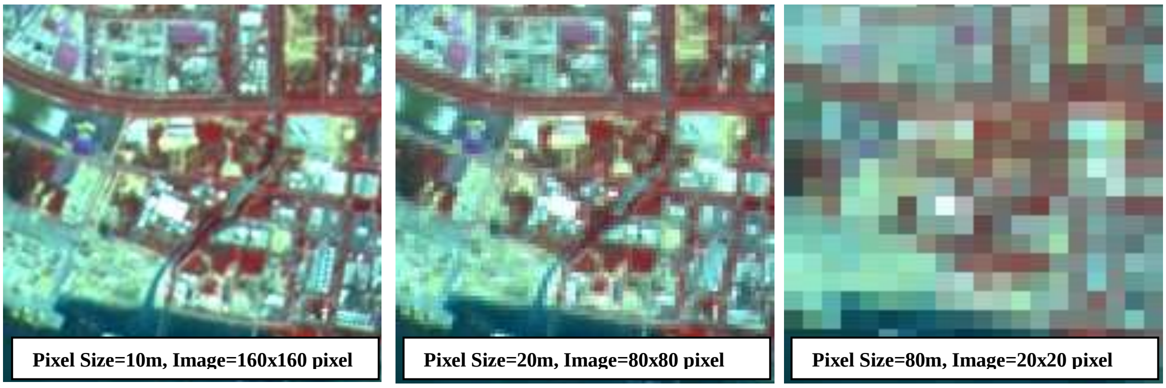
Spatial resolution refers to the size of the smallest object that can be resolved on the ground. In a digital image, the resolution is limited by the pixel size, i.e. the smallest resolvable object cannot be smaller than the pixel size. The intrinsic resolution of an imaging system is determined primarily by the instantaneous field of view (IFOV) of the sensor, which is a measure of the ground area viewed by a single detector element in a given instant in time. However this intrinsic resolution can often be degraded by other factors which introduce blurring of the image, such as improper focusing, atmospheric scattering and target motion. The pixel size is determined by the sampling distance.

A **"High Resolution"** image refers to one with a small resolution size. Fine details can be seen in a high resolution image. On the other hand, a **"Low Resolution"** image is one with a large resolution size, i.e. only coarse features can be observed in the image. An image sampled at a small pixel size does not necessarily have a high resolution. The following three images illustrate this point. The first image is a **SPOT** image of 10 m pixel size. It was derived by merging a SPOT **panchromatic** image of 10 m resolution with a SPOT **multispectral** image of 20 m resolution. The merging procedure "colours" the panchromtic image using the colours derived from the multispectral image. The effective resolution is thus determined by the resolution of the panchromatic image, which is 10 m. This image is further processed to degrade the resolution while maintaining the same pixel size. The next two images are the blurred versions of the image with larger resolution size, but still digitized at the same pixel size of 10 m. Even though they have the same pixel size as the first image, they do not have the same resolution.



10 m resolution, 10 m pixel | 30 m resolution, 10 m pixel | 80 m resolution, 10 m pixel

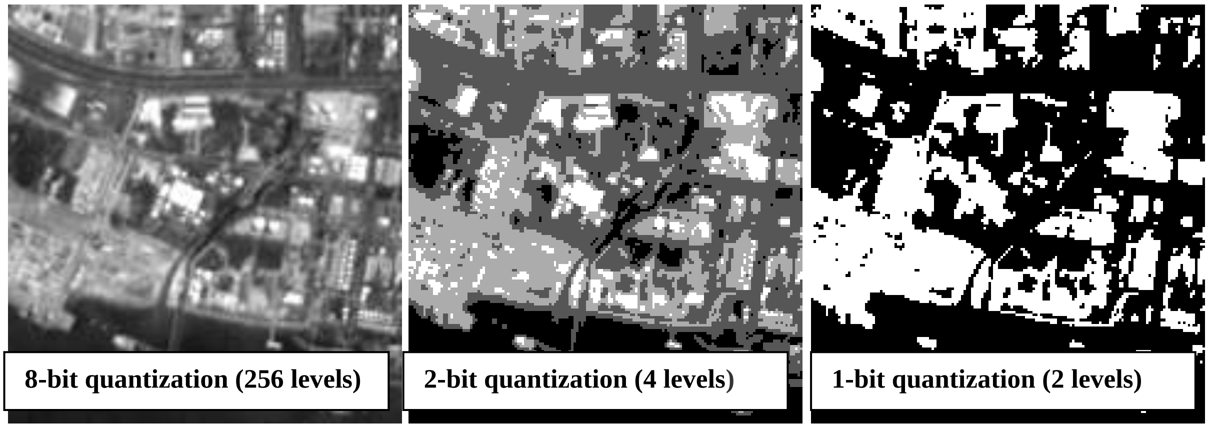
The following images illustrate the effect of pixel size on the visual appearance of an area. The first image is a SPOT image of 10 m pixel size derived by merging a SPOT panchromatic image with a SPOT multispectral image. The subsequent images show the effects of digitizing the same area with larger pixel sizes.



Pixel Size=10m, Image=160x160 pixel | Pixel Size=20m, Image=80x80 pixel | Pixel Size=80m, Image=20x20 pixel

2-Radiometric Resolution

Radiometric Resolution refers to the smallest change in intensity level that can be detected by the sensing system. The intrinsic radiometric resolution of a sensing system depends on the signal to noise ratio of the detector. In a digital image, the radiometric resolution is limited by the number of discrete quantization levels used to digitize the continuous intensity value. The following images illustrate the effects of the number of quantization levels on the digital image. The first image is a SPOT panchromatic image quantized at 8 bits (i.e. 256 levels) per pixel. The subsequent images show the effects of degrading the radiometric resolution by using fewer quantization levels.



3-Spectral resolution

The wavelength width of the different frequency bands recorded – usually, this is related to the number of frequency bands recorded by the platform. Current Landsat collection is that of seven bands, including several in the infra-red spectrum, ranging from a spectral resolution of 0.07 to 2.1 μm. The Hyperion sensor on Earth Observing-1 resolves 220 bands from 0.4 to 2.5 μm, with a spectral resolution of 0.10 to 0.11 μm per band.

4-Temporal resolution

The frequency of flyovers by the satellite or plane, and is only relevant in time-series studies or those requiring an averaged or mosaic image as in deforesting monitoring. This was first used by the intelligence community where repeated coverage revealed changes in infrastructure, the deployment of units or the modification/introduction of equipment. Cloud cover over a given area or object makes it necessary to repeat the collection of said location.

Visual Interpretation

Analysis of remote sensing imagery involves the identification of various targets in an image, and those targets may be environmental or artificial features, which consist of points, lines, or areas. Targets may be defined in terms of the way they reflect or emit radiation. This radiation is measured and recorded by a sensor, and ultimately is depicted as an image product such as an 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***.

