Remote Sensing : Concepts

Recommended Readings

- **Remote sensing of the environment**
  by J.R. Jensen (Publication : Springer)
- **Remote sensing and image interpretation**
  by T.M. Lillesand, R.W. Kiefer (Publication : Wiley)
- **Fundamentals of Remote sensing**
  by George Joseph

www.ccrs.nrcan.gc.ca

Discussion Topics

- **What is Remote Sensing ?**
- **How & when did it start?**
- **How is it today ?**
- **What is Remote Sensing Process ?**
- **What is Electromagnetic Radiation (EMR)?**
- **What is Electromagnetic Spectrum ?**
- **Radiation interactions (with atmosphere & target)**
- **Spectral Signature**
- **Passive & Active Remote Sensing**
- **Satellite image characteristics**

What is Remote Sensing?

- **It is the science of acquiring information**

about the Earth's surface

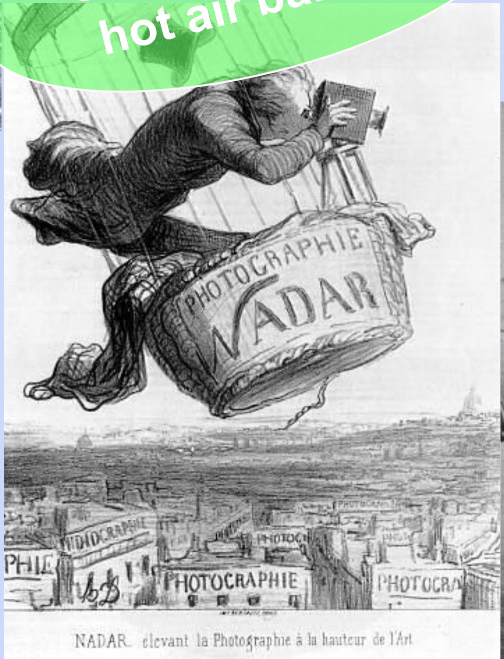
<u>without</u> actually <u>being in contact</u> with it.

- **This is done by sensing and recording reflected or emitted energy and processing, analyzing, an d applying that information.**

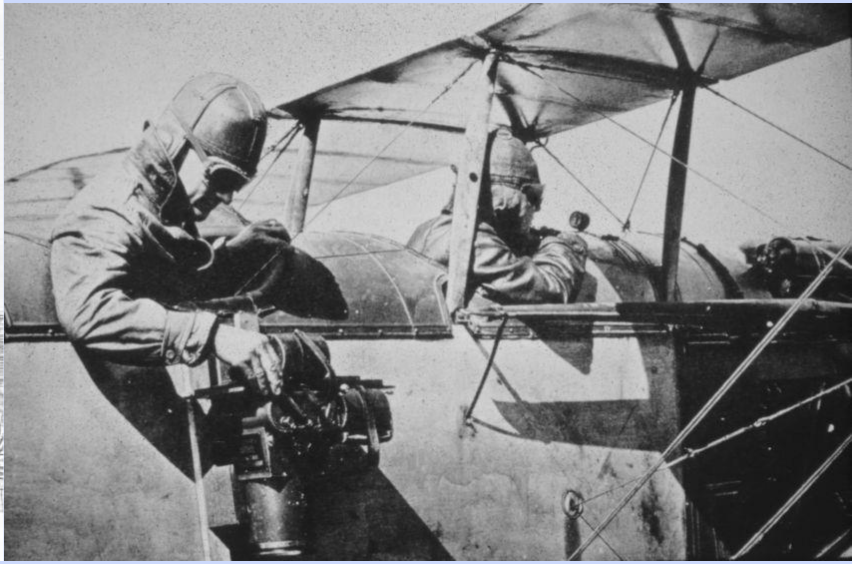
How & when did it start?

Using Kites

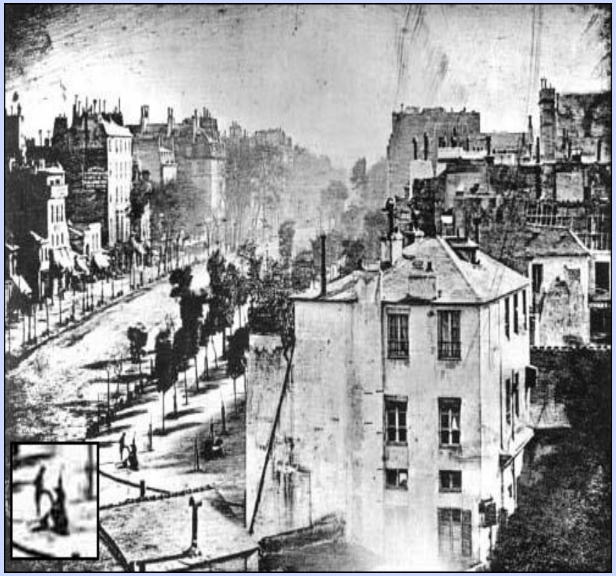
Using Pigeon & hot air balloon



Using Aircrafts



How & when did it start?



1839 : Paris

1860 : Paris

How is it today?

How is it today?

Abu Dhabi : PAN image

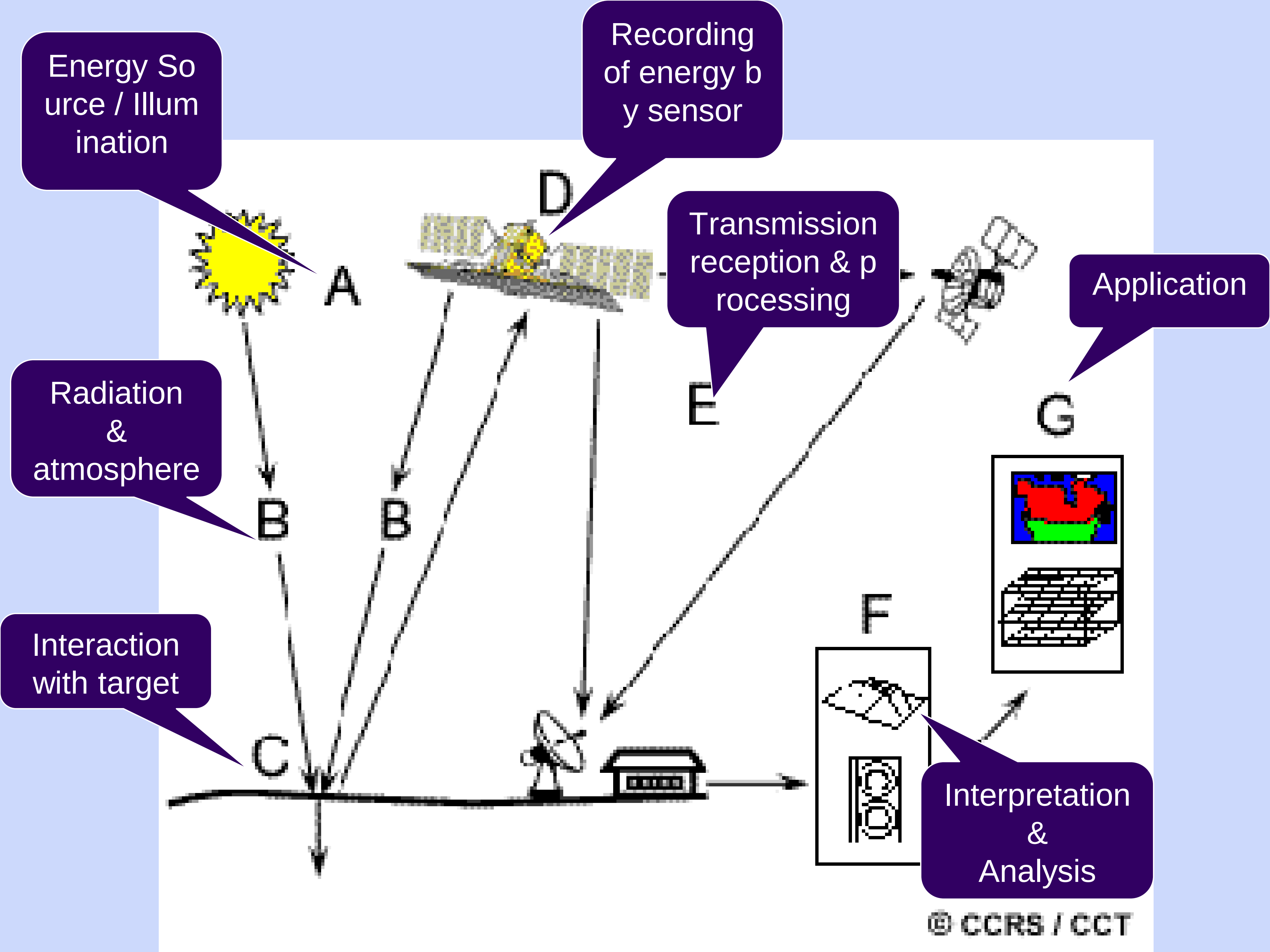
How is it today?

Mumbai (LISS III + PAN image)

How is it today?

Statue of Liberty (IKONOS)

What is Remote Sensing Process ?



Energy So urce / Illum ination
Recording of energy b y sensor
Transmission reception & p rocessing
Application
Radiation & atmosphere
Interaction with target
Interpretation & Analysis
A
B
B
C
D
E
F
G
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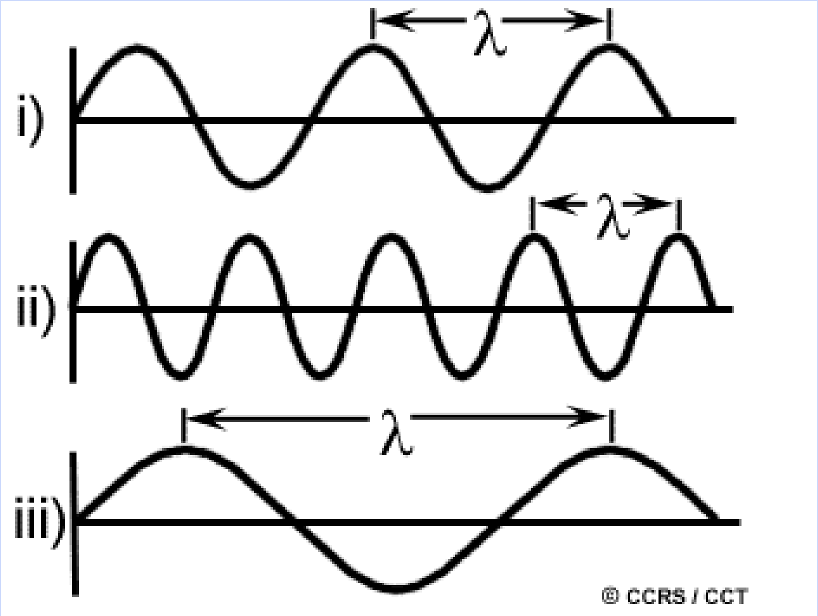
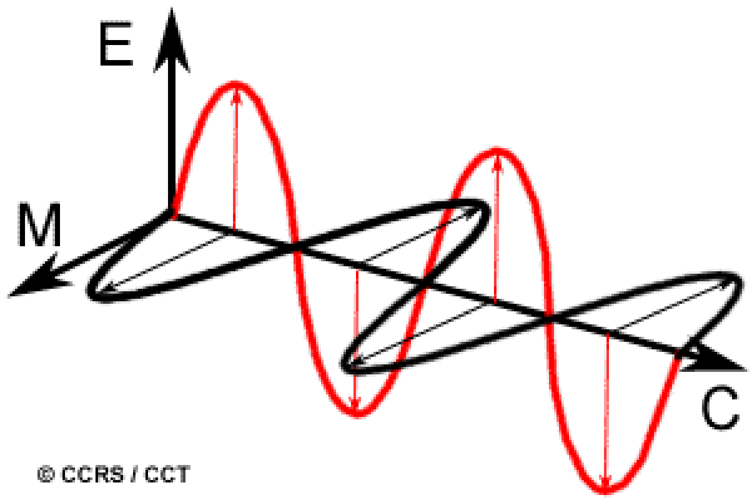
What is Electromagnetic Radiation (EMR)?

- **First requirement for remote sensing is to have an <u>energy source</u> to <u>illuminate the target</u>.**
- **This energy is in the form of electromagnetic radiation.**
- **Two characteristics of EMR are wavelength & frequency.**



What is Electromagnetic Radiation (EMR)?

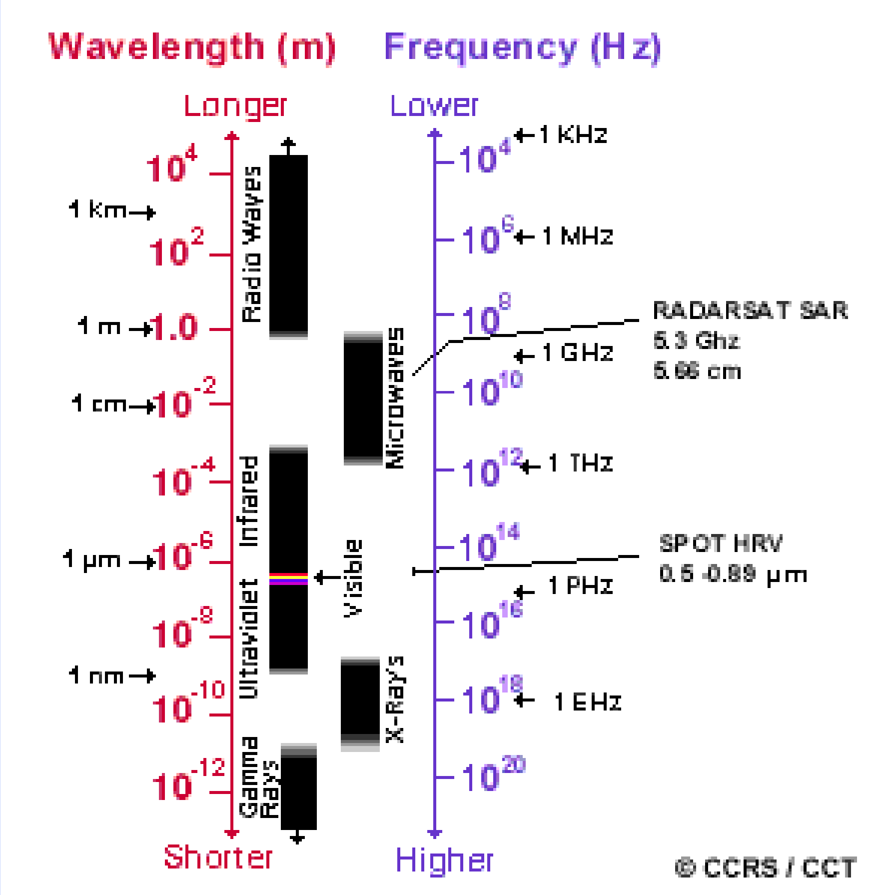


Electromagnetic radiation consists of an

electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling,

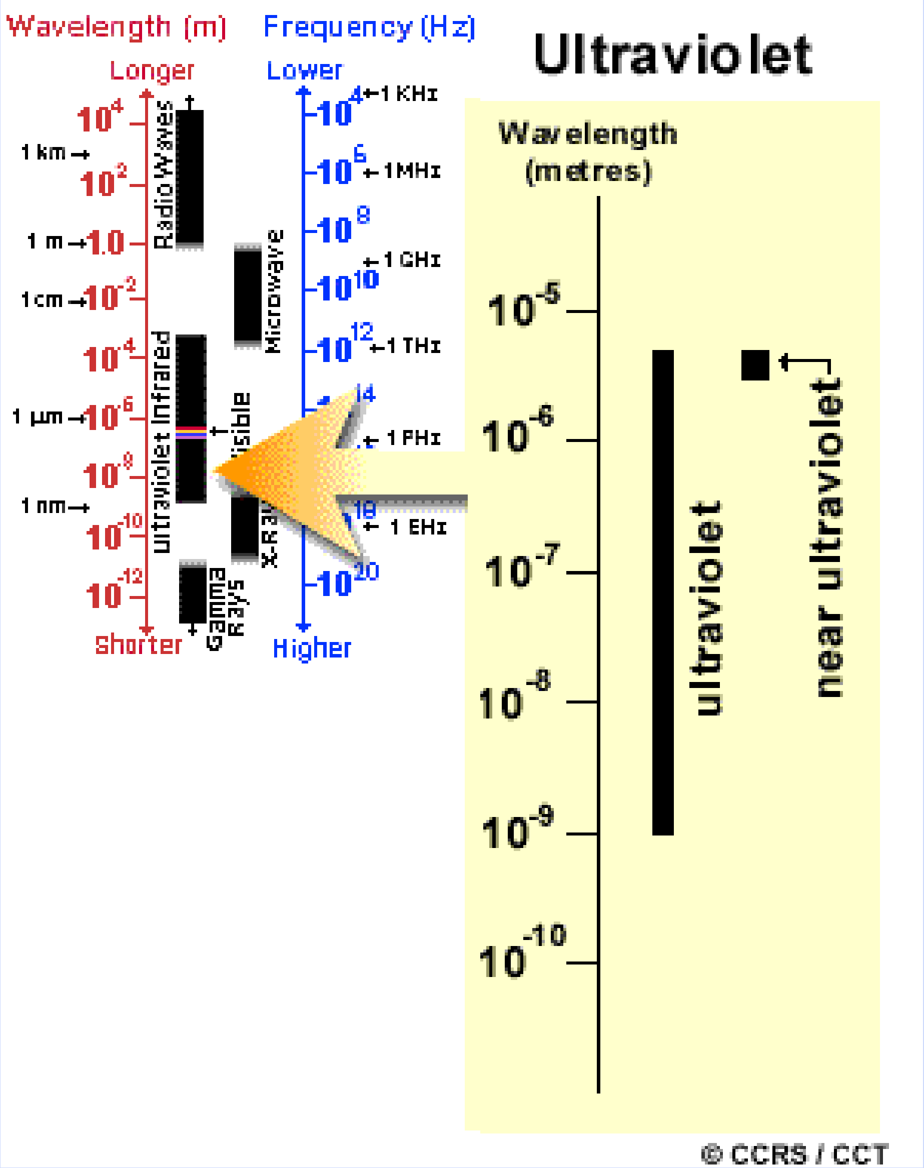
and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c).

