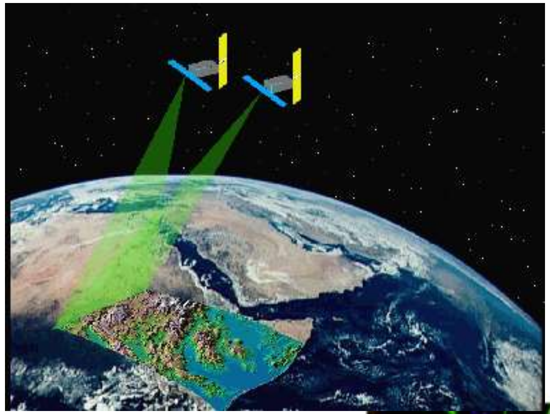
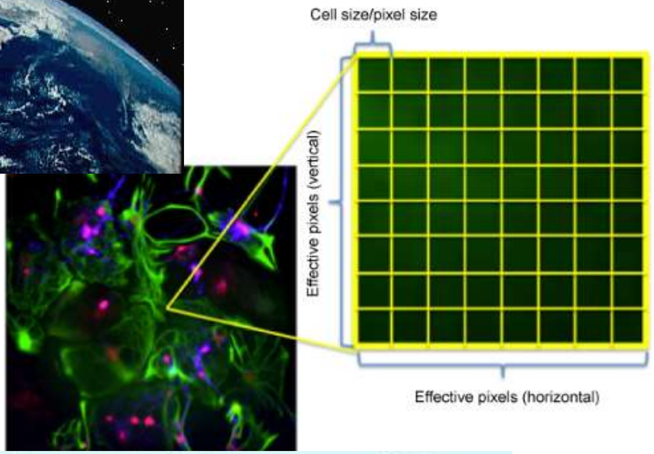
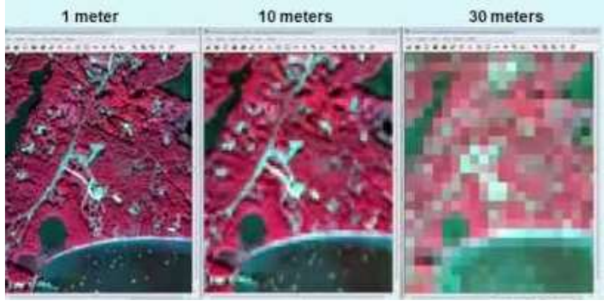
Introduction to Digital Image & Processing Techniques

Geological Survey of India
Training Institute
Mission-V

Introduction to Digital Image & Processing Techniques







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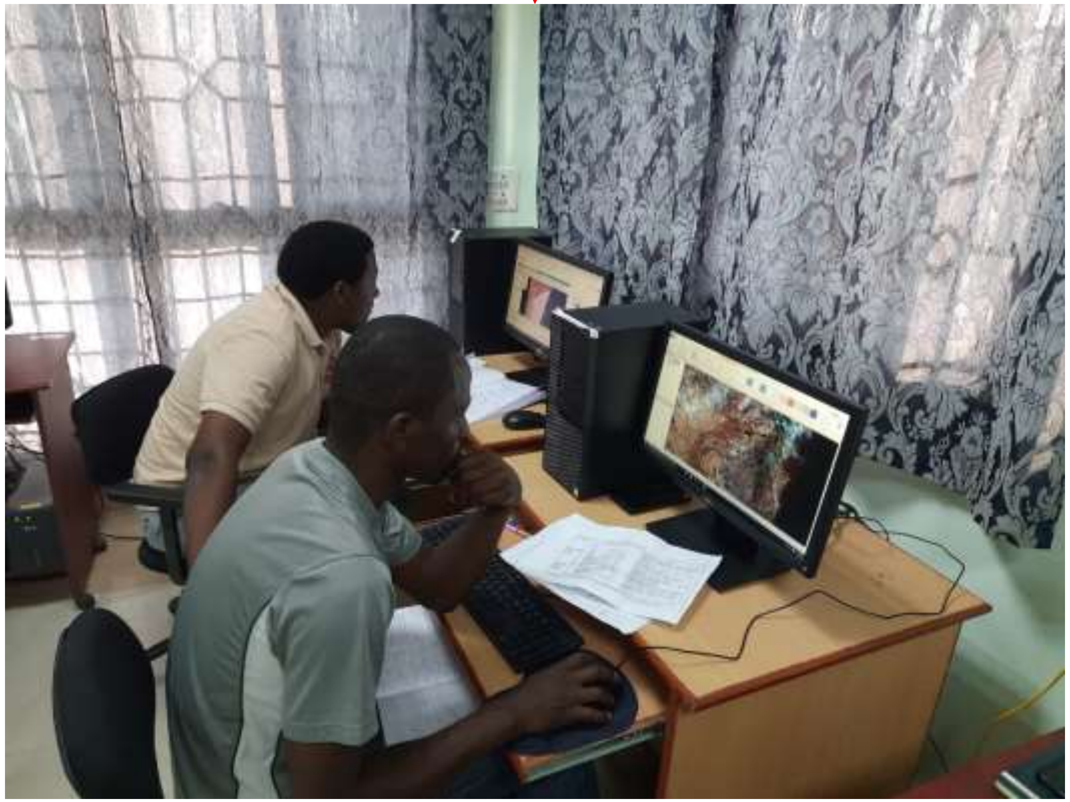
- **Digital Number (DN)**
- **Digital Image (Pixel)**
- **Data Format**
- **Processing Techniques**