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

2-Shape refers to the general form, structure, or outline of individual objects. Shape can be a very distinctive clue for interpretation. Straight edge shapes typically represent urban or agricultural (field) targets, while natural features, such as forest edges, are generally more irregular in shape, except where man has created a road or clear cuts. Farm or crop land irrigated by rotating sprinkler systems would appear as circular shapes.

3-Size of objects in an image is a function of scale. It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target. A quick approximation of target size

can direct interpretation to an appropriate result more quickly. For example, if an interpreter had to distinguish zones of land use, and had identified an area with a number of buildings in it, large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use.

4-Pattern refers to the spatial arrangement of visibly discernible objects. Typically an orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern. Orchards with evenly spaced trees and urban streets with regularly spaced houses are good examples of pattern.

5-Texture refers to the arrangement and frequency of tonal variation in particular areas of an image. Rough textures would consist of a mottled tone where the grey levels change abruptly in a small area, whereas some of the textures would have very little tonal variation. Smooth textures are most often the result of uniform, even surfaces, such as fields, asphalt, or grasslands. A target with a rough surface and irregular structure, such as a forest canopy, results in a rough textured appearance. Texture is one of the most important elements for distinguishing features in radar imagery.

6-Shadow is also helpful in interpretation as it may provide an idea of the profile and relative height of a target or targets which may make identification easier. However, shadows can also reduce or eliminate interpretation in their area of influence, since targets within shadows are much less (or not at all) discernible from their surroundings. Shadow is also useful for enhancing or identifying topography and landforms, particularly in radar imagery.

7-Association takes into account the relationship between other recognizable objects or features in proximity to the target of interest. The identification of features that one would expect to associate with other features may provide information to facilitate identification. In the example given above, commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds, and sports fields. In our example, a lake is associated with boats, a marina, and adjacent recreational land.

Image Correction

1-Radiometric correction

Gives a scale to the pixel values, e. g. the monochromatic scale of 0 to 255 will be converted to actual radiance values.

2-Atmospheric correction

Eliminates atmospheric haze by rescaling each frequency band so that its minimum value (usually realised in water bodies) corresponds to a pixel value of 0. The digitizing of data also make possible to manipulate the data by changing gray-scale values.

Glossary

Albedo: Ratio of the amount of electromagnetic energy (solar radiation) reflected by a surface to the amount of energy incident upon the surface.

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer.

AVHRR: Advanced very high-resolution radiometer.

AVIRIS: Airborne visible-infrared imaging spectrometer.

Band: Broadcasting frequency within given limits.

Bandwidth: The total range of frequency required to pass a specific modulated (spectral resolution) signal without distortion or loss of data.

CEO: Center for Observing the Earth from Space at Yale University

ETM+: Enhanced Thematic Mapper Plus

EM: Electromagnetic

GPS: Global Positioning System

GIS: Global Information System

IFOV: Instantaneous field of view: the solid angle through which a detector is sensitive to radiation

IKONOS: A high-resolution earth observation satellite launched in 1999, which occupies a 682-km sun synchronous orbit and employs linear array technology collecting data in four multispectral bands at a nominal resolution of 4 m, as well as a 1-m-resolution panchromatic band.

Landsat: A series of unmanned NASA earth resource satellites that acquire multispectral images in the visible and IR bands.

NAD: North Atlantic Datum

NDVI: Normalized Difference Vegetation Index

NIR Near Infrared Remote sensing of energy naturally reflected or radiated from the terrain.

Radiation: Act of giving off electromagnetic energy.

RGB: Red, Green, and Blue—the colors used in constructing visible and false color image representations.

MIR: Mid Infrared

Spatial Resolution: The ability to distinguish between closely spaced objects on an image. Commonly expressed as the most closely spaced line-pairs per unit distance distinguishable.

Spectral Reflectance: Reflectance of electromagnetic energy at specified wavelength intervals.

Spectral Resolution: Range of wavelengths recorded by a detector.

SWIR: Short Wave Infrared

TM: Thematic Mapper

UTM: Universal Transverse Mercator

VI: Vegetation Index

VNIR: Visible Near Infrared

WGS: Worldwide Geographic System

WRS: Worldwide Reference System

Republic of Iraq

Ministry of Higher Education

and Scientific Research

University of Technology

REMOTE SENSING

Third Class

First Edition (2011)

Laser Branch

Department of Applied Sciences

University of Technology

Dr. Abdulrahman K. Ali

Applications of Remote Sensing

There are probably hundreds of applications - these are typical:

Meteorology - Study of atmospheric temperature, pressure, water vapour, etc..

Oceanography: Measuring sea surface temperature, mapping ocean currents, and wave energy spectra and depth sounding of coastal and ocean depths

Glaciology- Measuring ice cap volumes, ice stream velocity, and sea ice distribution. **(Glacial)**

Geology- Identification of rock type, mapping faults and structure.

Geodesy- Measuring the figure of the Earth and its gravity field.

Topography and cartography - Improving digital elevation models.

Agriculture Monitoring the biomass of land vegetation

Forest- monitoring the health of crops, mapping soil moisture

Botany- forecasting crop yields.

Hydrology- Assessing water resources from snow, rainfall and underground aquifers.

Disaster warning and assessment - Monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters.

Planning applications - Mapping ecological zones, monitoring deforestation, monitoring urban land use.

Oil and mineral exploration- Locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.

Military- developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements

Urban- determining the status of a growing crop

Climate- the effects of climate change on glaciers and Arctic and Antarctic regions

Sea- Monitoring the extent of flooding

Rock- Recognizing rock types

Space program- is the backbone of the space program

Seismology: as a premonition.

Geographic Information System GIS

A Geographic Information System (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS also allows the integration of these data sets for deriving meaningful information and outputting the information derivatives in map format or tabular format.

Three Views of a GIS

A GIS can be viewed in three ways:

1) The Database View: A GIS is a unique kind of database of the world—a geographic database (geo database). It is an "Information System for Geography." Fundamentally, a GIS is based on a structured database that describes the world in geographic terms.

2) The Map View: A GIS is a set of intelligent maps and other views that show features and feature relationships on the earth's surface. Maps of the underlying geographic information can be constructed and used as "windows into the database" to support queries, analysis, and editing of the information.

3) The Model View: A GIS is a set of information transformation tools that derive new geographic datasets from existing datasets. These geo-processing functions take information from existing datasets, apply analytic functions, and write results into new derived datasets.

By combining data and applying some analytic rules, we can create a model that helps answer the question you have posed.