What is Electromagnetic Spectrum?



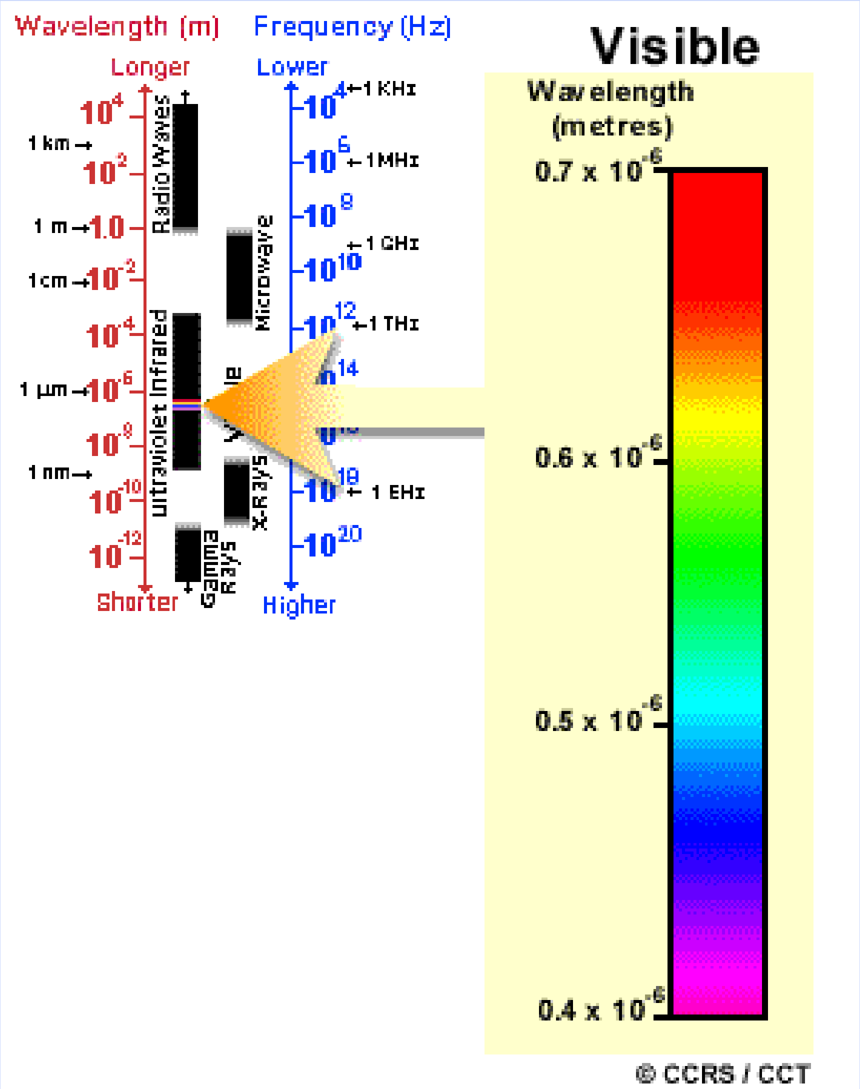
- **It ranges from the shorter wavelengths (including gam ma and x-rays) to the longer wavelengths (including micr owaves and broadcast radio waves).**

What is Electromagnetic Spectrum?

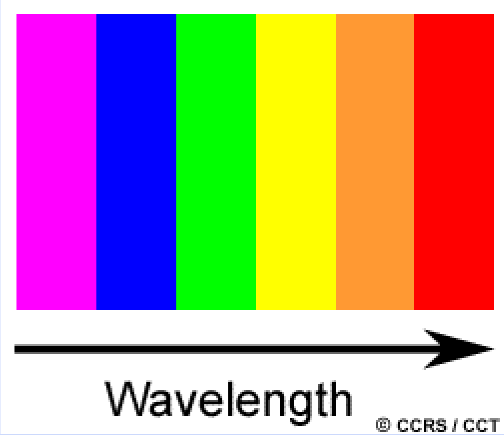


- The ultraviolet or UV porti on of the spectrum has the shortest wavelengths which are practical for remote sen sing.
- This radiation is just beyo nd the violet portion of the v isible wavelengths, hence it s name.
- Some Earth surface materi als, primarily rocks and min erals, fluoresce or emit visib le light when illuminated by UV radiation.

What is Electromagnetic Spectrum?



- The light which our eyes - our " remote sensors" - can detect is part of the visible spectrum.



Violet: 0.4 - 0.446 µm
Blue: 0.446 - 0.500 µm
Green: 0.500 - 0.578 µm
Yellow: 0.578 - 0.592 µm
Orange: 0.592 - 0.620 µm
Red: 0.620 - 0.7 µm

Radiation interaction: with atmosphere

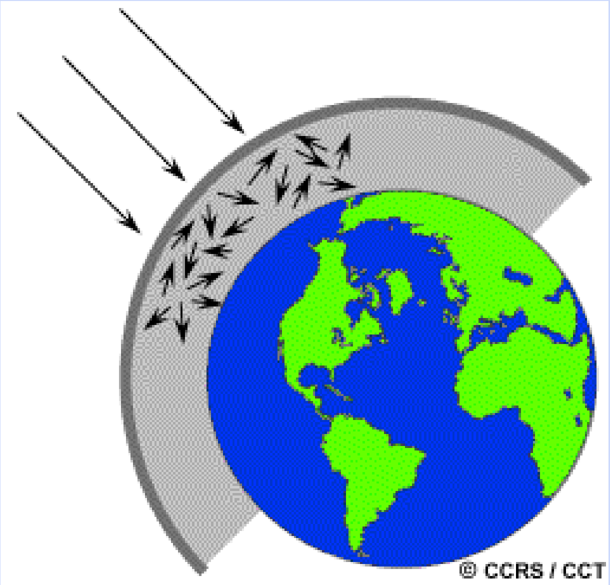
- **Radiation before reaching the Earth's surface has to travel through some distance of the Earth's atmosph ere.**

- **Atmosphere contains particles & gases.**

- **Particles and gases in the atmosphere can affect th e incoming light and radiation.**

- **These effects are caused by the mechanisms of sca ttering and absorption.**

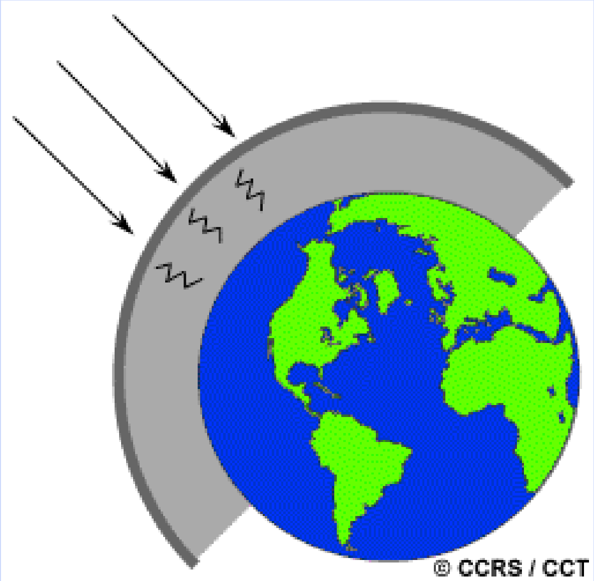
Radiation interaction: with atmosphere



- **Scattering** occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path.

- **How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere.**

Radiation interaction: with atmosphere



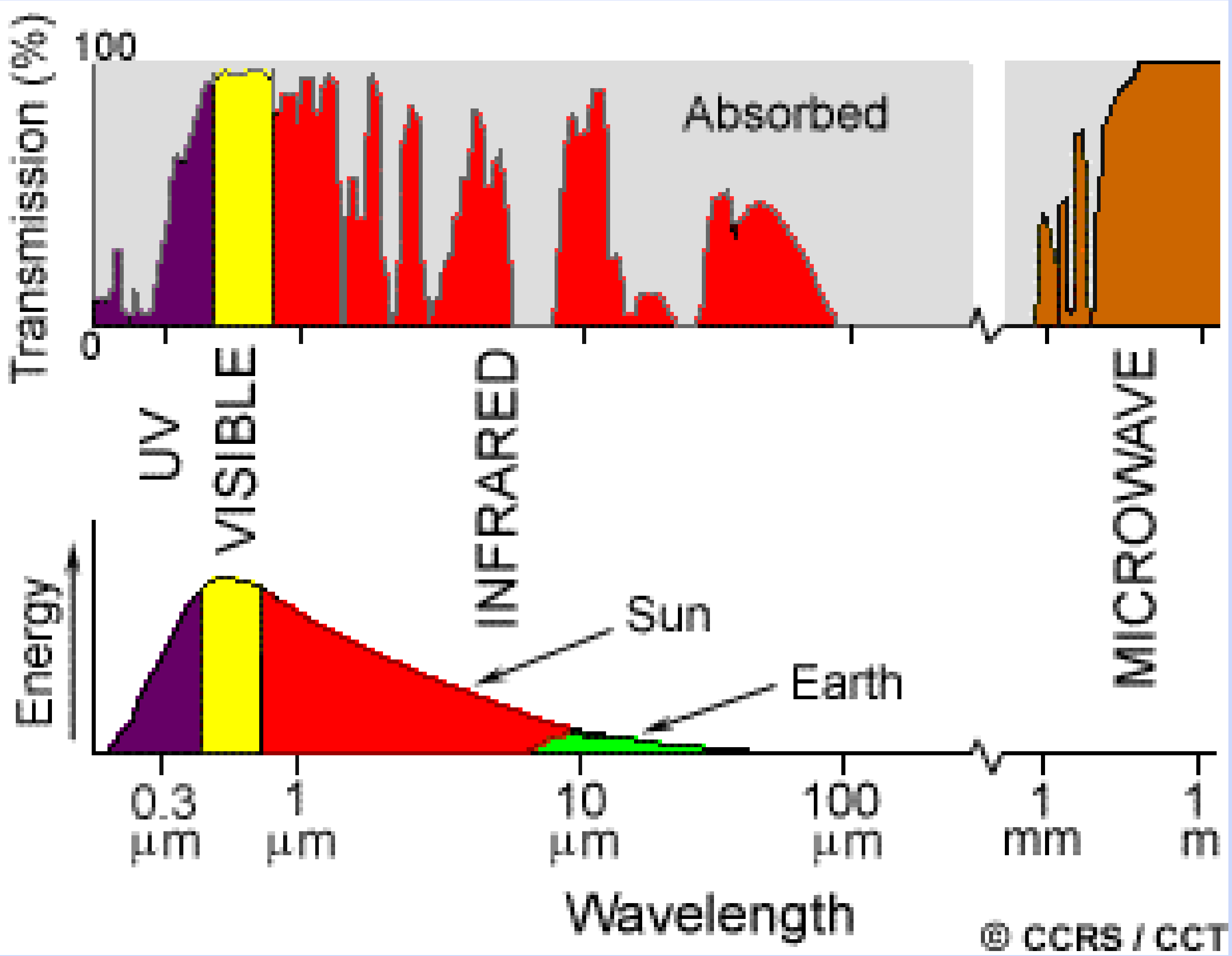
- **<u>Absorption</u> is the other main mecha nism at work when electromagnetic ra diation interacts with the atmosphere .**

- **This phenomenon causes molecules in the atmosphere to absorb energy a t various wavelengths.**

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

Those areas of the spectrum which are not severely in fluenced by atmospheric absorption and thus, are use ful to remote sensors, are called atmospheric window s.

Atmospheric window



Radiation interaction: with target

• Radiation that is not absorbed or scattered in the atmosphere reaches and interacts with the Earth's surface and different targets.

• 3 forms of interaction (when energy strikes upon the surface or incidents)

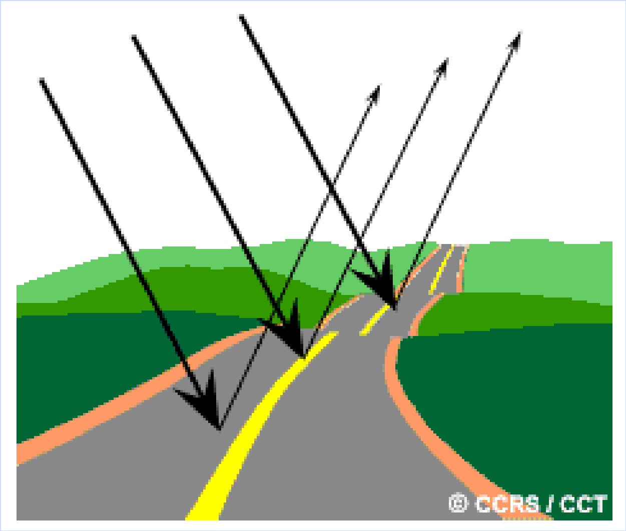
Absorption (A) : When radiation is absorbed into the target

Transmission (T): When radiation passes through a target

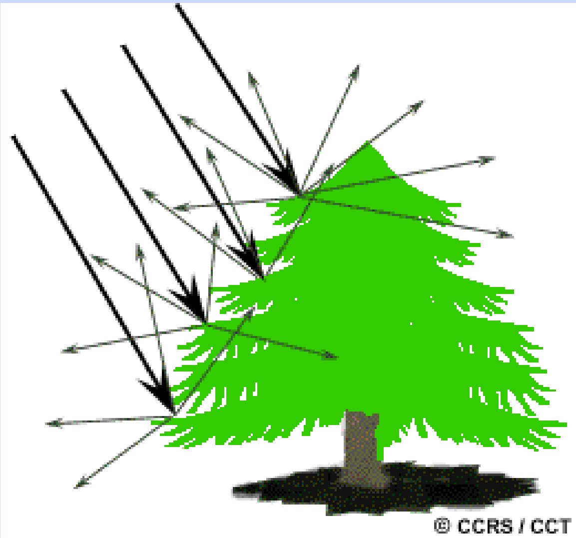
Reflection (R): when radiation "bounces" off the target

Radiation interaction: with target

- **We are most interested in measuring the radiation ref lected from targets.**
- **Two types of reflection:**
  - **Specular reflection and**
  - **Diffuse reflection.**



Specular reflection (mirror-like)



Diffused reflection (rough surface)

Spectral Signature

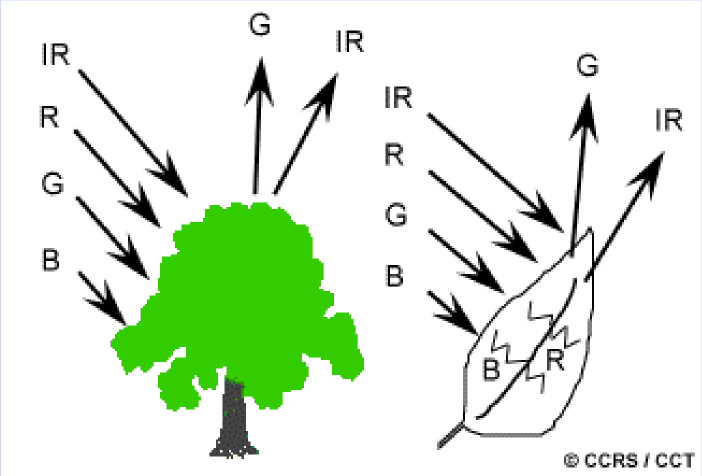
- **Spectral Signature or spectral response refers to respo nse of a target to radiation in terms of absorption, trans mission, and reflection.**

- **It depends on the complex make-up of the target that is being looked at (material composition, surface propertie s, etc) , and the wavelengths of radiation involved.**

- **Thus by comparing the response patterns of different f eatures we may be able to distinguish between them, thi s may not be achieved if we only compared them at one wavelength.**

- **Spectral response can be quite variable, even for the sa me target type, and can also vary with time**

Spectral Signature : Leaves



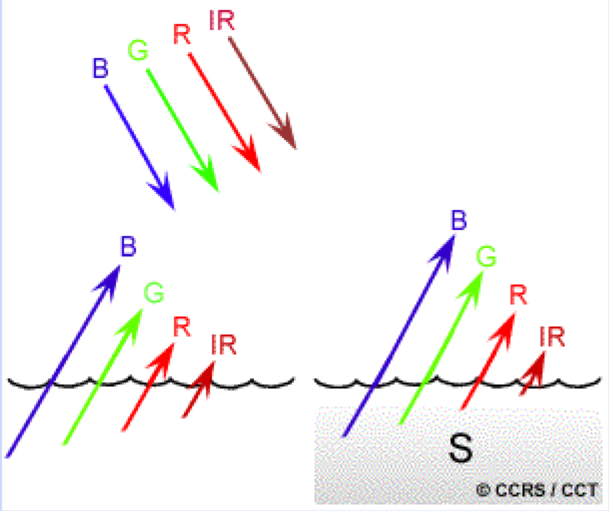
- Leaves : Chlorophyll strongly absorbs r adiation in the red and blue wavelengths but reflects green wavelengths.