Remote Sensing Data products

Pictorial Data

Digital Data



PICTORIAL DATA

❖It gives information in the form of image and aerial photographs.

❖These are generally taken by **sophisticated cameras which use visible parts of electromagnetic energy.**

❖Therefore, aerial photographs give exact view of objects on reduce scale. The images are may be black/ white/ coloured (depends on camera).

DIGITAL DATA

❖**The image provided by satellite called satellite image.** These images are taken by sensors which uses: RGB- visible portion of EMR, Infrared- invisible

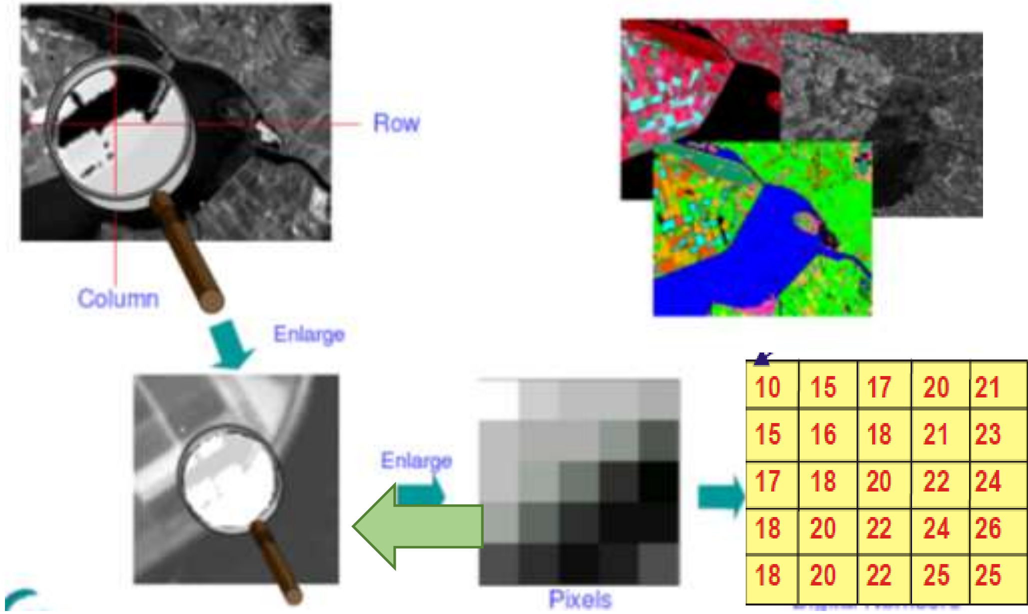
❖Satellite image may be black/ white/ coloured.

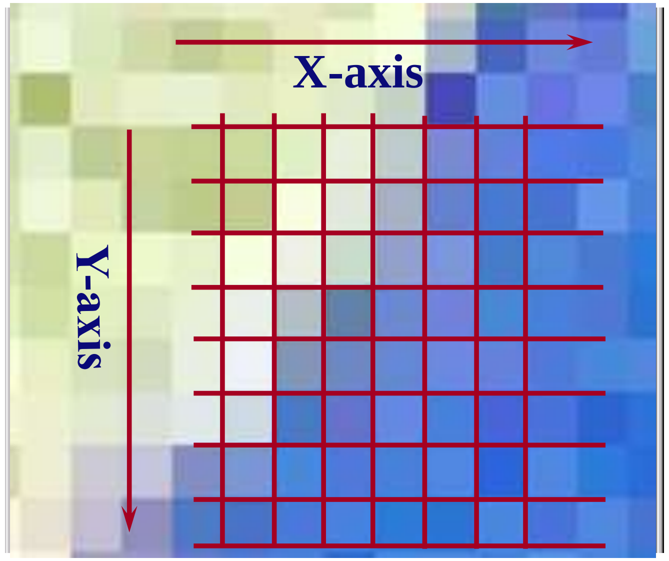
What is Digital image?