Global Positioning System GPS

The Global Positioning System (GPS) is a space-based global navigation satellite system (GNSS) that provides reliable location and time information in all weather and at all times and anywhere on or near the Earth when and where there is an unobstructed line of sight to four or more GPS satellites. It is

maintained by the United States government and is freely accessible by anyone with a GPS receiver.

GPS was created and realized by the U.S. Department of Defence (USDOD) and was originally run with 24 satellites. It was established in 1973 to overcome the limitations of previous navigation systems.

Basic concept of GPS

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include

- the time the message was transmitted
- precise orbital information (the ephemeris)
- the general system health and rough orbits of all GPS satellites (the almanac).

The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite. These distances along with the satellites' locations are used with the possible aid of trilateration, depending on which algorithm is used, to compute the position of the receiver. This position is then displayed, perhaps with a moving map display or latitude and longitude; elevation information may be included. Many GPS units show derived information such as direction and speed, calculated from position changes.

Three satellites might seem enough to solve for position since space has three dimensions and a position near the Earth's surface can be assumed. However, even a very small clock error multiplied by the very large speed of light, the speed at which satellite signals propagate results in a large positional error.

Therefore receivers use four or more satellites to solve for the receiver's location and time. The very accurately computed time is effectively hidden by most GPS applications, which use only the location. A few specialized GPS applications do however use the time; these include time transfer, traffic signal timing, and synchronization of cell phone base stations.

Although four satellites are required for normal operation, fewer apply in special cases. If one variable is already known, a receiver can determine its position using only three satellites. For example, a ship or aircraft may have known elevation. Some GPS receivers may use additional clues or assumptions (such as reusing the last known altitude, dead reckoning, inertial navigation, or including information from the vehicle computer) to give a less accurate (degraded) position when fewer than four satellites are visible.

1. Application of Remote Sensing and GIS in Civil Engineering

Remote sensing and GIS techniques become potential and indispensable tools for solving many problems of civil engineering. Remote sensing observations provides data on earth’s resources in a spatial format, GIS co-relates different kinds of spatial data and their attribute data, so as to use them in various fields of civil engineering.

a- In structural engineering:

Structural Health Monitoring (SHM) provides designers with feedback of structural performance, assisting in development of structures with higher utility and lower manufacturing costs. Structural Health Monitoring nowadays continues to advance from conventional strain gauges to FBG Fibre Optic Sensors (FOS) and major breakthroughs in wireless remote monitoring. Fibre optic sensors use optical wavelength of fibre Bragg grating to measure

temperature and strain. FOS has many advantages over the traditional electrical system such as:

- Suitable for long-term permanent SHM: monitor structure during construction stage and whole lifespan as well
- No calibration needed
- One cable can have hundreds of the sensors
- Simple installation
- Cable can run kilometres, no length limit
- Fibre optic sensors use light signal - no electrical sparking, intrinsically safe
- Gauge length can be few metres long to measure global behaviours of structures
- Suitable for both static and dynamic measurement

The primary of monitoring is to ensure the longevity and safety of the structure as well as optimizing its management. To implement corrective measures and maintenance action, monitoring must be enable the timely detection of any condition or behaviour that could deteriorate the structure, deem it unsafe or potentially results in its failure.

The monitoring programme plays a fundamental role during the construction phase as it enables the verification of design hypotheses and construction processes, affecting, in some cases, the construction rate of the structures and overall quality. Most defects are introduced already at the time of construction. Monitoring also allows performance evaluation of new materials and technologies used in bridge construction and rehabilitation. This objective is easily achieved with fibre optic sensors since these sensors effectively integrate in new materials such as fibrereinforced polymer composite.

Furthermore, fibre optic sensors adapt perfectly to long-term monitoring of bridges behaviour as well as short-term monitoring of bridges dynamic behaviour under traffic load.

Finally, monitoring can be used as a tool for "supervised lifetime extension" of bridges approaching the end of their life or in need of major repair. It ensures that such bridges are operated safely while allowing the postponement of major investments and traffic disruption.

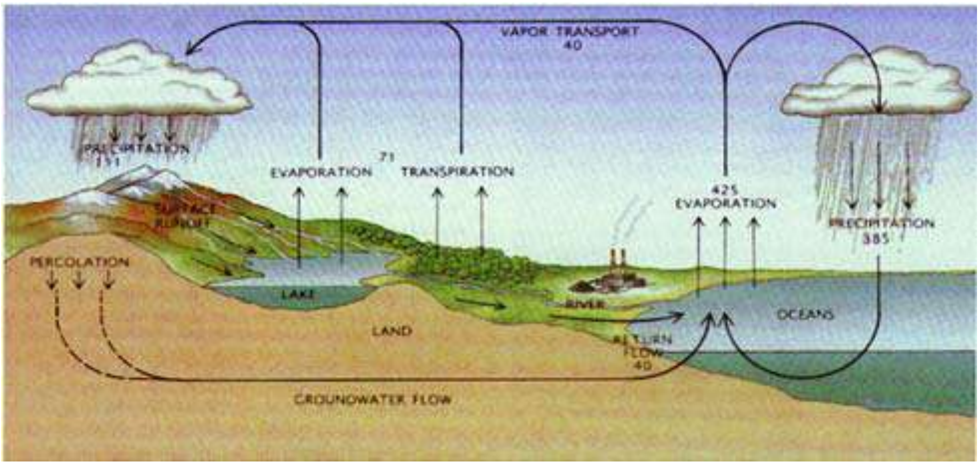
b- Town Planning and Urban Development:

To achieve the objectives of making metropolis cities more livable and of international standard, a co-coordinated and integrated approach among the various agencies involved in urban development and provision of services are needed including participatory process in planning and implementation at local body levels. As well as to have planned and organized disposal of population through growth centres, which will acts as counter-magnets to the cities growth. This growth may not able to withstand the existing infrastructure, traffic, road, drainage and utility networks etc. Advance urban planning is required for a planned development of the area for which up to date real time and accurate information are the vital important. Geographical Information system
& Remote Sensing is inevitable technology in the development of national Infrastructure and planning and they provide solution related to many environmental.

Applications of Remote Sensing to Hydrology and Hydrogeology

The Hydrological Cycle

A brief overview of hydrological processes will help to set a framework for describing those areas where remote sensing can assist in observing and in managing water resource system. Generally speaking, the hydrological cycle traces water through different physical processes, from liquid water through evaporation into the atmosphere, back into the liquid (or sometimes the frozen) state as precipitation falling on land areas either run off into rivers and streams, or percolate into the soil, or evaporate. Moisture reaching the water table becomes ground water. As a general rule, both surface and ground water flow under the force of gravity toward streams and lakes, and ultimately oceans. The return of water to the oceans can thought of as completing the cycle.