- Leaves appear "greenest" to us in the s ummer, when chlorophyll content is at its maximum.

- In autumn, reduction in chlorophyll in th e leaves, results in less absorption and p roportionately more reflection of the red wavelengths, making the leaves appear r ed or yellow.

- The internal structure of healthy leaves act as excellent diffuse reflectors of near-infrared wavelengths.

Spectral Signature : Water

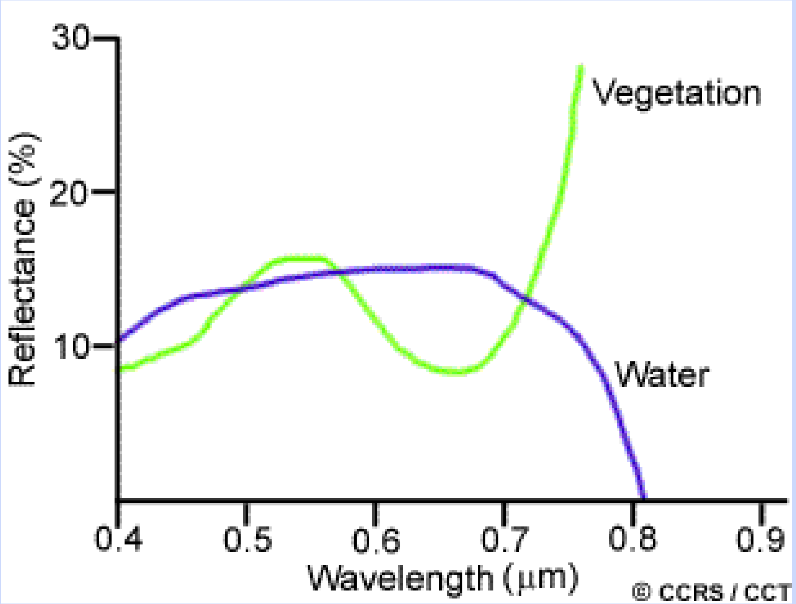


- Longer wavelength visible (red) and near infrared radiation is absorbed m ore by water than shorter visible wave lengths (violet).

- Thus water typically looks blue or bl ue-green due to stronger reflectance at these shorter wavelengths, and dar ker if viewed at red or near infrared w avelengths.

- If there is suspended sediment pres ent in the upper layers of the water bo dy, then this will allow better reflectivi ty and a brighter appearance of the w ater.

Spectral Signature : Leaves vs Water

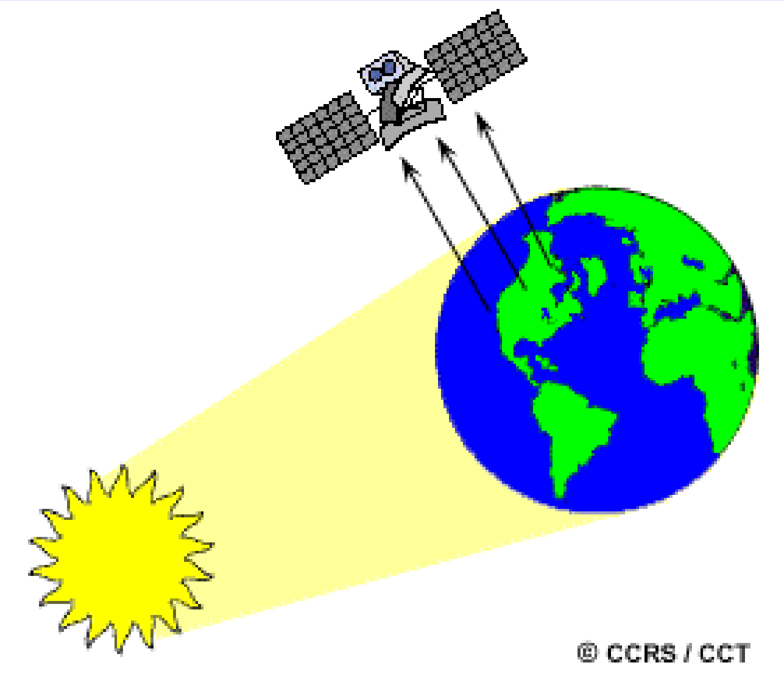


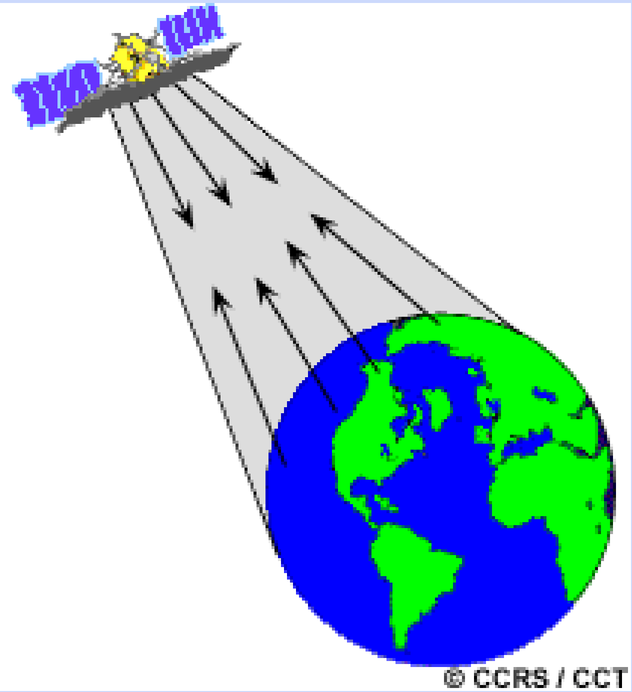
- **Water and vegetation may reflect somewhat similarly in the visible wavelengths but are almost always separable in the infrared.**

Passive & Active Remote Sensing

- **Remote sensing that uses naturally available energy is termed as Passive Remote Sensing.**

- **Active Remote Sensing uses energy provided by se nsors (i.e. own energy source for illumination)**





Passive & Active Remote Sensing

- **Passive Sensors measure all reflected energy, this can only take place during the time when the sun is illuminating the Earth.**

- **Energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded.**

- **Active Sensors can obtain measurements anytime, regardless of the time of day or season.**

- **Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated.**

Satellite image characteristics

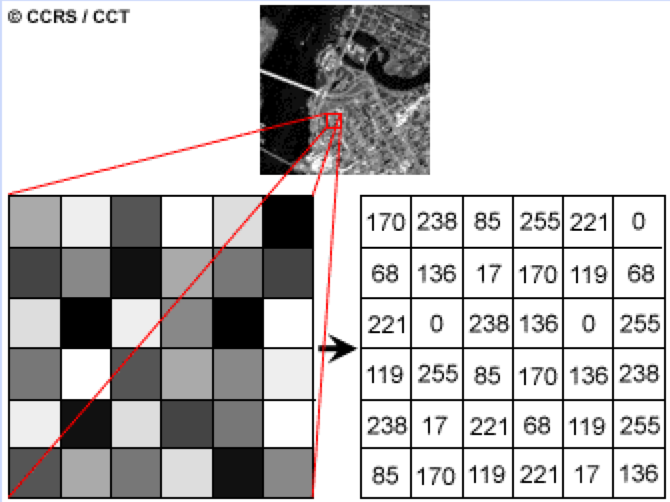
- **Electromagnetic energy may be detected either photographically or electronically.**

- **An image refers to any pictorial representation, regardless of what wavelengths or remote sensing device has been used to detect and record the electromagnetic energy.**

- **A photograph refers specifically to images that have been detected as well as recorded on photographic film.**

- **Photos are normally recorded over the wavelength range from 0.3 μm to 0.9 μm - the visible and reflected infrared. Based on these definitions, we can say that all photographs are images, but not all images are photographs.**

Satellite image characteristics



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

- **An mage or photograph displayed in a digital format can be subdivided into small equal-sized and shaped areas, called picture elements or pixels (cells).**

- **Each cell represents the brightness of each area with a numeric value called Brightness Value (BV) or Digital Number (DN).**

Satellite image characteristics

- The information from different wavelength range s is gathered and stored in separate channels, ref erred to as bands.

- Information from different channels can be comb ined and displayed digitally using the three primar y colours (blue, green, and red).

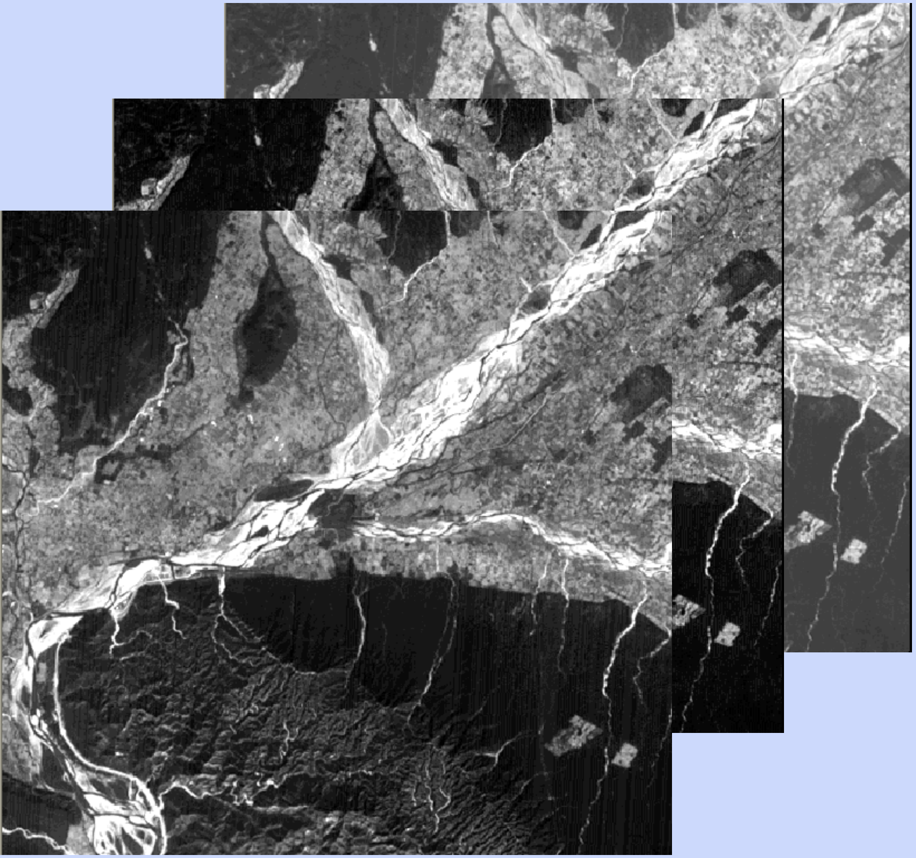
- The data from each channel is represented as on e of the primary colours and, depending on the rel ative brightness (i.e. the digital value) of each pixe l in each channel, the primary colours combine in different proportions to represent different colour s.

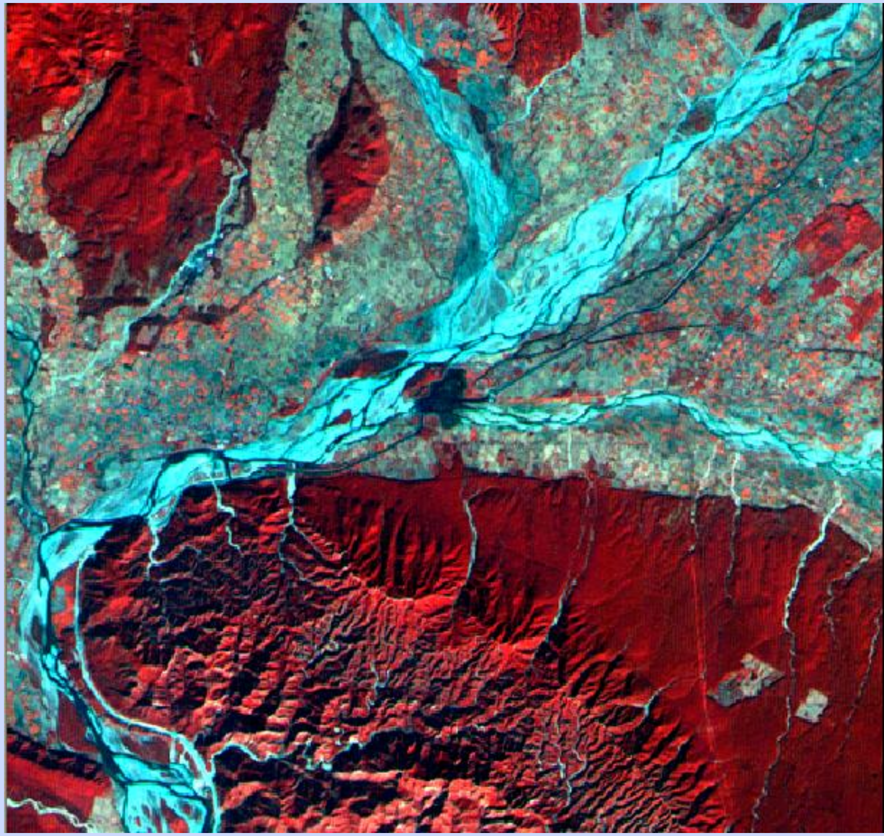
Satellite image characteristics

- **Thus when data from single channel or band is displayed, it shows variation in brightness value as different shades of gray ranging form white to black.**

- **When two or more bands or channels are combi ned and displayed, it produces colour image.**

Satellite image : Bands





Discussion Topics

- **Platforms & Sensors**
- **Orbits & Swath**
- **Data Reception**
- **Data Processing**
- **Data Products**
- **Image Resolutions (4)**
- **Multispectral Scanning**

Platforms

- **It refers to a surface on which the sensor rests.**
- **It may be**
    - **Ground Borne**
    - **Air Borne**
    - **Space Borne**

Platforms : Types

Ground Borne

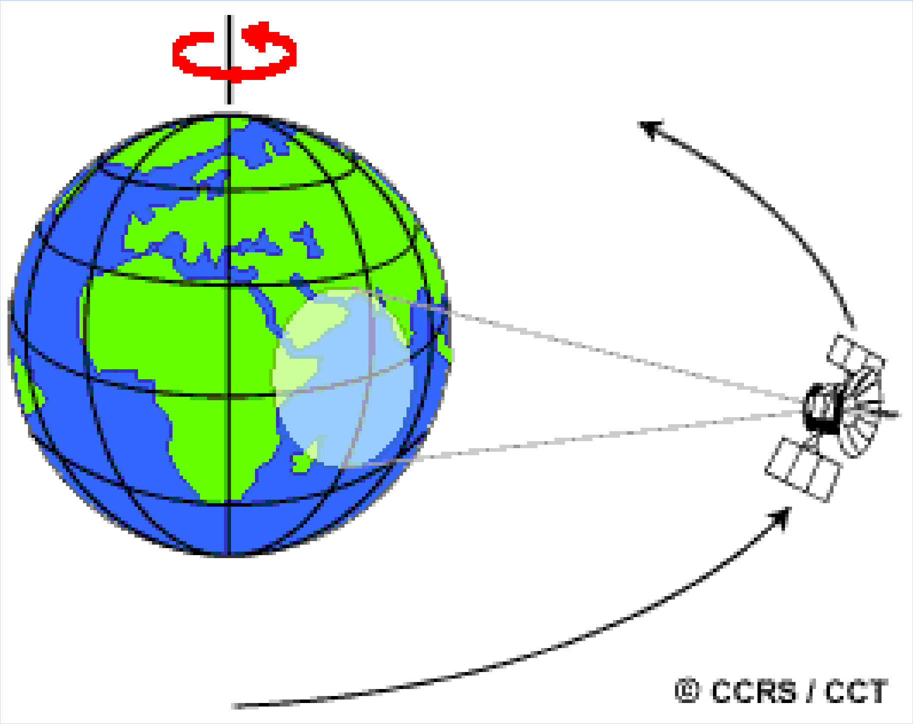
Air Borne

Space Borne

Orbits

- **The path followed by a satellite is referred to as its orbit.**
- **Satellite orbits are matched to the capability and objective of the sensor(s) they carry.**
- **Orbit selection can vary in terms of altitude and their orientation and rotation relative to the Earth.**
- **Types :**
  - **Geostationary**
  - **Polar (Sun synchronous)**