- A digital image is an array (matrix) of numbers depicting spatial distribution of certain field parameter (parameters such as electromagnetic radiation, emission, temperature, or some geophysical or topographical elevation etc).

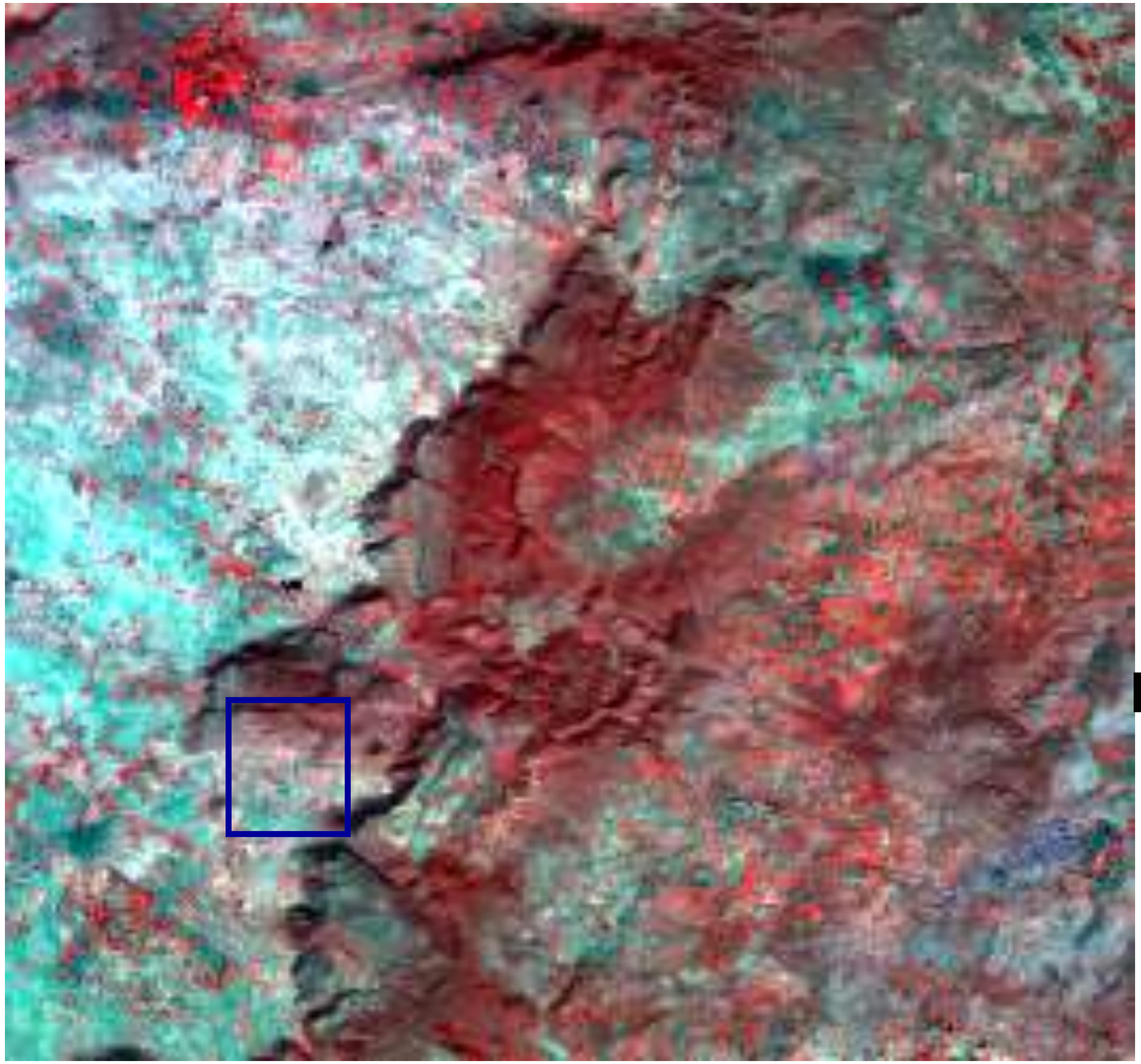
- A digital image consist of discrete picture elements called pixel.