Precipitation

Accurate measurement of precipitation is a continuing goal in meteorological research and a continuing need in hydrology which depends greatly on these data for modelling. Ground-based radar is probably the most accurate method of determining a real precipitation in use today. Satellite images from GOES, NOAA, TIROS-N, TRMM and NIMBUS opened a whole new world of data on

clouds and frontal systems. Work carried out by several researchers has led to the following conclusions:

A. In thick clouds (more than one kilometer) rain is possible when the upper surface of the cloud is at less that –15 C.

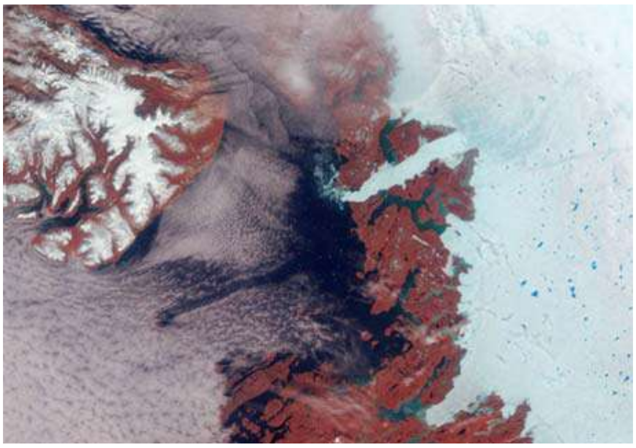
B. The probability of rain is inversely proportional to the temperature of the upper surface of the cloud.

C .Precipitation intensity is directly proportional to the area of the upper surface of the cloud at temperature of less than –15 C.

Snow

For the hydrologists who must forecast water levels, snow represents one of the most complicated and most difficult to measure parameters. Snow extent, distribution, water equivalent, water content, thickness and density all play a large part in assessment of the snow-pack` s contribution to runoff. Snow pack water equivalent has been measured by aircraft gamma-radiation surveys in the USA. The method is based on the absorption of natural gamma radiation by water (snow). As hydrologists come to accept satellite remote-sensing data on snow mapping, they also come to learn the limitations of satellite remote sensing. Despite some indications that the reflectance of snow may, under certain circumstances, be related to the snow thickness.

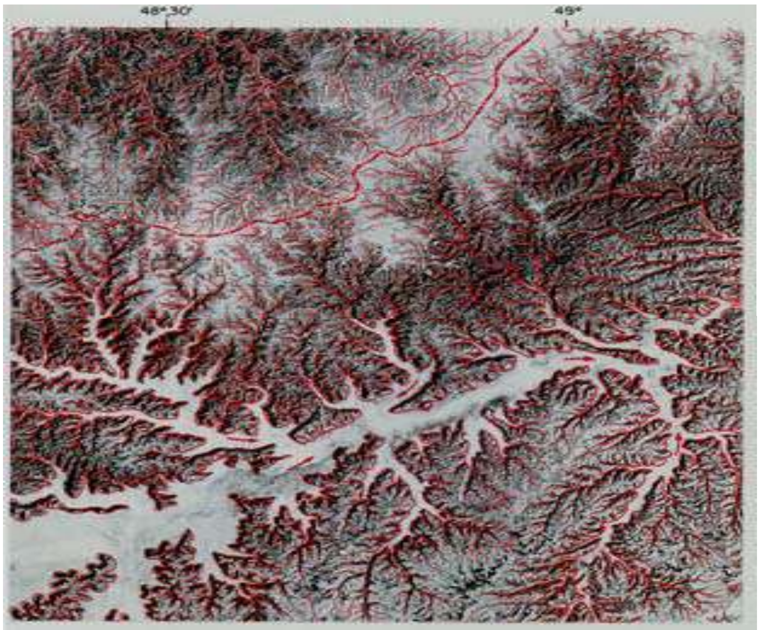
Glaciers Glaciers play an important role in the hydrological cycle of many mountainous areas. Terrestrial photography of glaciers was an important early reference method. Traversing and conducting scientific studies on glaciers are difficult, and glacieologists were quick to appreciate the value of remote sensing, first from aircraft, later from satellites (Landsat, HCMM, NIMBUS and IceSat …etc).



Surface Water: One of the best known applications of remote sensing to water resources is the inventorying of surface water bodies, particularly streams, lakes, marshes and bogs, within a given region. The area covered by open water is readily delineated by various remote- sensing techniques because of the particular radiation characteristics of water. Decreased reflectivity of soils moisturized at the surface facilities the delineation of recently flooded areas, if these are barren. The delineation of floods in vegetation-covered areas is more difficult, but is possible either by use of radar or through a combination of radiation and topographic data. Remotely sensed data obtained on flood-plain characteristics can be combined with data obtained during floods for flood mapping and delineating flood hazard areas. Characteristics of river channel such as width, depth, roughness, degree of tortuousity and braiding can also be obtained from remote-sensing surveys.

Ground Water

Ground water is concerned with water in the saturated zones beneath the surface of the Earth. Ground water information most useful to water resource managers includes: the presence or absence of ground water in designated areas, the depth to ground water, the quantity and quality of water available for development, recharge rates to aquifer, the possible impact of pumping on land subsidence, a real extent of the aquifer, locations of recharge and discharge areas, and the interaction between withdrawals at wells and natural discharge into rivers. Whereas this information is generally sought by hydrogeologists using conventional methods, remote sensing can help in the planning of conventional measurements and can be used to estimate some hydrogeological variables quantitatively and others qualitativelyThe storage capacity of ground water reservoirs depends on their extent, which depends on geological properties of the area. Ground water forms the base flow for many streams and is the source of water for springs and seeps..



Applications in Hydrology

Hydrology is the study of water on the Earth's surface, whether flowing above ground, frozen in ice or snow, or retained by soil. Hydrology is inherently related to many other applications of remote sensing, particularly forestry, agriculture and land cover, since water is a vital component in each of these disciplines. Most hydrological processes are dynamic, not only between years, but also within and between seasons, and therefore require frequent observations. 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.

Examples of hydrological applications include:

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

Applications of Remote Sensing in Weather Forecasting and Warnings

A- Applications of meteorological satellites

Meteorological satellites are indispensable in weather forecasting and warning services. Because of their huge areal coverage, meteorological satellite images can be used to keep. track of weather systems days before they come close to an area. This is particularly useful in monitoring severe weather systems like tropical cyclones. The very basic application of meteorological satellite is in identification of clouds. Clouds can be broadly classified into three categories according to the cloud base height, namely, low, medium and high clouds. Some clouds, such as cumulonimbus (a type of thundery clouds), span the three layers. Different clouds have different characteristics in terms of shape and pattern and have different tones in the visible and infrared images. These differences enable the identification of clouds using a combination of the visible and the infrared images. For instance, fog and low dense clouds are characterized by their sharp boundary and smooth texture on satellite image. They appear in bright white to medium gray tone on the visible image, but in dark to medium gray colour on infrared image. Thundery clouds such as cumulonimbus, however, contains abundant moisture and extends to great height. They appear in globular shape and are in very bright tone on both the visible and infrared images. Apart from identification of clouds, meteorological satellites are widely used in many areas of applications. Here below are some examples:

An excellent tool in unravelling volcanic ash beneath clouds. The operating principle is that volcanic ash and clouds exhibit different characteristics in the IR1 and IR2 infrared images.