Orbits



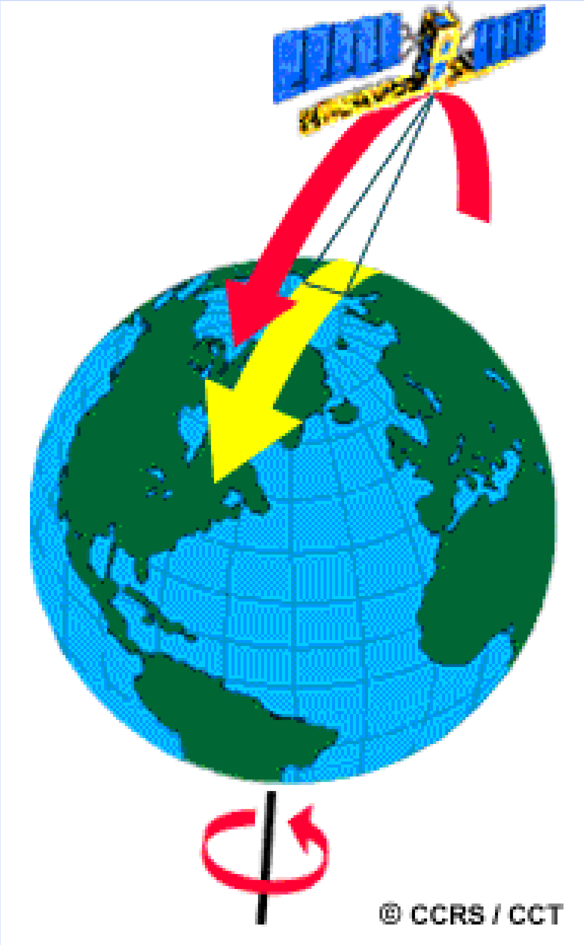
- Satellites following Geostatio nary orbit view the same porti on of the Earth's surface at all times

- These are at altitude of appro ximately 36,000 kilometres

- They revolve around the Eart h with the speed equal to rotat ion speed of Earth (hence they appear stationary relative to th e Earth).

Examples: Weather and communications satellites

Orbits

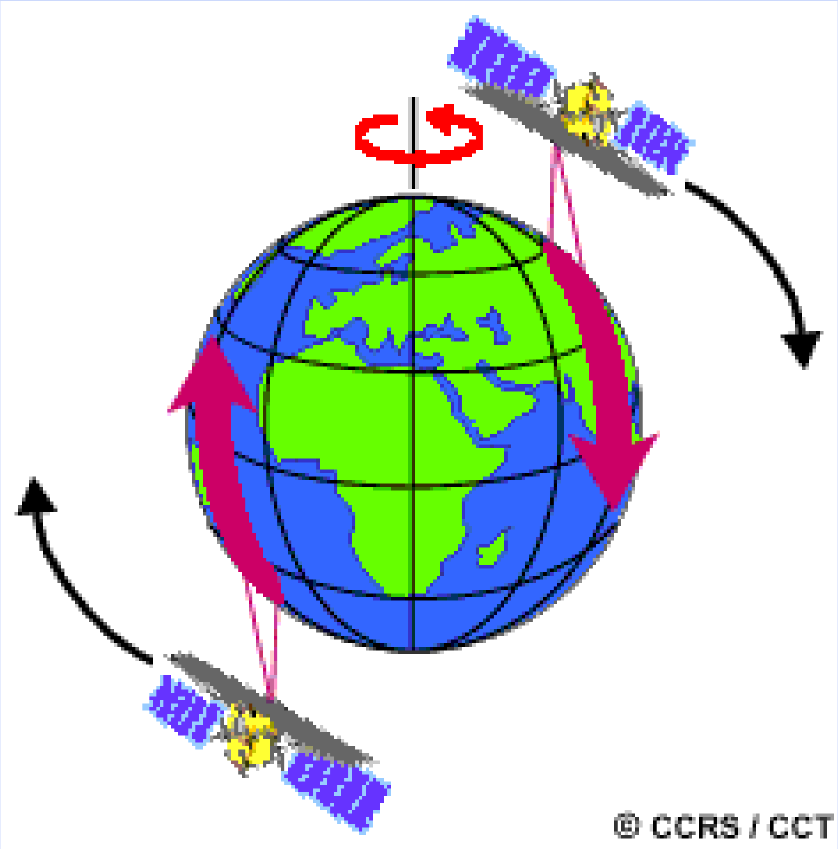


• About 800-1000 Km above Earth's s urface

• Some satellites follow orbits (basica lly north-south) which, in conjunction with the Earth's rotation (west-east) al lows them to cover most of the Earth' s surface over a certain period of time .

• Many of these satellite orbits are als o sun-synchronous such that they co ver each area of the world at a consta nt local time of day called local sun ti me.

Orbits



- Satellite's travel towards North pole is termed as 'Ascending pa ss' while that towards South pol e is termed as 'Descending pass '

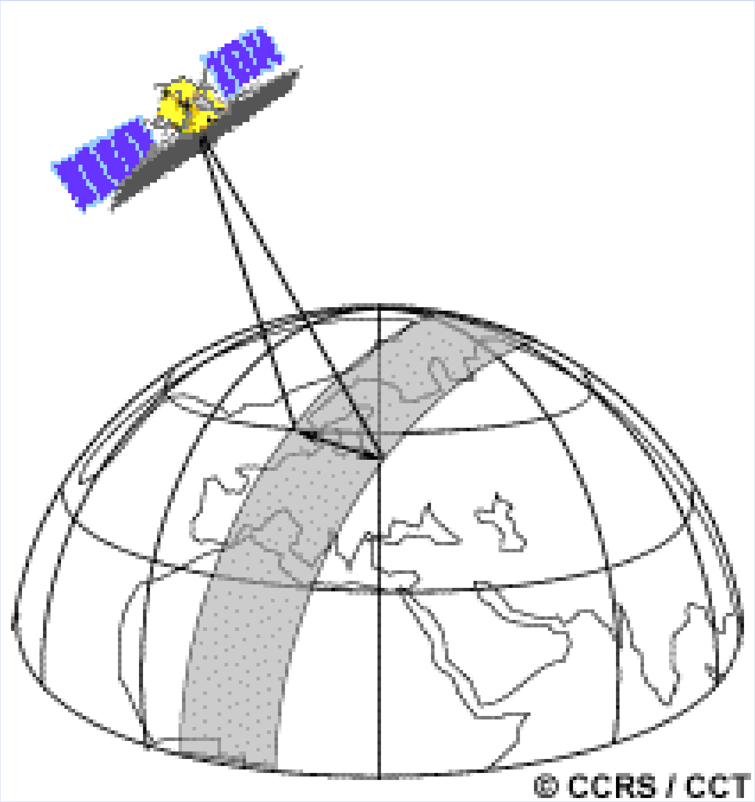
- In sun-synchronous orbits, the ascending pass is most likely on the shadowed side of the Earth while the descending pass is on the sunlit side.

Orbits

- **Sensors recording reflected solar energy only image the surface on a descending pass, when solar illumination is available.**

- **Active sensors which provide their own illumination or passive sensors that record emitted (e.g. thermal) radiation can also image the surface on ascending passes.**

Swath

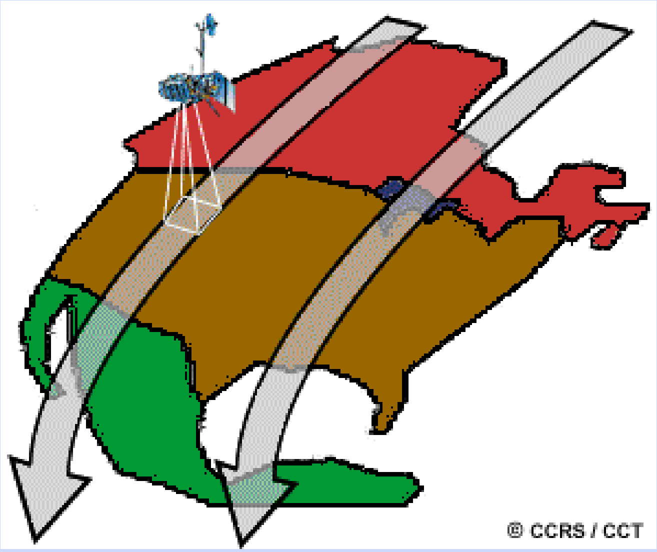


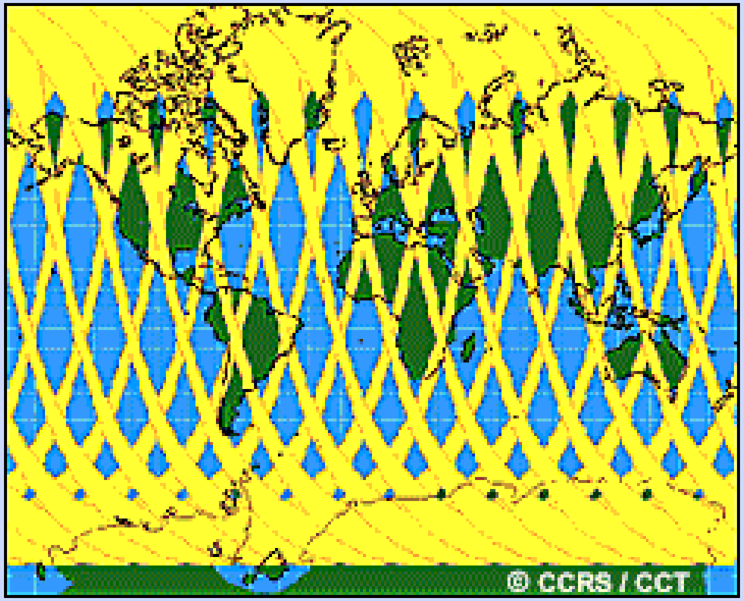
- As a satellite revolves around the Earth, the sensor captures a certain portion (strip of constant width) of the Earth's surface. The area imaged on the surface, is referred to as the swath.

- Imaging swaths for spaceborne sensors generally vary between tens and hundreds of kilometres wide.

- As the satellite orbits the Earth from pole to pole, its east-west position wouldn't change if the Earth didn't rotate.

Satellite Passes





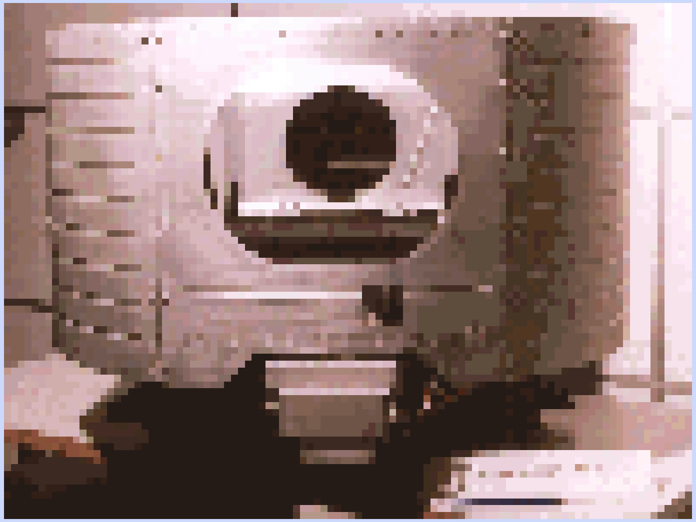
- As the satellite orbits the Earth from pole to pole, its east-west position wouldn't change if the Earth didn't rotate.

- However, as seen from the Earth, it seems that the satellite is shifting westward because the Earth is rotating (from west to east) beneath it.

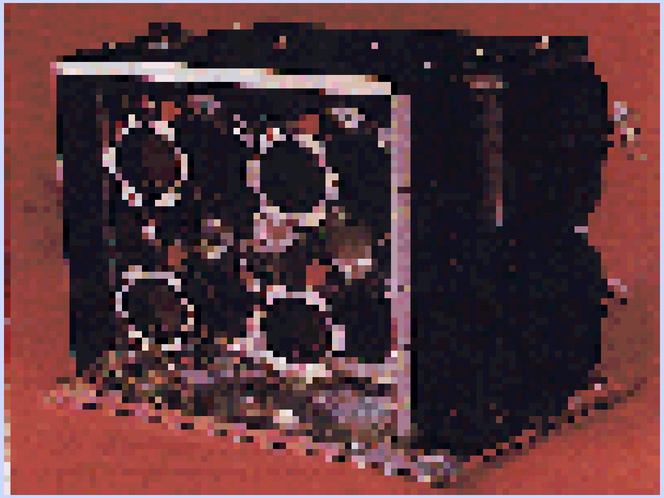
- This apparent movement allows the satellite swath to cover a new area with each consecutive pass.

Sensors

- **Devices or the instruments which sense the energy and can produce photograph or image for the recorded energy from object.**
- **Mounted on the platform**



PAN



LISS III

Some Popular Sensors & their Swath

Sensor	Orbit (altitude)	Swath
PAN	817 Km	23 Km
LISS III	817 Km	141 Km
LISS IV		
Cartosat-1		
Cartosat-2		

Data Reception

- **The data captured by the satellite and stored in its storage medium is downloaded at Ground Control Station.**

- **Indian Ground Control Station is located at Shadnagar, 55km south of Hyderabad city to receive data from various Remote Sensing Satellites both Indian and Foreign origin.**

- **It has three Antenna Receive systems (Terminals) to support multi- mission operations.**

- **They are capable to Track and Receive data from any Remote Sensing Satellite, which is in sun-synchronous, polar near circular orbit**

Data Reception

Data Reception

- **The Ground Station basically consists of**
  - **(1) Antenna & Receive System**
  - **(2) Archival & Quick Look Browse System**
  - **(3) Test Facility and**
  - **(4) Support systems (Communication Networks; UPS and Standby DG power systems etc.)**

- **Data reception is followed by Data Processing for gene ration of products**

Data Processing

- **As per user requirements, Data processing caters to gen eration of satellite data products for all IRS series satellite s and some foreign satellites.**

- **The raw data recorded at the ground station is corrected for geometric and radiometric distortions. Data products a re categorized as Standard products and Value Added pro ducts.**

- **Raw data is archived on media. A catalog of all the archiv ed media is maintained. This media forms the input for dat a product generation.**

Data Processing

Archival facility

Data Processing Facility

Data Processing

Photo Processing facility

Data Products

Photographic Products

- **Black & White (B/W) Photographs**
- **Colour Photographs (Natural & False Colour Composites)**
- **Negative & Positive Transparencies**
- **Paper prints**

Digital Products

- **LGSOWG (Landsat Ground Station Operators Working Group) or Super Structure Format**
- **Fast Format**
- **GeoTIFF (Geographic Tagged Image File Format)**
- **Hierarchical Data Format (HDF)**
- **CDs or Digital Audio Tape (DAT)**

Satellite image procurement

- **Satellite images are usually through national agencies or their authorised channel partners.**

- **In India, the purchaser needs to send the request to NRSC (National Remote Sensing Center, Hyderabad).**

- **The archive images may be browsed through the ‘image search’ option on www.nrsc.gov.in. The data price list is also available on the website.**

Image Resolutions (4)

- **Resolution = the ability to distinguish two spatially cl ose or spectrally similar objects**

- **This refers to the size of the smallest possible featur e that can be detected.**

- **Image resolution refers to**
  - **Spatial Resolution**
  - **Spectral Resolution**
  - **Radiometric Resolution**
  - **Temporal Resolution**

Spatial Resolution

- **Images are composed of a matrix of picture elements, or pixels, which are the smallest units of an image.**

- **Image pixels are normally square and represent a certain area on an image.**

- **When an image is displayed at full resolution, each pixel represents a ground area corresponding to the spatial resolution of the sensor.**

- **It is expressed in terms of linear dimension (usually in meters)**

Example : spatial resolution of IKONOS is 1m & spatial resolution of Quickbird is 0.60m.

Spatial Resolution

Coarse Resolution

Fine Resolution

Spatial Resolution of some of the popular images

Sensor	Spatial Resolution
WiFS	188 M
LISS III	23.5 M
LISS IV	5.8 M (Colour)
PAN	5.8 M (Grayscale)
Cartosat-1	2.5 M
Cartosat-2	1.0 M
IKONOS	1.0 M
QuickBird	0.60 M
WorldView-01	0.50 M

Spectral Resolution

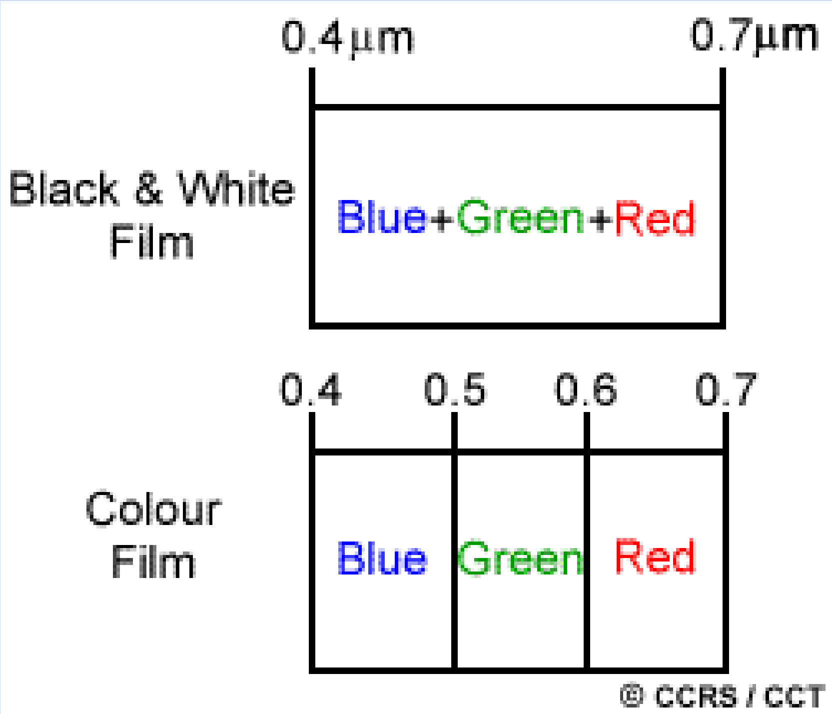
• **Spectral resolution describes the ability of a sensor to define fine wavelength intervals.**

• **As learnt earlier, spectral response changes from obje ct to object based on its material and surface properties .**

• **Thus different classes of features in an image can ofte n be distinguished by comparing their responses over d istinct wavelength ranges.**

• **Broad classes, such as water and vegetation, can usua lly be separated using very broad wavelength ranges - t he visible and near infrared. However, rock types may re quire higher spectral resolution to distinguish them.**

Spectral Resolution



- Black and white film records wa velengths extending over much, or all of the visible portion of the electromagnetic spectrum. Its sp ectral resolution is fairly coarse.

- Colour film has higher spectral resolution, as it is individually se nsitive to the reflected energy at the blue, green, and red wavelen gths of the spectrum.

- Thus, it can represent features of various colours based on their reflectance in each of these disti nct wavelength ranges.

Spectral Resolution

- **Many remote sensing systems record energy over se veral separate wavelength ranges at various spectral r esolutions.**

- **Hyperspectral sensors : They detect hundreds of ver y narrow spectral bands throughout the visible, near-i nfrared, and mid-infrared portions of the electromagne tic spectrum.**

- **Their very high spectral resolution facilitates fine dis crimination between different targets based on their s pectral response in each of the narrow bands.**

Radiometric Resolution

- The radiometric resolutio n of an imaging system des cribes its ability to discrimi nate very slight differences in energy.

- It is also called as Quanti zation Level.

- The finer the radiometric r esolution of a sensor, the more sensitive it is to detec ting small differences in ref lected or emitted energy.

Radiometric Resolution

- **Imagery data are represented by positive digital num bers which vary from 0 to (one less than) a selected po wer of 2.**

- **This range corresponds to the number of bits used fo r coding numbers in binary format. . Each bit records a n exponent of power 2.**

- **The maximum number of brightness levels available depends on the number of bits used in representing th e energy recorded.**

- **Thus, for a 8-bit sensor digital values will range from 0 to 255, while that for a 4-bit sensor will range from 0 t o 15.**

Temporal Resolution

- It refers to the length of time it takes for a satellite to complete one entire orbit cycle. (It is the time period required to image the exact same area at the same viewing angle a second time).

- The revisit period of a satellite sensor is usually several days.

- The actual temporal resolution of a sensor depends on a variety of factors, including the satellite/sensor capabilities, the swath overlap, and latitude.

- Spectral characteristics of features may change over time and these changes can be detected by collecting and comparing multi-temporal (multi-date) imagery.

Temporal Resolution

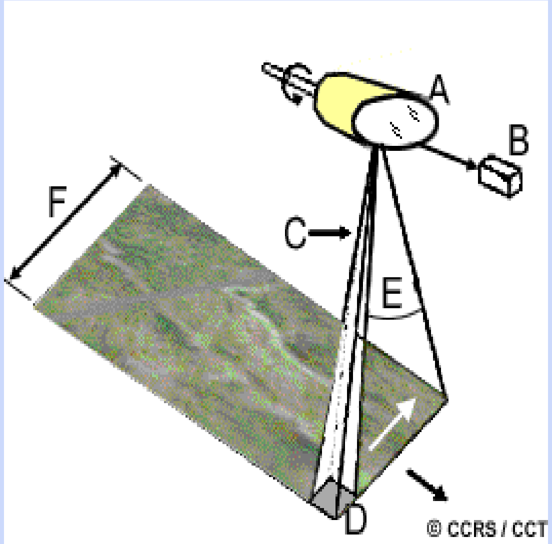
- **Temporal Resolution is important in imaging**
  - **Short-lived phenomena (floods, oil slicks, etc.)**

  - **Multi-temporal comparisons are required (e.g. t he spread of a forest disease from one year to t he next)**

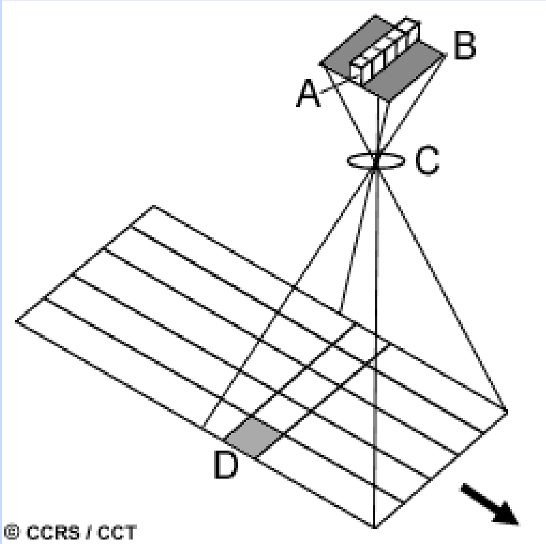
  - **The changing appearance of a feature over tim e can be used to distinguish it from near-similar features (wheat / maize)**

Multispectral Scanning

- **A scanning system used to collect data over a variety of different wavelength ranges is called a multispectral scanner (MSS)**

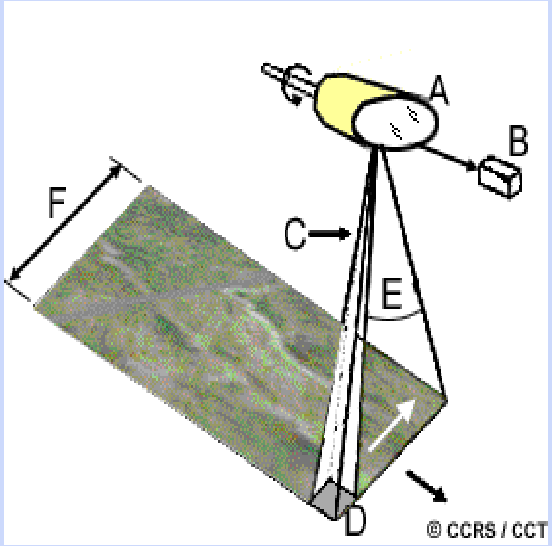


Across Track Scanning



Along Track Scanning

Across Track Scanning



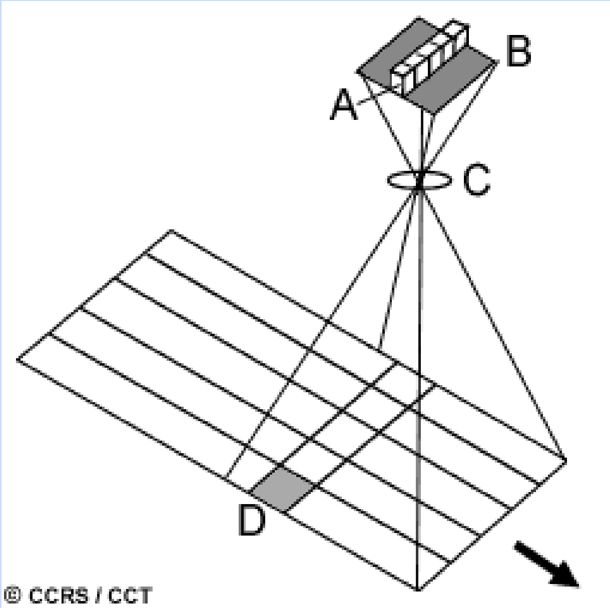
• Across-track scanners scan the Eart h in a series of lines.
• The lines are oriented perpendicular to the direction of motion of the senso r platform (i.e. across the swath).
• Each line is scanned from one side o f the sensor to the other, using a rotati ng mirror (A).
• As the platform moves forward over t he Earth, successive scans build up a two-dimensional image of the Earth´s surface

Across Track Scanning

- **Airborne scanners typically sweep large angles (betw een 90º and 120º), while satellites, because of their hig her altitude need only to sweep fairly small angles (10-20º) to cover a broad region.**

- **Because the distance from the sensor to the target in creases towards the edges of the swath, the ground re solution cells also become larger and introduce geome tric distortions to the images.**

Along Track Scanning



• **Along-track scanners also use the f orward motion of the platform to reco rd successive scan lines and build up a two-dimensional image, perpendicul ar to the flight direction.**

• **However, instead of a scanning mirr or, they use a linear array of detectors .**

• **These systems are also referred to a s pushbroom scanners, as the motion of the detector array is analogous to t he bristles of a broom being pushed a long a floor.**

Advantages of Along Track Scanning

- **The array of detectors combined with the pushbroom motion allows each detector to "see" and measure the energy from each ground resolution cell for a longer period of time (dwell time).**

- **This allows more energy to be detected and improves the radiometric resolution.**

- **Detectors are usually solid-state microelectronic devices, they are generally smaller, lighter, require less power, and are more reliable and last longer because they have no moving parts.**

- **Challenge: Cross-calibration of thousands of detectors to achieve uniform sensitivity across the array is necessary and complicated.**

Discussion Topics

- **Elements of visual interpretation**
  - **Tone**
  - **Shape**
  - **Size**
  - **Pattern**
  - **Texture**
  - **Shadow**
  - **Association.**

Tone

- **Tone refers to the relative brightness or colour of objects in an image.**

- **Tone is the fundamental element for distinguishing between different targets or features.**

- **Variation in tone also allows the elements of shape, texture, and pattern of objects to be distinguished.**

Shape

- Shape refers to the general for m, structure, or outline of individ ual objects.

- Shape can be a very distinctive clue for interpretation.

E.g. Forest versus farms

Size

- **Size of objects in an image is a function of scale.**

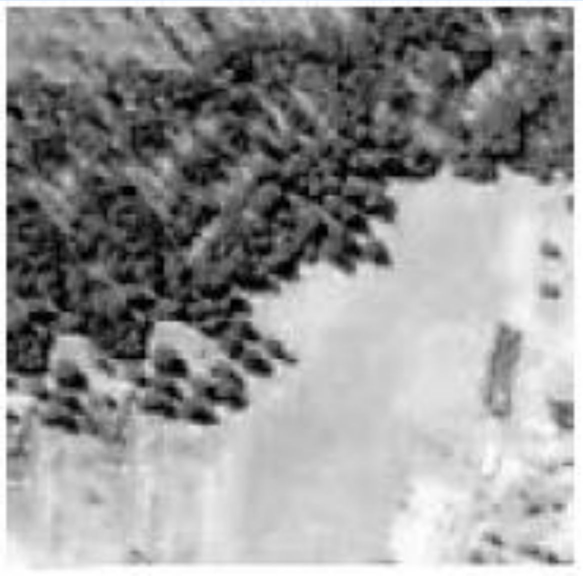
- **It is important to assess the size of a target relative to other objects in a scene, as well as the absolute size, to aid in the interpretation of that target.**

- **E.g. : Large buildings such as factories or warehouses would suggest commercial property, whereas small buildings would indicate residential use.**

Pattern

- **Pattern refers to the spatial arrangement of visibly discernible objects.**

Texture



•Texture refers to the arrangement a nd frequency of tonal variation in pa rticular areas of an image.

• Rough textures would consist of a mottled tone where the grey levels c hange abruptly in a small area, wher eas smooth textures would have ver y little tonal variation.

E.g.--Fields or grasslands usually ha ve smooth texture while forest tend t o have rough texture.

Shadow

- **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.**

Association

- 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.

Discussion Topics

- **Digital Image Processing (DIP)**
  - **Image Correction (Pre-processing)**
  - **Image Enhancement**
  - **Image Classification**

Image Correction

- **These are operations that are normally required prior to the main data analysis and extraction of information**

- **Includes :**
  - **Atmospheric corrections**
  - **Radiometric corrections**
  - **Geometric corrections**

Image Correction : Atmospheric

- **Any sensor that records EMR from the Earth's surfac e using visible or near-visible radiation will typically re gister a mixture of two kinds of energy.**

- **Molecular & aerosol scattering & absorption by gases (water vapor, ozone, oxygen, & aerosols)**

- **The value recorded at any pixel location on a remotel y sensed image does not represent the true ground-lea ving radiance at that point.**

- **Part of the brightness is due to the reflectance of the target of interest and the remainder is derived fr om the brightness of the atmosphere itself.**

- **It is intended to correct for sensor- and platform-spec ific radiometric and geometric distortions of data.**

Image Correction : Atmospheric

- **To retrieve surface reflectance from remotely sensed imagery is called atmospheric correction**

- **Process that converts the top-of atmosphere (TOA) radiance to surface reflectance**

- **Difficulties – variations of concentrations in time & space: aerosols & water vapor**
  - **Aerosols – shortwave bands**
  - **Water vapor – affects the near IR bands**

- **It involves :**
  - **Atmospheric parameter estimation**
  - **Surface reflectance retrieval**

Image Correction : Atmospheric

- **Atmospheric Correction methods**
  - **Invariant-object method (Single viewing angle imagery)**
  - **Look-up table method (Single viewing angle imagery)**
  - **Histogram matching methods**
  - **Dark object methods**
  - **Contract reduction methods**
  - **Cluster matching method**

Image Correction : Atmospheric

Dark Object Method (Dark Pixel Reduction Method)

- **The brightness values across image are observed for each band**

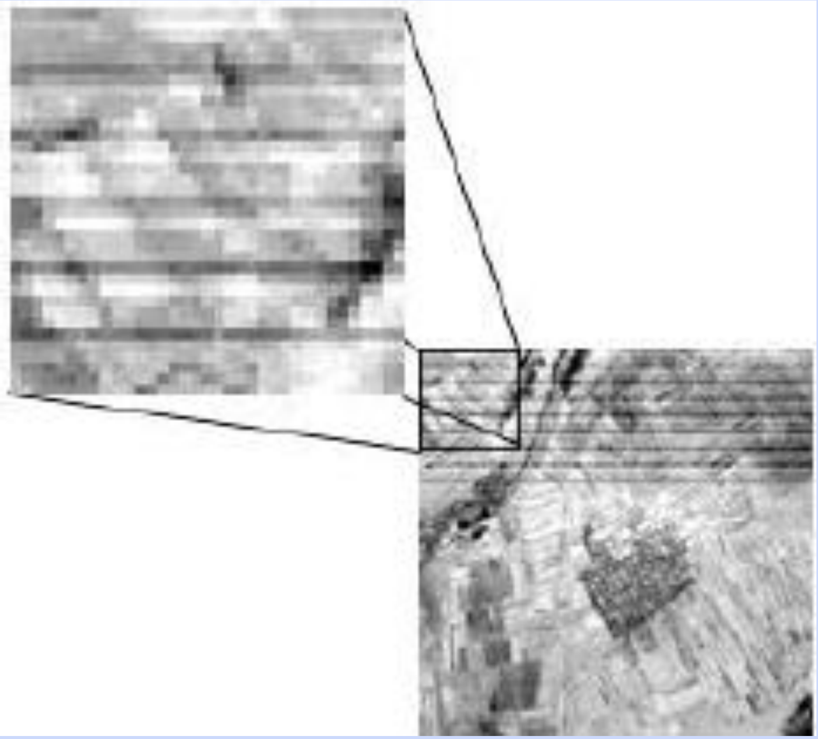
- **Minimum brightness value is determined for each band (Since scattering is wavelength dependent, the minimum values will vary from band to band.**

- **The correction is applied by subtracting the minimum observed value, determined for each specific band, from all pixel values in each respective band.**

Image Correction : Radiometric

- **Radiometric corrections include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise, and converting the data so they accurately represent the reflected or emitted radiation measured by the sensor.**

Image Correction : Radiometric

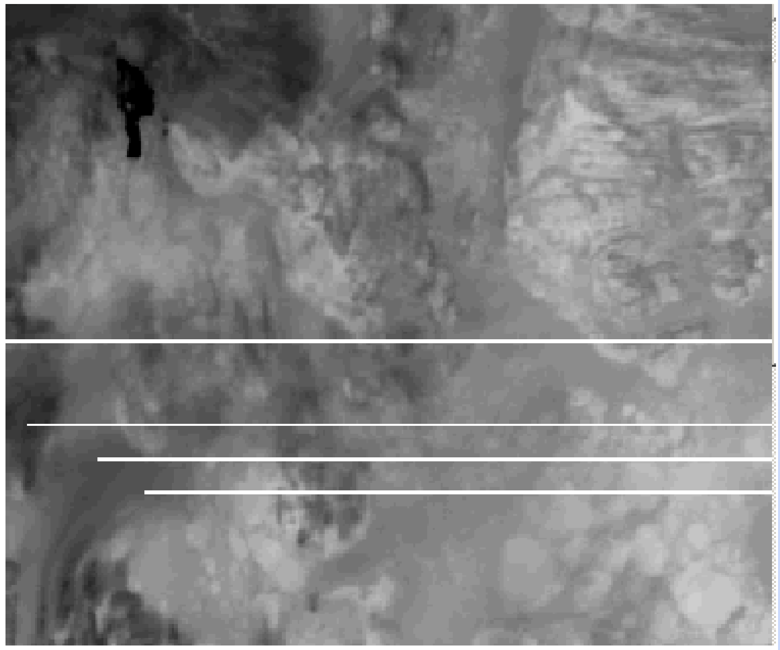


- Noise in an image may be du e to irregularities or errors tha t occur in the sensor response and/or data recording and tran smission.