Remote sensing application in geomorphology

Geomorphology is the science of study of the landforms of the earth Geomorphological analysis of surface forms of the earth is a direct form of interpretation from space images. Aerial photos with required forward overlap usually provide the third dimension of height, which adds to the precision of interpretation including morphometry. Geomorphology as a science developed much later than geology although several aspects of geomorphology are embedded in geological processes. Geomorphology deals with the genesis of relief forms of the surface of the earth's crust. Certain natural processes are responsible for the forms of the surface of the earth. A thorough understanding of various processes leading to landforms is necessary to understand the environment in which we live. Remote sensing is an effective tool in this understanding, as aerospace images contain integrated information of all that is on the ground, the landform, the ecology, the resources contained in the area and the impact of human actions on the natural landscape. The dynamism with which changes occur in the landscape is brought out effectively by repeated coverage of images of the same area at different times. Images convey many things even to the untrained eye and for a professional it conveys much more including many features hitherto unknown or unseen on the ground.

Geomorphology - basic concepts The earth's surface forms are primarily due to hypogene or endogenous processes, which include diastrophism, leading to geologic structure, tectonic activity and volcanism leading to volcanic landforms. These forms are modified by epigene or exogenous processes, which include erosion and depositional activities of water, wind and ice. Other activities include weathering, mass wasting or movement of material by gravitational action, land-ocean interaction resulting in landforms due to waves, currents, tides and tsunamis. Climate is another important factor, which has relevance in shaping of the earth's surface because the processes that act upon the surface material are different in different climatic zones (Van Westen 1994).

For example, limestone forms hills in a dry climate whereas in wet climate, it forms Karst topography with sink holes, caves and caverns predomination.

Remote Sensing applications in Agriculture

Introduction

Agriculture resources are among the most important renewable, dynamic natural resources. Comprehensive, reliable and timely information on agricultural resources is very much necessary for a country like India whose mainstay of the economy is agriculture. Agriculture survey are presently conducted throughtout the nation in order to gather information and associated statistics on crops, rangeland, livestock and other related agricultural resources. These information of data are most importance for the implementation of effective management decisions at local, panchayat and district levels. In fact, agricultural survey is a backbone of planning and allocation of the limited resources to different sectors of the economy.

With increasing population pressure throughout the nation and the concomitant need for increased agricultural production (food and fiber crops as well as livestock) there is a definite need for improved management of the nation agricultural resources. In order to accomplish this, it is first necessary to obtain reliable data on not only the types, but also the quality, quantity and location of these resources.

Remote sensing and its Importance in Agricultural survey

Remote sensing is nothing but a means to get the reliable information about an object without being in physical contact with the object. It is on the observation of an object by a device separated from it by some distance utilizing the characteristics response of different objects to emissions in the electromagnetic

energy is measured in a number of spectral bands for the purpose of identification of the object.

In such study single tabular form of data or map data is not sufficient enough which can provide can be, combined with information's obtained from existing maps and tabular data.

- Remote Sensing techniques using various plate form has provide its utility in agricultural survey
- Satellite data provides the actual synoptic view of large are at a time, which is not possible from conventional survey methods.
- The process of data acquisition and analysis is very fast through Geographic Information System (GIS) as compared to conventional methods.

Remote Sensing techniques have a unique capability of recording data in visible as well as invisible (i.e. ultraviolet, reflected infrared, thermal infrared and microwave etc.) part of electromagnetic spectrum. Therefore certain phenomenon, which cannot be seen by human eye, can be observed through remote sensing techniques i.e. the trees, which are affected by disease, or insect attack can be detected by remote sensing techniques much before human eyes see them.

Present system of Generating agricultural data and its Problems

The present system of agricultural data is collected throughout the nation. The main responsibility of collection agricultural survey lies on the Director of Land Records, Director of agriculture and District Statistical Office under the Ministry of Agriculture. These data are collected not only on a local but also some extent of district and state level. The associate of agricultural survey on crops (crop production, type of crop and crop yield), range land (condition of range, forest type, water quality, types of irrigation system and soil

characteristics) and livestock (livestock population, sex of animal, types of farm and distribution of animals).

The basic problems in this survey are;

- Reliability of data
- Cost and benefits
- Timeless
- Incomplete sample frame and sample size
- Methods of selection
- Measurement of area
- Non sampling errors
- Gap in geographical coverage
- Non availability of statistics at disaggregated level.

Remote Sensing techniques make it use before the remote sensing data may provide solution to these particular problems of agricultural survey.

Advantages of Remote Sensing techniques in Agricultural survey

With the primary aim of improving the present means of generating agricultural data, a number of specific advantages may result form the use of remote sensing techniques.

1. **Vantage point**

   Because the agricultural landscape depends upon the sun as a source of energy, it is exposed to the aerial view and, consequently, is ideally suited or remote sensing techniques.

2. **Coverage**

   With the use of high-altitude sensor platforms, it is now possible to record extensive areas on a single image. The advent of high-flying

aircraft and satellites, single high quality images covering thousand of square miles

3. **Permanent record**

   After an image is obtained, it serves as a permanent record of a landscape at a point in time which agriculture changes can be monitored and evaluated.

4. **Mapping Base**

   Certain types of remote sensing imagery are, in essence, pictorial maps of the landscape and after rectification (if needed), allow for precise measurement (such as field acreages) to be made on the imagery, obviating time-consuming on the ground surveys. These images may also aid ground data sampling by serving as a base map for location agriculture features while in the field, and also as a base for the selection of ground sampling point or areas.

5. **Cost savings**

   The costs are relatively small when compared with the benefits, which can be obtained form interpretation of satellite imagery.

6. **Real-time capability**

   The rapidly with which imagery can be obtained and interpreted may help to eliminate the lock of timeliness which plagues, so many agricultural survey.

Other advantages of Remote Sensing

- Easy data acquisition over inaccessible area.
- Data acquisition at different scales and resolutions
- The images are analyzed in the laboratory, thus reducing the amount of fieldwork.