- Common forms of noise incl ude systematic striping or ban ding and dropped lines.

- Both of these effects should be corrected before further en hancement or classification is performed.

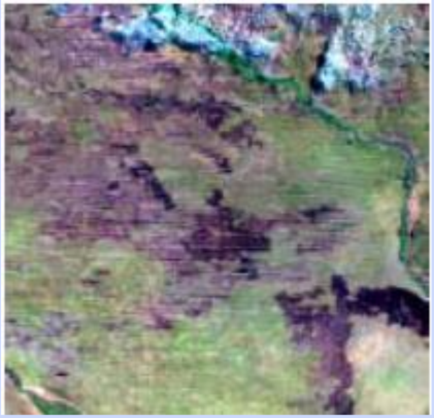
Image Correction : Radiometric

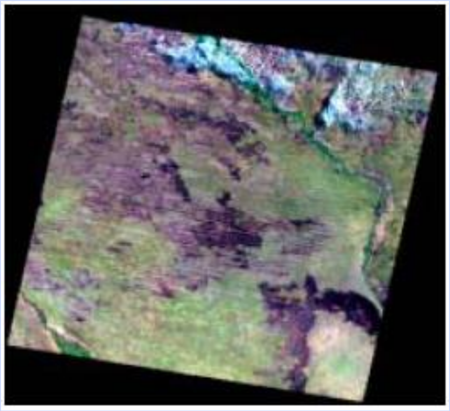


- Dropped lines occur when there are systems errors which result in missing or defective data along a scan line.

- Dropped lines are normally 'corrected‘ by replacing the line with the pixel values in the line above or below, or with the average of the two.

Image Correction : Geometric





- **Remote Sensing data are affected by geometric distortions due to**
  - **sensor geometry,**
  - **platform instabilities,**
  - **earth rotation,**
  - **earth curvature etc.**

- **Some of these distortions are corrected by image supplier, others have to be corrected by referencing images to existing maps or other images.**

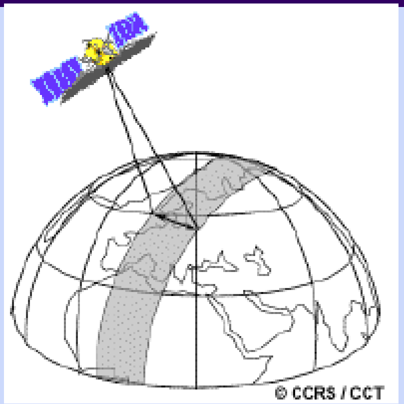


Image Correction : Geometric

- **Geometric corrections are intended to compensate for these distortions so that the geometric represent ation of the imagery will be as close as possible to t he real world.**

- **Many of these variations are systematic, or predict able in nature and can be accounted for by accurate modeling of the sensor and platform motion and the geometric relationship of the platform with the Earth .**

- **Other unsystematic, or random, errors cannot be modeled and corrected through geometric registrati on of the imagery to a known ground coordinate sys tem must be performed.**

Image Correction : Geometric

Sources of geometric distortions : Systematic

- **Scan skew: ground swath is not normal to the pola r axis**

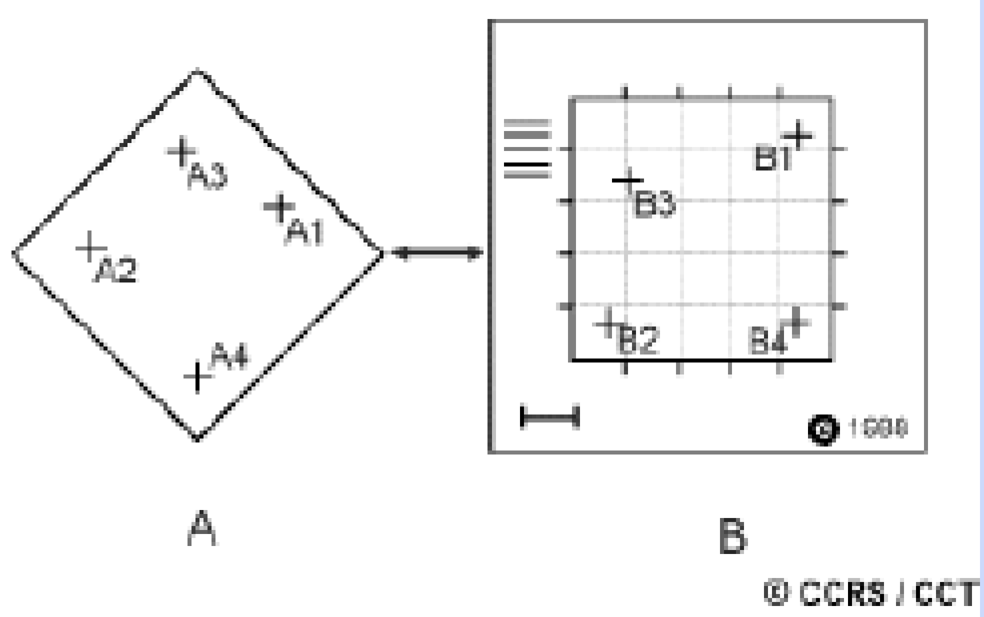
- **Mirror-scan Velocity and panoramic distortion: alo ng-scan distortion (pixels at edge are slightly larger) .**

- **Earth rotation: earth rotates during scanning**

Sources of geometric distortions : Non-systematic

- **Altitude and attitude variations in satellite**

Image Correction : Geometric



• **The geometric registration process involves identifying the image coordinates (i.e. row, column) of several clearly discernible points, called ground control points (or GCPs), in the distorted image (A - A1 to A4), and matching them to their true positions in ground coordinates (e.g. latitude, longitude).**

Image Correction : Geometric

- The true ground coordinates are typically measured either on field using GPS or DGPS or measured from a map (the latitude-longitude grid may already be prin ted or the common features in raw map and the refere nce map are identifiable).

- If there's single raw map, and the coordinates are ap plied either through field observation or through lat-lo ng printed on it, this is known as 'map registration'.

- If there's a raw map and a reference map or image (a lready with coordinates), geometric correction can be through features common in them. This is known as ' map to map registration'.

Image Correction : Geometric

- **It includes**

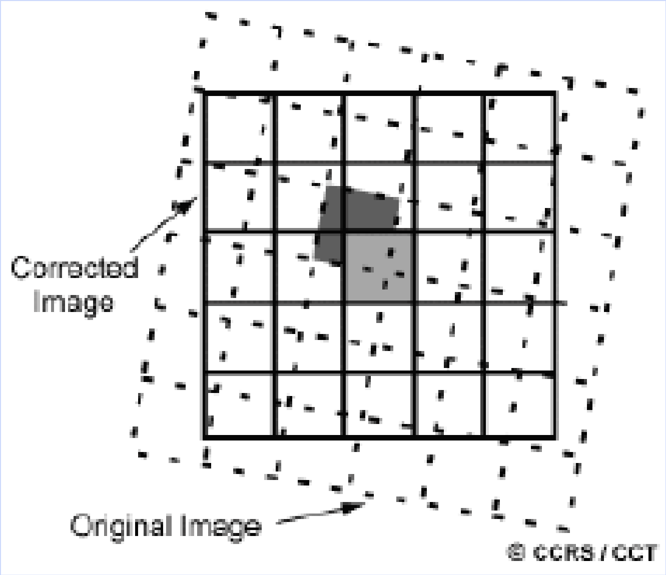
  Rectification (applying coordinates to be planimetric)

  Resampling (extrapolating data to a new grid)

- **Rectification is through marking GCPs and assignin g them coordinates**
  - **Map registration**
  - **Map-to-map registration**

- **Resampling**
  - **Nearest neighbour**
  - **Bilinear interpolation**
  - **Cubic convolution**

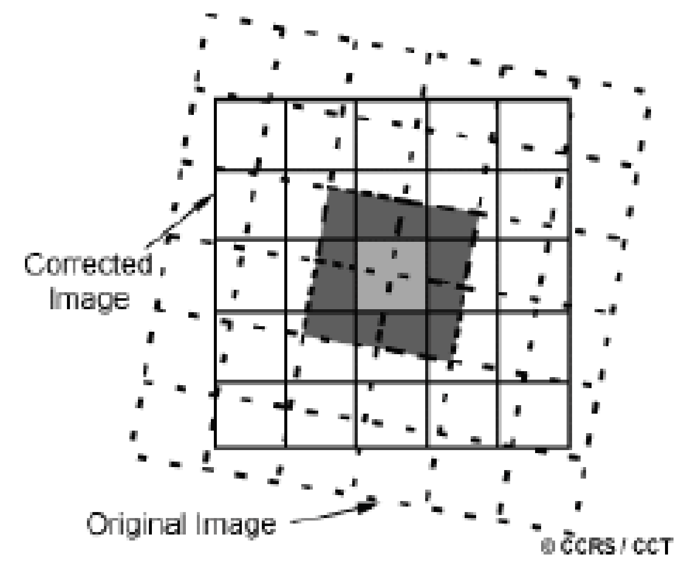
Image Correction : Geometric



- **Nearest neighbour resampling uses the digital value from the pi xel in the original image which is nearest to the new pixel location in the corrected image.**

- **This is the simplest method and does not alter the original values, but may result in some pixel valu es being duplicated while others are lost.**

Image Correction : Geometric

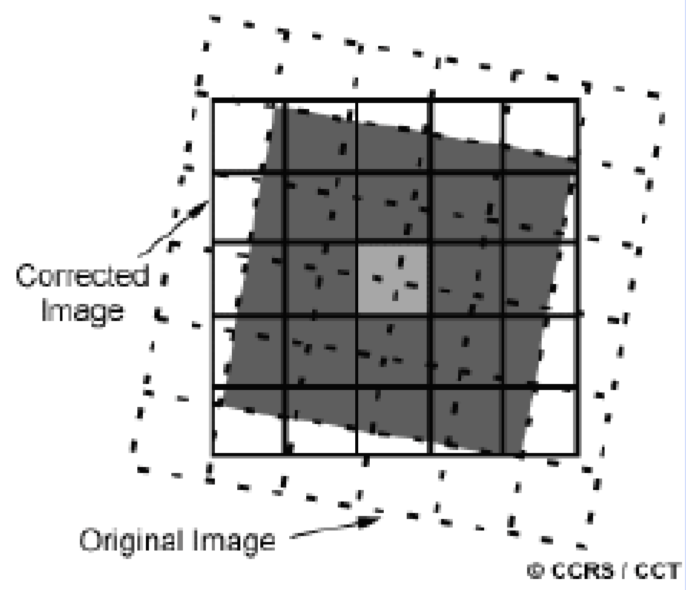


• **Bilinear interpolation resamplin g takes a weighted average of fo ur pixels in the original image ne arest to the new pixel location.**

• **The averaging process alters t he original pixel values and crea tes entirely new digital values in the output image.**

• **This may be undesirable if furt her processing and analysis, su ch as classification based on sp ectral response, is to be done.**

Image Correction : Geometric



- **Cubic convolution resampling calculates a distance weighted a verage of a block of sixteen pixe ls from the original image which surround the new output pixel lo cation.**

- **This method results in complet ely new pixel values.**

Image Enhancement

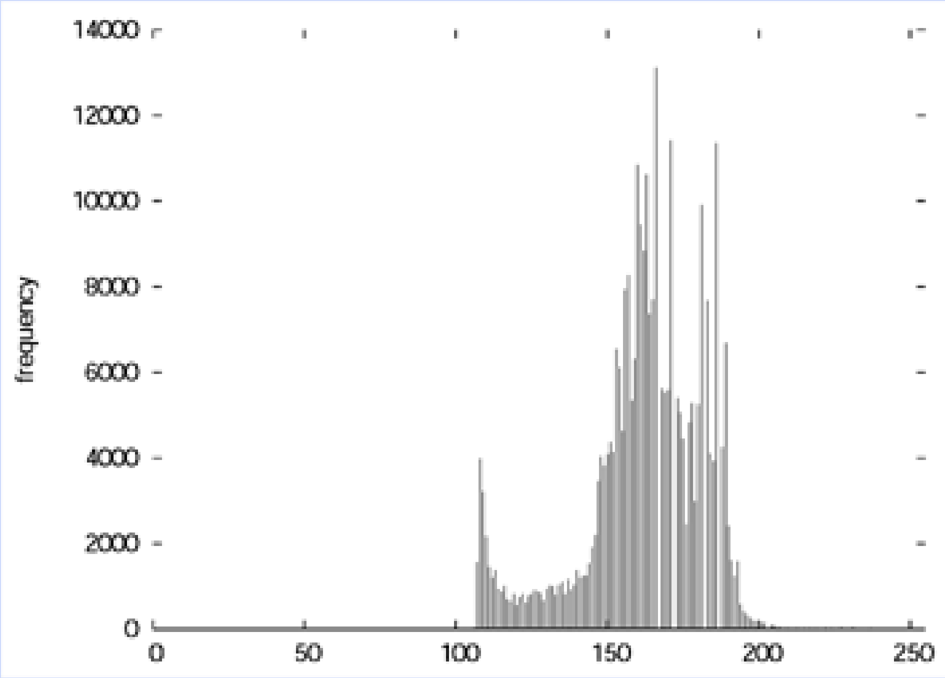
- **Image processing functions that are used to improve the appearance of the imagery to assist in visual interpretation of images and image analysis are termed as Image Enhancement.**

Image Enhancement includes:

- **Contrast enhancement**
  - **linear stretching**
  - **histogram equalization**
  - **piecewise stretching**

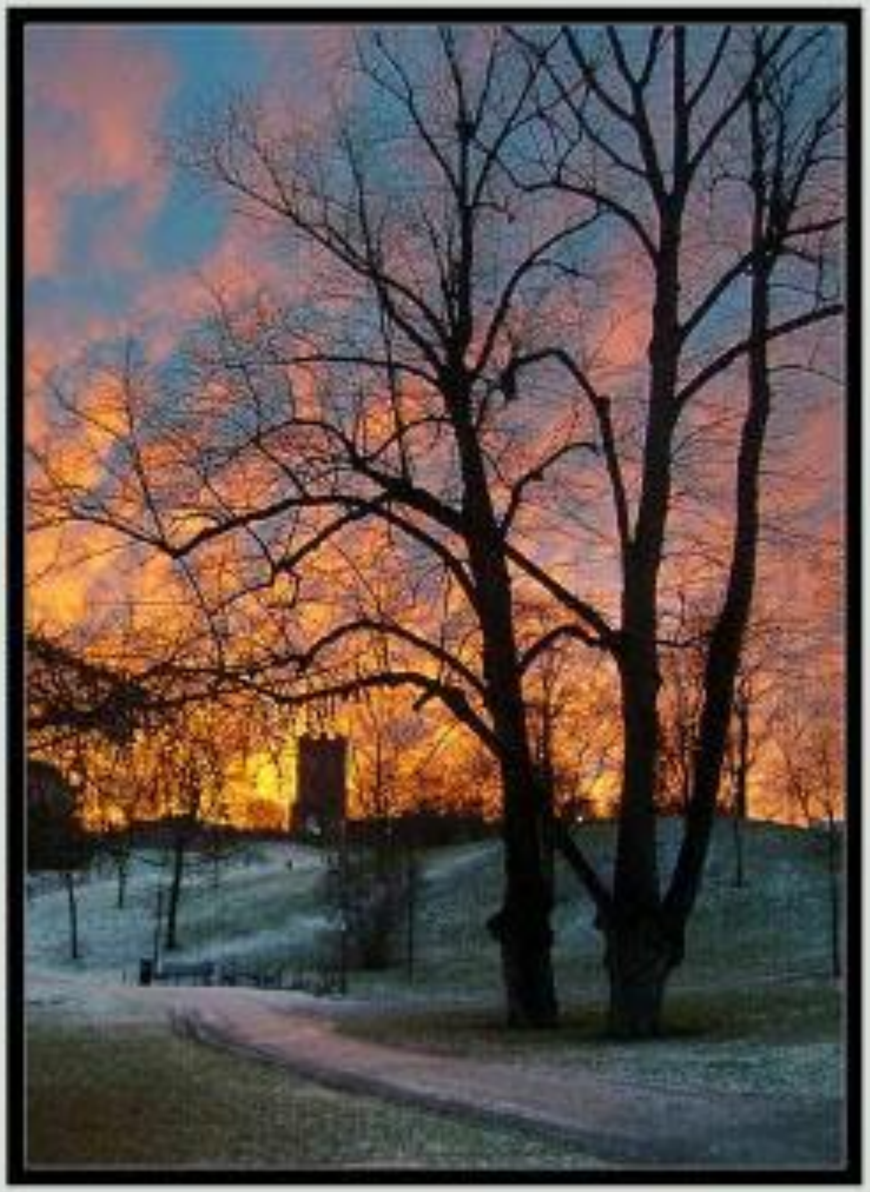
- **Spatial enhancement**
  - **low pass filter**
  - **high pass filters**

Image Histogram



- **A histogram is a graphical re presentation of the brightness values that comprise an image .**
- **The brightness values (i.e. 0-255) are displayed along the x-axis of the graph.**
- **The frequency of occurrence of each of these values in the i mage is shown on the y-axis.**

Image Histogram



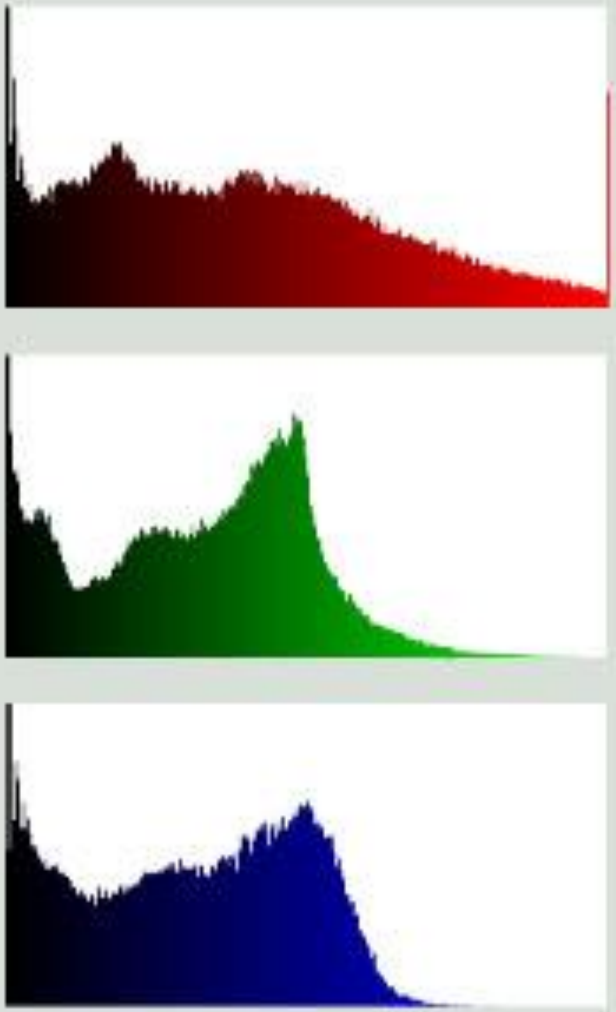
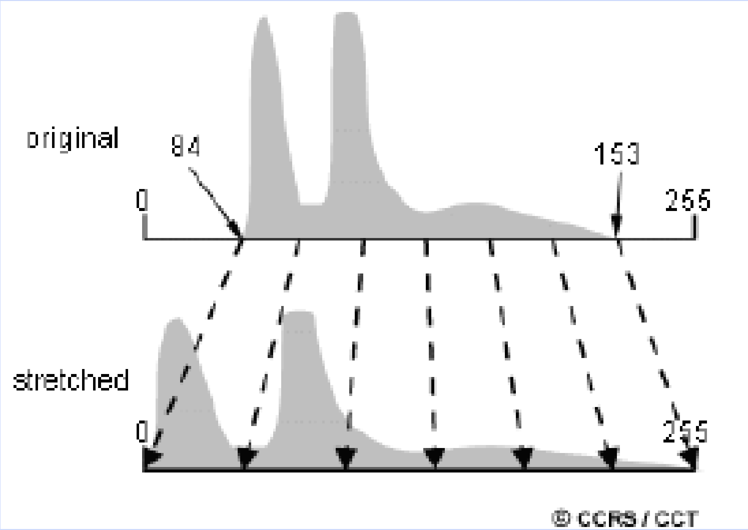


Image Enhancement : Contrast enhancement

- **In raw imagery, the useful data often populates only a small portion of the available range of digital values (commonly 8 bits or 256 levels).**

- **Contrast enhancement involves changing the original values so that more of the available range is used, thereby increasing the contrast between targets and their backgrounds.**

Image Enhancement : Linear contrast stretch



This involves identifying lower and upper bounds from the histogram (usually the minimum and maximum brightness values in the image) and applying a transformation to stretch this range to fill the full range.

Example: A linear stretch uniformly expands this small range to cover the full range of values from 0 to 255.

This enhances the contrast in the image with light toned areas appearing lighter and dark areas appearing darker, making visual interpretation much easier

Image Enhancement : Linear contrast stretch

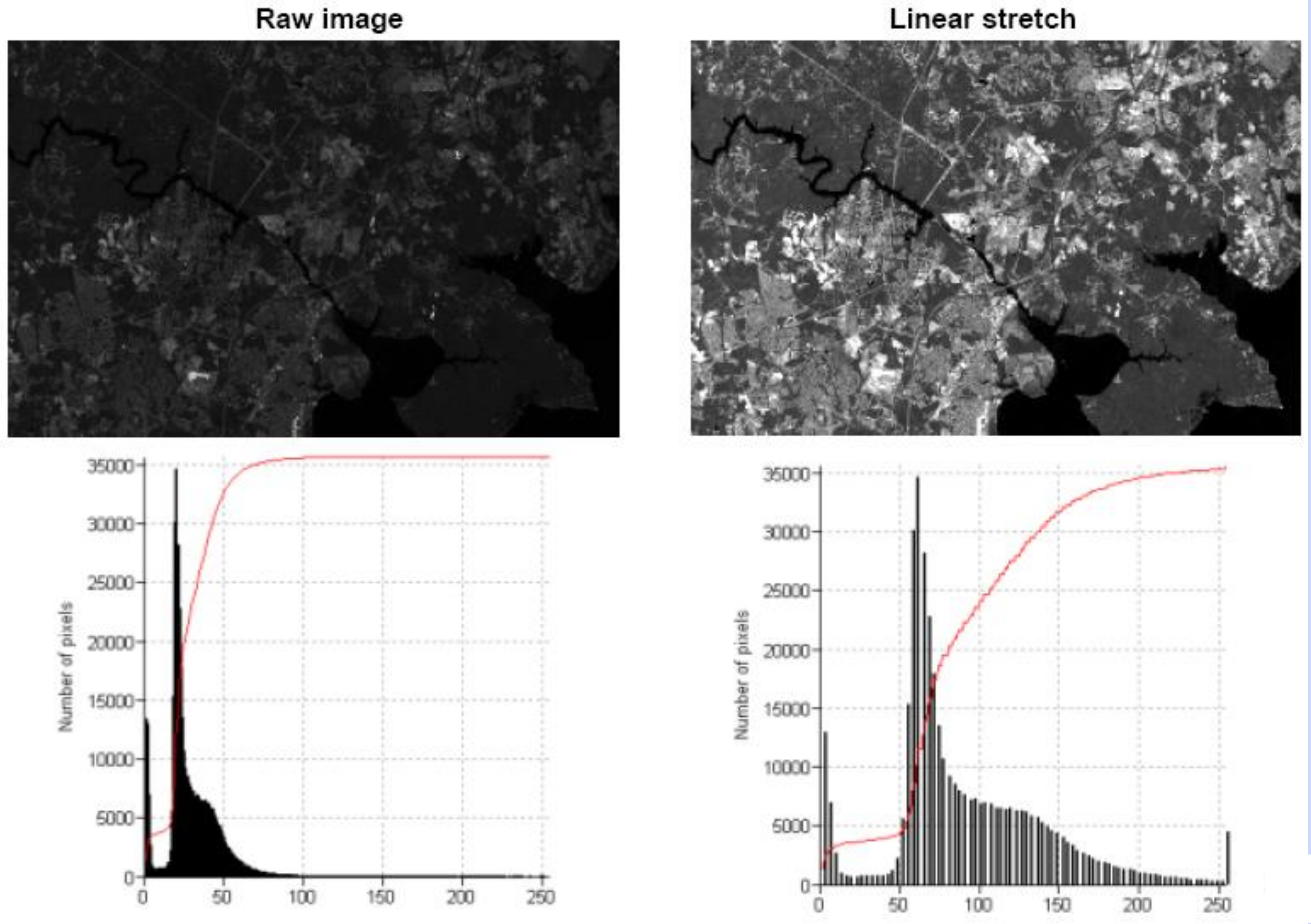
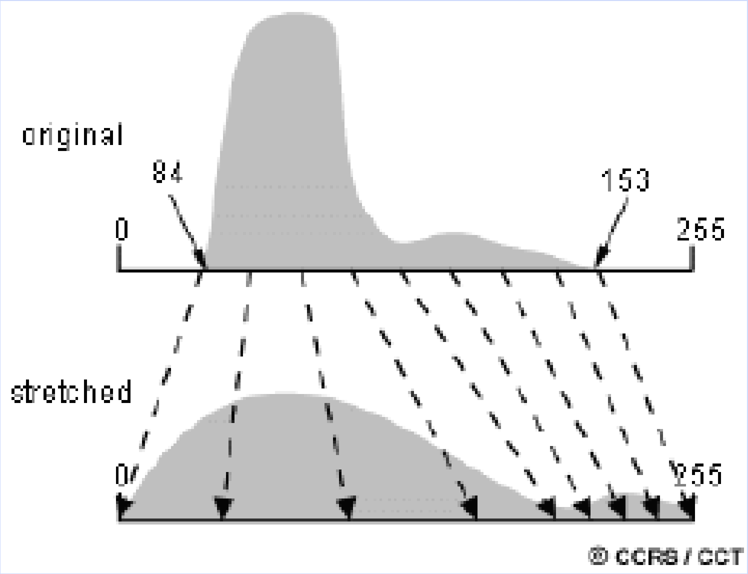


Image Enhancement : Histogram Equalization



- This stretch assigns more displ ay values (range) to the frequently occurring portions of the histogram.

- In this way, the detail in these areas will be better enhanced rel ative to those areas of the origin al histogram where values occur less frequently.

Image Enhancement : Histogram Equalization

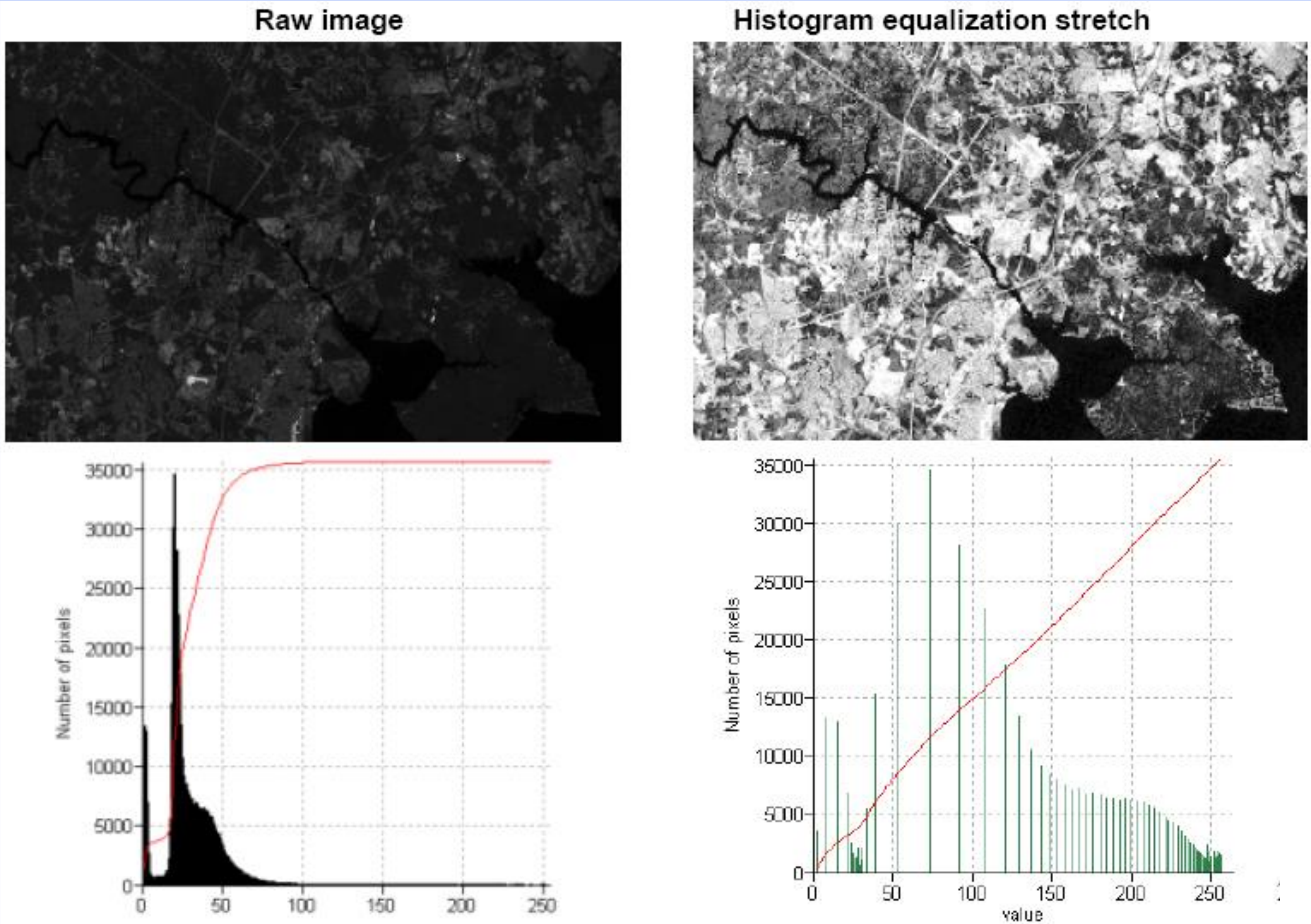
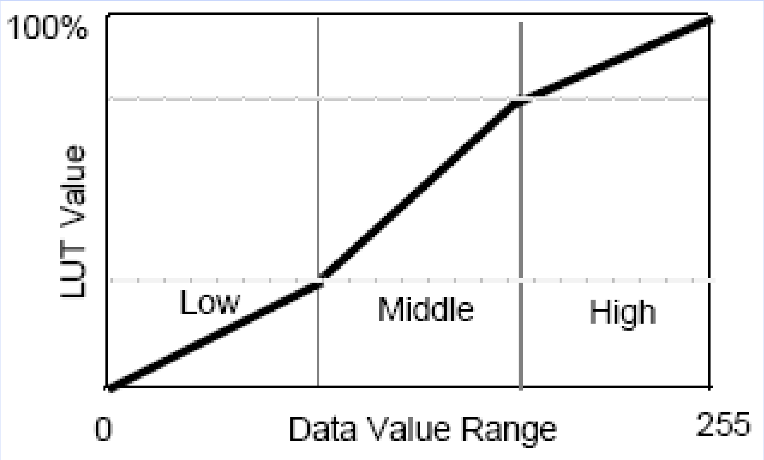


Image Enhancement : Piecewise stretching



- A piecewise linear contrast stretch allows for the enhancement of a specific portion of data by dividing the lookup table into three sections: low, middle, and high.

- It enables you to create a number of straight line segments that can simulate a curve.

- You can enhance the contrast or brightness of any section in a single color gun at a time.