- Colour composites can be produced from three individual band images, which provide better details of the area then a single band image or aerial photograph.
- Stereo-satellite data may be used for three-dimensional studies. At present, all advantages listed above have been demonstrated either operationally or experimentally:

Application of Remote sensing techniques for Agricultural survey

The specific application of remote sensing techniques can be used for i) detection ii) identification iii) measurement iv) monitoring of agricultural phenomena.

Area of specific applications

a) Applicable to crop survey

1. Crop identification	10. Effects of fertilizes
2. Crop acreage	11. Soil toxicity
3. Crop vigor	12. Soil moisture
4. Crop density	13. Water quality
5. Crop maturity	14. Irrigation requirement
6. Growth rates	15. Insect infestations
7. Yield forecasting	16. Disease infestations
8. Actual yield	17. Water availability
9. Soil fertility	18. Location of canals

b) Applicable to range survey

1. Delineation of forest types	7. Water quality
2. Condition of range	8. Soil fertility
3. Carrying capacity	9. Soil moisture
4. Forage	10. Insect infestations
5. Time of seasonal change	11. Wildlife inventory

6. Location of water

c) Applicable to livestock survey

1. Cattle population
2. Sheep population
3. Pig population
4. Poultry Population
5. Age sex distribution
6. Distribution of animals
7. Animal behavior
8. Disease identification
9. Types of farm buildings

Application of remote sensing in Seismology

A wide range of satellite methods is applied now in seismology. The first applications of satellite data for earthquake exploration were initiated in the '70s, when active faults were mapped on satellite images. It was a pure and simple extrapolation of airphoto geological interpretation methods into space. The modern embodiment of this method is alignment analysis. Time series of alignments on the Earth's surface are investigated before and after the earthquake. A further application of satellite data in seismology is related with geophysical methods. Electromagnetic methods have about the same long history of application for seismology. Stable statistical estimations of ionosphere-lithosphere relation were obtained based on satellite ionozonds. The most successful current project "DEMETER" shows impressive results. Satellite thermal infra-red data were applied for earthquake research in the next step. Numerous results have confirmed previous observations of thermal anomalies on the Earth's surface prior to earthquakes. A modern trend is the application of the outgoing long-wave radiation for earthquake research. Spectacular pictures of co-seismic deformations were presented. Current researches are moving in the direction of pre-earthquake deformation detection. GPS technology is also widely used in seismology both for ionosphere sounding and for ground movement detection. Satellite gravimetry has demonstrated its first very

impressive results on the example of the catastrophic Indonesian earthquake in 2004. Relatively new applications of remote sensing for seismology as atmospheric sounding, gas observations, and cloud analysis are considered as possible candidates for applications.

Introduction

Remote sensing has been used for earthquake research from the ‘70s, with the first appearance of satellite images. First of all it was used in structural geological and geomorphological research. Active faults and structures were mapped on the base of satellite images. This method is very limited in time series analysis. There was no possibility to measure short term processes before and after the earthquake. It was simple an extrapolation of airphoto geological interpretation methods into space.

The modern version of this method is active tectonic analysis with the application of alignment analysis. Time series of alignment distributions on the Earth's surface are investigated before and after an earthquake.

The current situation of remote sensing application for earthquake research indicates a few phenomena, related with earthquakes, particularly the Earth's surface deformation, surface temperature and humidity, atmosphere temperature and humidity, gas and aerosol content. Both horizontal and vertical deformations scaled from tens of centimeters to meters are recorded after the shock. Such deformations are recorded by the Interferometric Synthetic Aperture Radar (InSAR) technique with confidence. Pre-earthquake deformations are rather small, on the order of centimeters. A few cases of deformation mapping before the shock using satellite data are known at present time. Future developments lay in precision longwave SAR systems with medium spatial resolution and combined with the GPS technique. There are

numerous observations of surface and near surface temperature increases of 3–5 °C prior to Earth crust earthquakes. Methods of earthquake prediction are developing using thermal infrared (TIR) surveys. Multiple evidence of gas and aerosol content changes before earthquakes are reported for ground observations. Satellite methods allow one to measure the concentrations of gases in atmosphere: O_3, CH_4, CO_2, CO, H_2S, SO_2, HCl and aerosols. However the spatial resolution and sensitivity of modern systems restricts the application of satellite gas observation in seismology and the first promising results have been obtained only for ozone, aerosol and air humidity.

Deformations

One of the main directions of remote sensing application for seismology is deformation mapping.

Surface deformations in seismic cycles can be divided into three phases: pre-seismic or inter-seismic, co-seismic and post-seismic ones. Co-seismic deformations are evaluated up to meters and tens of meters while pre-seismic movements amount to centimetres. Post-seismic deformations are also measured in centimetres, but subsequent landslides can increase deformations to meters. Most current research is focused on co-seismic and post-seismic (landslide) deformations

Discussion

A wide spectrum of satellite remote sensing methods are applied in seismology nowadays. The value of these methods for earthquake research is varied. Optical methods have limited applications, mostly for rapid assessment of damages in an epicentral zone. Other applications such as alignment analysis and cloud form analysis related with earthquakes do not have an adequate scientific basis for seismological application. Vigorous extension of InSAR methods applications in seismology is observed now. Modern radar systems in conjunction with GPS/GLONASS will provide whole seismic cycle monitoring. Broad application of InSAR methods is limited by the high data cost and

complex data analysis. Thermal satellite data applications are developing in two directions at the moment: thermal anomalies in seismic fault research and emitted longwave radiation measurements in seismic zones. Thermal anomalies research in seismic faults is developing in the direction of seismic activity monitoring and close integration with ground observations. Emitted longwave radiation observations demonstrate promising results, but data accumulation is required. The nature of ongoing longwave radiation anomalies remains unclear.

Some common remarks on satellite data application in seismology can be made: (1) The level of automatic data processing is insufficient. There is still too much manual labour and author arbitrariness in data processing—this concerns both exotic earthquake cloud analysis and high technique radar methods. Some results are irreproducible. (2) There is a weak physical and geological basis for many of the proposed methods. The nature and driving forces of some phenomena need clarification and connection with current understanding of physics and geology.

Conclusions

This review of modern remote sensing techniques in seismology demonstrates the following:

(1) remote sensing methods are being broadly used for earthquake research; (2) a wide spectra of remote sensing methods are applied—from optical sensors to radar systems; (3) the list of parameters studied by remote sensing are: surface deformation (both vertical and horizontal), surface temperature, various heat fluxes on the Earth's and top clouds surfaces and some others; (4) future development of remote sensing application for earthquakes related with new directions: L-band radar systems, highresolution microwave radiometers, gas analyzers; (5) we will probably again approach an epoch of "belief" in earthquake prediction, where remote sensing can play a key role due to its global scope, calibration, and automatic data processing.