Image Enhancement : Spatial Filtering

- **Spatial filters are designed to highlight or suppress specific features in an image based on their spatial f requency.**

- **Spatial frequency is related to image texture and it refers to the frequency of the variations in tone that appear in an image.**

- **In an image “rough" textured areas have high spati al frequencies and the tone changes abruptly over a small area, while "smooth" areas have low spatial fre quencies and these are areas with little variation in t one over several pixels.**

Image Enhancement : Spatial Filtering

- **A common filtering procedure involves moving a 'window' of a few pixels in dimension (e.g. 3x3, 5x5, etc.) over each pixel in the image, applying a mathe matical calculation using the pixel values under that window, and replacing the central pixel with the new value.**

- **The window is moved along in both the row and column dimensions one pixel at a time and the calc ulation is repeated until the entire image has been filtered and a "new" image has been gener ated.**

Image Enhancement : Low Pass Filter

- **A low-pass filter is designed to emphasize larger, homogeneous areas of similar tone and reduce the smaller detail in an image.**

- **Thus, low-pass filters generally serve to smooth the appearance of an image.**

- **A Low pass filter passes low - frequency signals but attenuate (reduces the amplitude of) signals with frequencies higher than the cutoff frequency.**

- **Types : Average & median filters**

Image Enhancement : Low Pass Filter

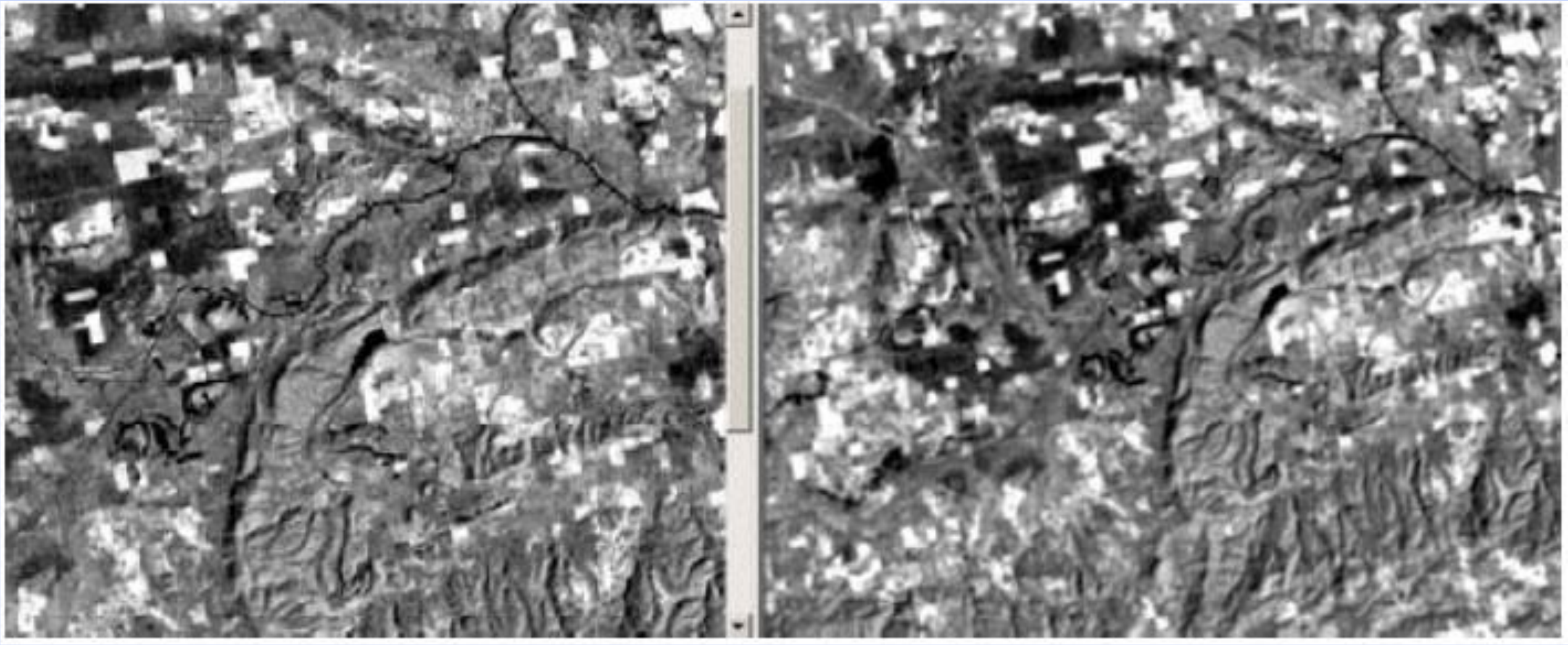


Image Enhancement : High Pass Filter

- **High-pass filters do the opposite of low pass filter**

- **It sharpens the appearance of fine detail in an image.**

- **A high pass filter passes high frequencies well but att enuates (i.e., reduces the amplitude of) frequencies lo wer than the filter's cutoff frequency.**

- **Type : Directional or edge detection**

Image Enhancement : High Pass Filter

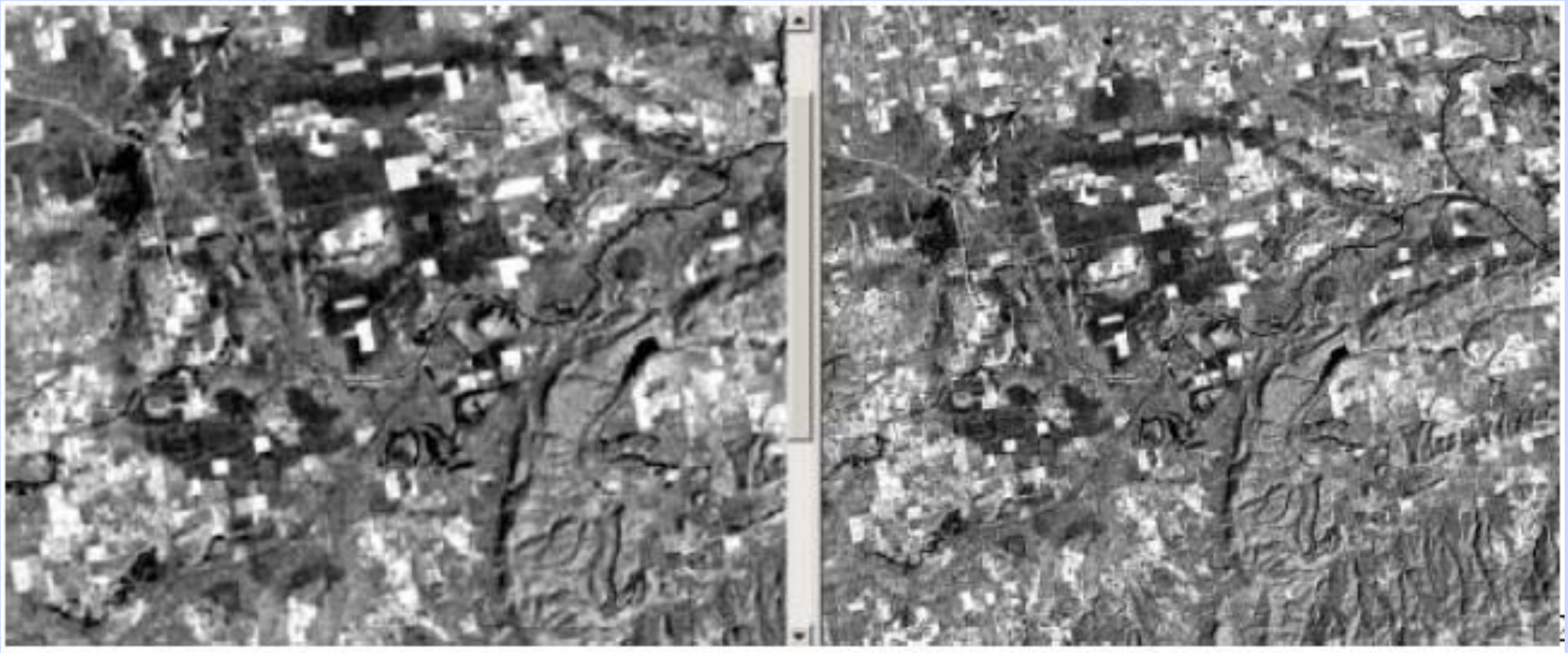


Image Classification

- **Image classification is used to digitally identify and classify pixels in the data.**

- **Classification is usually performed on multi-channel data sets and this process assigns each pixel in an im age to a particular class or theme based on statistical characteristics of the pixel brightness values.**

- **Classification can be done by supervised and unsup ervised techniques.**

Aerial Photography

Aerial Photography

- Air borne remote sensing
- Uses camera mounted in aircraft
- Aircraft with the camera mounted on it flies over the area to be captured and captures the photographs
- Photo capture, now-a-days, is automatic
- Aerial photographs may be digital or hard copy form
- Aerial photographs may be grayscale or coloured (natural colour or false colour composite)

Types of aerial photographs

Vertical

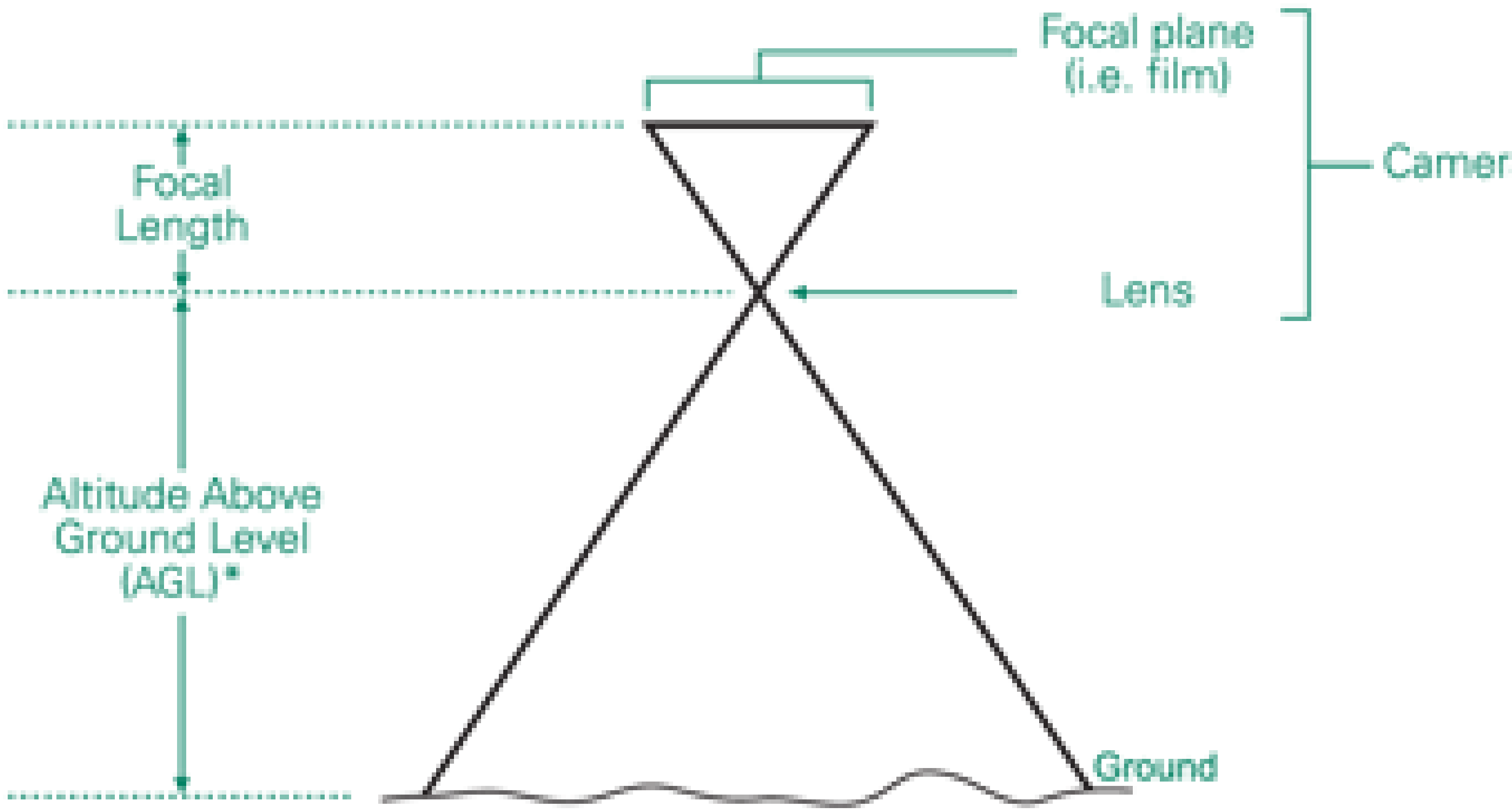
Oblique

Types of aerial photographs

High Oblique

Low Oblique

Basics of aerial photography

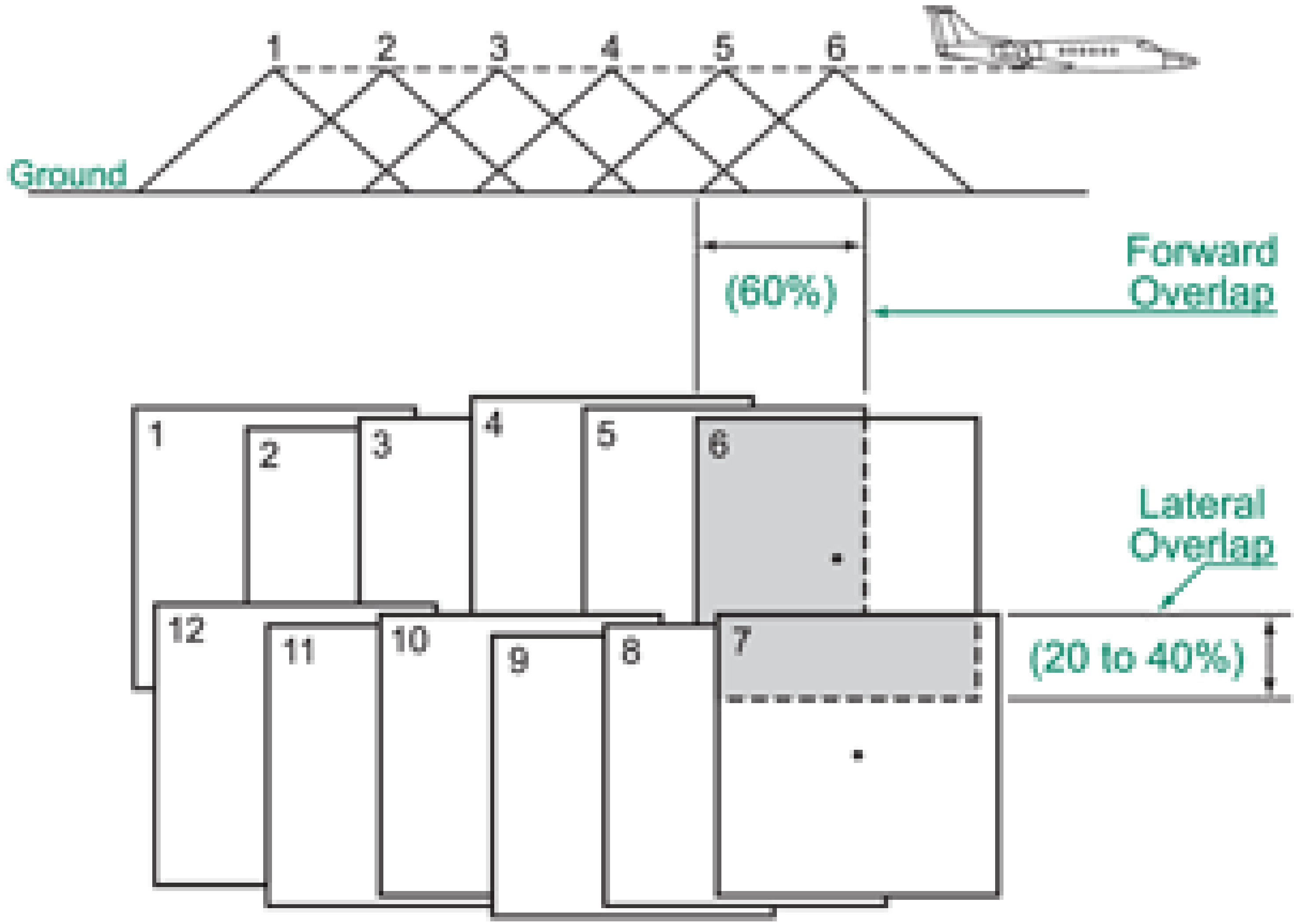


* Altitude Above Ground Level (AGL) is calculated by subtracting the ground elevation from the plane's altitude Above Sea Level (ASL).

$$\frac{\text{FOCAL LENGTH}}{\text{ALTITUDE (AGL)}} = \frac{152 \text{ mm}}{7\,600 \text{ m}} = \frac{152 \text{ mm}}{7\,600\,000 \text{ mm}} = \frac{1}{50\,000}$$

SCALE: 1/50 000

Basics of aerial photography



Photographic Overlap