The described processes in the ionosphere, atmosphere, hydrosphere and lithosphere associated with earthquakes represent the fundamental science issue of lithosphere-atmosphere-ionosphere coupling. The solution of this problem is quite far away. We can mention specifically the problems of the nature of thermal anomalies, the nature of emitted longwave radiation anomalies, ionosphere-lithosphere coupling and so on. All these issues interface with the problem of understanding the nature of earthquakes

Applications of remote sensing in minerals

The search for metals and materials needed to sustain our culture has been carried out since primitive man has searched for flint to craft hand tools. Today, the materials needed to drive our economic and technological growth are just as crucial. Most of the easily accessible metal ores were discovered decades ago; and thus the search has turned to more subtle deposits and more remote locations.

Since the inception of rudimentary aerial photography at the turn of the twentieth century, remote sensing has been used as a tool in the search for economic mineral deposits. As the level of technology has improved, the value of remotely sensed data has increased. The page will highlight the history and implementations of remote sensing on mineral exploration today.

Introduction

The value of remote sensing data to mineral exploration has evolved and increased as technology has improved. In the early days of aerial photography, aerial photos were used when available to evaluate topography and plan prospecting and sampling forays. After World War II, the analysis of aerial photo data became much more sophisticated and actual geological data began to be extracted. The use of stereoscopic pairs enabled geologist to interpret subtle structural features. Nonetheless, the primary use of remotely gathered data was

comparative. If a particular type of deposit was being mined in a district, aerial photos would be used to locate similar features elsewhere within the district. This trends of comparative photography continued until well into the satellite age when satellite imagery became commercially available. The availability of multi-spectral, radar, and IR imaging, in variety of combinations allowed geologists to evaluate regions in much more detail then ever. In addition, the multiple flyovers allowed a prospect to be viewed in different light during different seasons. This greatly reduced the cost of regional exploration by precluding the need for repeated trips to a locale to reassess. Another advantage was the ability to gather data through cloud and surface cover with radar imagery. This allowed data to be collected from the tropics and arid regions that had previously been inhospitable to large regional field exploration. The computer age further enhanced the usefulness of data by allowing imagery to be digitally enhanced to highlight specific features. Now spectral studies can be done which allow the identification of specific minerals from space. The most elementary operation of remote sensing in mineral exploration is using aerial photographs to identify topographic surface features which may imply the subsurface geology. Such telling surface features as differential erosion, outcropping rock, drainage patterns, and folds/faults can be identified. These features can be compared to other potential targets in the region when looking for similar deposits. Faults fractures and contacts often provide a conduit or depositional environment for hydrothermal or magmatic fluids in regions of known mineralization, and thus make excellent targets for further investigation

Remote Sensing Systems

LIDAR

LIDAR or **LADAR** {**Light(Laser) Detection And Ranging**} is an optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the target with light, often using pulses from a laser. LIDAR technology has application in archaeology, geography, geology, geomorphology, seismology, forestry, remote sensing and atmospheric physics.

General description

LIDAR uses ultraviolet, visible, or near infrared light to image objects and can be used with a wide range of targets, including non-metallic objects, rocks, rain, chemical compounds, aerosols, clouds and even single molecules. A narrow laser beam can be used to map physical features with very high resolution.

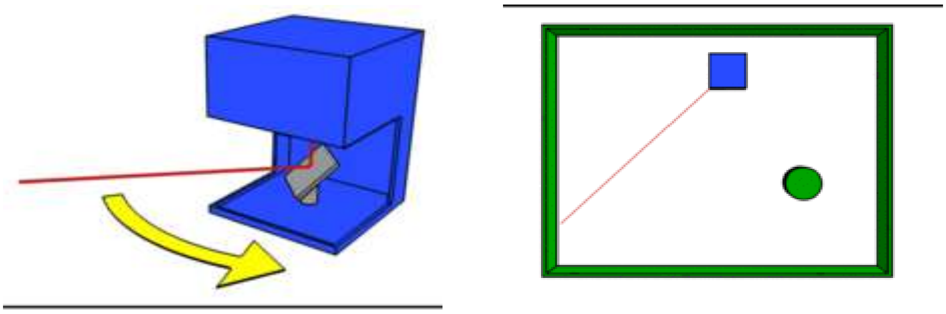
LIDAR has been used extensively for atmospheric research and meteorology. Downward-looking LIDAR instruments fitted to aircraft and satellites are used for surveying and mapping.

Wavelengths in a range from about 10 micrometers to the UV (250 nm) are used to suit the target. Typically light is reflected via backscattering. Different types of scattering are used for different LIDAR applications, most common are Rayleigh scattering, Mie scattering and Raman scattering as well as fluorescence.

Suitable combinations of wavelengths can allow for remote mapping of atmospheric contents by looking for wavelength-dependent changes in the intensity of the returned signal.

Basic of LIDAR System:

LIDAR system involves a laser range finder reflected by a rotating mirror (top). The laser is scanned around the scene being digitised, in one or two dimensions gathering distance measurements at specified angle intervals.



In general there are two kinds of LIDAR detection schema: i- incoherent: as direct energy detection (which is principally an amplitude measurement) and ii- Coherent detection: (which is best for doppler, or phase sensitive measurements). Coherent systems generally use Optical detection which being more sensitive than direct detection allows them to operate a much lower power but at the expense of more complex transceiver requirements.

In both coherent and incoherent LIDAR, there are two types of pulse models: *micropulse lidar* systems and *high energy* systems. Micropulse systems have developed as a result of the ever increasing amount of computer power available combined with advances in laser technology. They use considerably less energy in the laser, typically on the order of one microjoule, and are often "eye-safe," meaning they can be used without safety precautions. High-power systems are common in atmospheric research, where they are widely used for measuring many atmospheric parameters: the height, layering and densities of clouds, cloud particle properties (extinction coefficient, backscatter coefficient, depolarization), temperature, pressure, wind, humidity, trace gas concentration (ozone, methane, nitrous oxide, etc.).

Major components of LIDAR system:

1. **Laser**: 600–1000 nm lasers are most common for non-scientific applications. They are inexpensive but since they can be focused and easily absorbed by the eye the maximum power is limited by the need to make them eye-safe. A common alternative 1550 nm lasers are eye-safe at much higher power levels since this wavelength is not focused by the eye, but the detector technology is less advanced and so these wavelengths are generally used at longer ranges and lower accuracies. They are also used for military applications as 1550 nm is not visible in night vision goggles unlike the shorter 1000 nm infrared laser. Airborne topographic mapping LIDAR generally use 1064 nm diode pumped YAG lasers, while bathymetric systems generally use 532 nm frequency doubled diode pumped YAG lasers because 532 nm penetrates water with much less attenuation than does 1064 nm. Laser settings include the laser repetition rate (which controls the data collection speed). Pulse length is generally an attribute of the laser cavity length, the number of passes required through the gain material (YAG, YLF, etc.), and Q-switch speed. Better target resolution is achieved with shorter pulses, provided the LIDAR receiver detectors and electronics have sufficient bandwidth.
2. **Scanner and optics**:- How fast images can be developed is also affected by the speed at which it can be scanned into the system. There are several options to scan the azimuth and elevation, including dual oscillating plane mirrors, a combination with a polygon mirror, a dual axis scanner. Optic choices affect the angular resolution and range that can be detected. A hole mirror or a beam splitter are options to collect a return signal.
3. **Photodetector and receiver electronics**: - Two main photodetector technologies are used in LIDAR: solid state photodetectors, such as silicon avalanche photodiodes, or photomultipliers. The sensitivity of the receiver is another parameter that has to be balanced in a LIDAR design.

4. **Position and navigation systems**: - LIDAR sensors that are mounted on mobile platforms such as airplanes or satellites require instrumentation to determine the absolute position and orientation of the sensor. Such devices generally include a Global Positioning System receiver and an Inertial Measurement Unit (IMU).

Applications of LIDAR

This LIDAR-equipped mobile robot uses its LIDAR to construct a map and avoid obstacles.

1-Agriculture

Agricultural Research Service scientists have developed a way to incorporate LIDAR with yield rates on agricultural fields. This technology will help farmers direct their resources toward the high-yield sections of their land.

LIDAR also can be used to help farmers determine which areas of their fields to apply costly fertilizer. LIDAR can create a topological map of the fields and reveals the slopes and sun exposure of the farm land. Researchers at the Agricultural Research Service blended this topological information with the farm land’s yield results from previous years. This technology is valuable to farmers because it indicates which areas to apply the expensive fertilizers to achieve the highest crop yield.

2-Archaeology

LIDAR has many applications in the field of archaeology including aiding in the planning of field campaigns, mapping features beneath forest canopy, and providing an overview of broad, continuous features that may be indistinguishable on the ground. LIDAR can also provide archaeologists with the ability to create high-resolution digital elevation models 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. With LIDAR the ability to produce high-resolution datasets quickly and relatively cheaply can be an advantage. Beyond efficiency, its ability to penetrate forest canopy has led to the discovery of features that were not distinguishable through traditional geo-spatial methods and are difficult to reach through field surveys.

3-Biology and conservation

LIDAR has also found many applications in forestry. Canopy heights, biomass measurements, and leaf area can all be studied using airborne LIDAR systems. Similarly, LIDAR is also used by many industries, including Energy and Railroad, and the Department of Transportation as a faster way of surveying. Topographic maps can also be generated readily from LIDAR, including for recreational use such as in the production of orienteering maps.

In oceanography, LIDAR is used for estimation of phytoplankton fluorescence and generally biomass in the surface layers of the ocean. Another application is airborne lidar bathymetry of sea areas too shallow for hydrographic vessels.

4-Geology and soil science

High-resolution digital elevation maps generated by airborne and stationary LIDAR have led to significant advances in geomorphology, the branch of geoscience 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. Aircraft-based

LIDAR and GPS have evolved into an important tool for detecting faults and measuring uplift. The output of the two technologies can produce extremely accurate elevation models for terrain that can even measure ground elevation through trees.

5-Hydrology

LIDAR offers a lot of information to the aquatic sciences. High-resolution digital elevation maps generated by airborne and stationary LIDAR have led to significant advances in the field of Hydrology.

6-Meteorology and atmospheric environment

The first LIDAR systems were used for studies of atmospheric composition, structure, clouds, and aerosols. Initially based on ruby lasers, LIDAR for meteorological applications was constructed shortly after the invention of the laser and represent one of the first applications of laser technology.

Elastic backscatter LIDAR is the simplest type of lidar and is typically used for studies of aerosols and clouds. The backscattered wavelength is identical to the transmitted wavelength, and the magnitude of the received signal at a given range depends on the backscatter coefficient of scatterers at that range and the extinction coefficients of the scatterers along the path to that range. The extinction coefficient is typically the quantity of interest.

Differential Absorption LIDAR (DIAL) is used for range-resolved measurements of a particular gas in the atmosphere, such as ozone, carbon dioxide, or water vapor. The LIDAR transmits two wavelengths: an "on-line" wavelength that is absorbed by the gas of interest and an off-line wavelength that is not absorbed. The differential absorption between the two wavelengths is

a measure of the concentration of the gas as a function of range. DIAL LIDARs are essentially dual-wavelength backscatter LIDARS.

Raman LIDAR is also used for measuring the concentration of atmospheric gases, but can also be used to retrieve aerosol parameters as well. Raman LIDAR exploits inelastic scattering to single out the gas of interest from all other atmospheric constituents. A small portion of the energy of the transmitted light is deposited in the gas during the scattering process, which shifts the scattered light to a longer wavelength by an amount that is unique to the species of interest.

Doppler LIDAR is used to measure wind speed along the beam by measuring the frequency shift of the backscattered light. Scanning LIDARs, have been used to measure atmospheric wind velocity in a large three dimensional cone.

7-Law enforcement

LIDAR speed guns are used by the police to measure the speed of vehicles for speed limit enforcement purposes and offer a number of advantages over radar speed guns.

8-Military

Few military applications are known to be in place and are classified, but a considerable amount of research is underway in their use for imaging. Higher resolution systems collect enough detail to identify targets, such as tanks. Examples of military applications of LIDAR include the Airborne Laser Mine Detection System (ALMDS) for counter-mine warfare by Arete Associates.

Utilizing LIDAR and THz interferometry wide area raman spectroscopy, it is possible to detect chemical, nuclear, or biological threats at a great distance.

In atmospheric physics, LIDAR is used as a remote detection instrument to measure densities of certain constituents of the middle and upper atmosphere, such as potassium, sodium, or molecular nitrogen and oxygen. These measurements can be used to calculate temperatures. LIDAR can also be used to measure wind speed and to provide information about vertical distribution of the aerosol particles. In nuclear fusion research facility, LIDAR Thomson Scattering is used to determine Electron Density and Temperature profiles of the plasma.

9-Robotics

LIDAR technology is being used in Robotics for the perception of the environment as well as object classification. Refer to the Military section above for further examples.

10-Transportation

LIDAR has been used in Adaptive Cruise Control (ACC) systems for automobiles. Systems use a lidar device mounted on the front of the vehicle, such as the bumper, to monitor the distance between the vehicle and any vehicle in front of it. In the event the vehicle in front slows down or is too close, the ACC applies the brakes to slow the vehicle. When the road ahead is clear, the ACC allows the vehicle to accelerate to a speed preset by the driver. Refer to the Military section above for further examples.