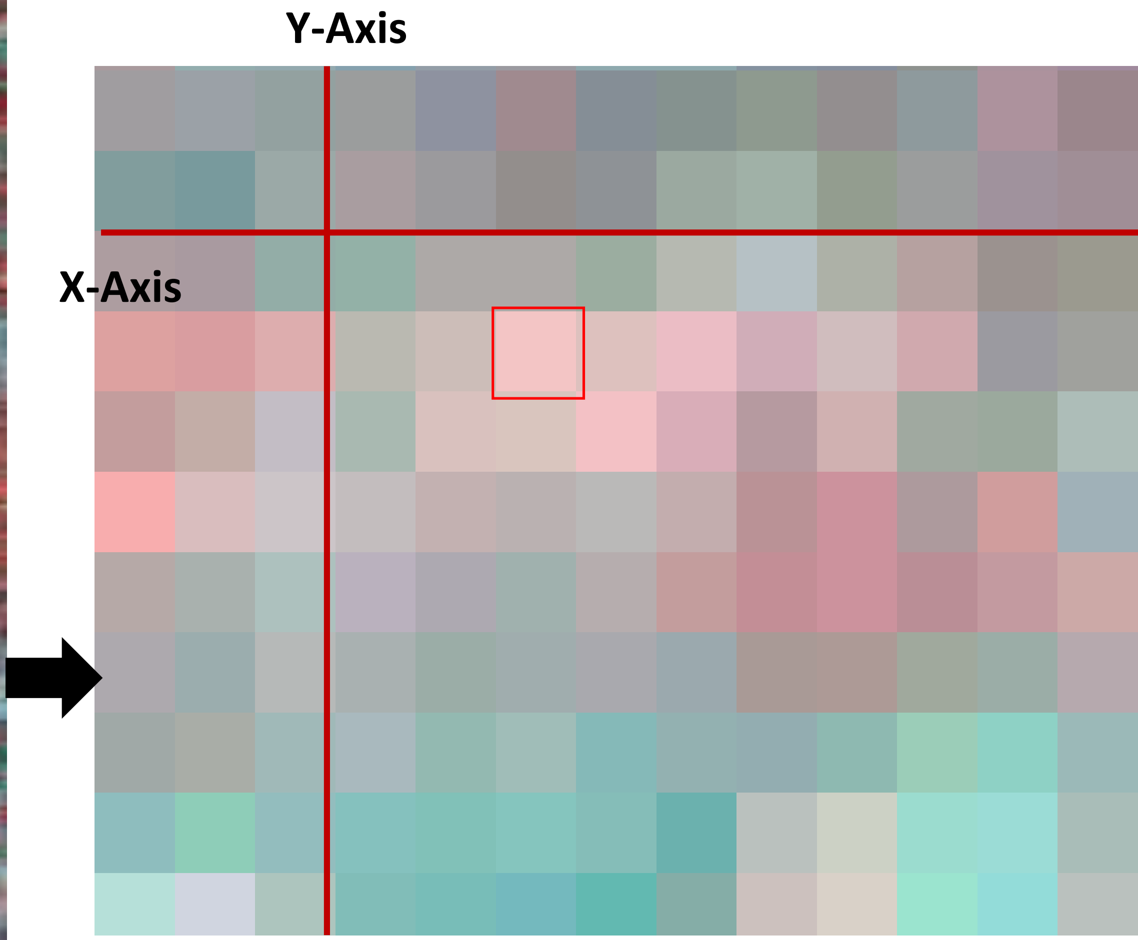
- **Each pixel is associated with a number known as Digital Number (DN) or Brightness Value (BV), that depicts the average radiance of a relatively small area within a scene.**





IMAGE



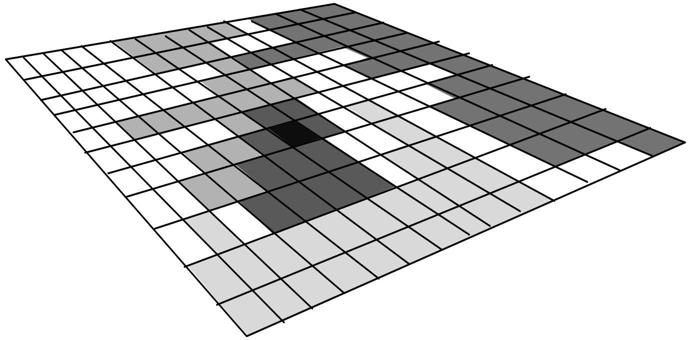


Digital image

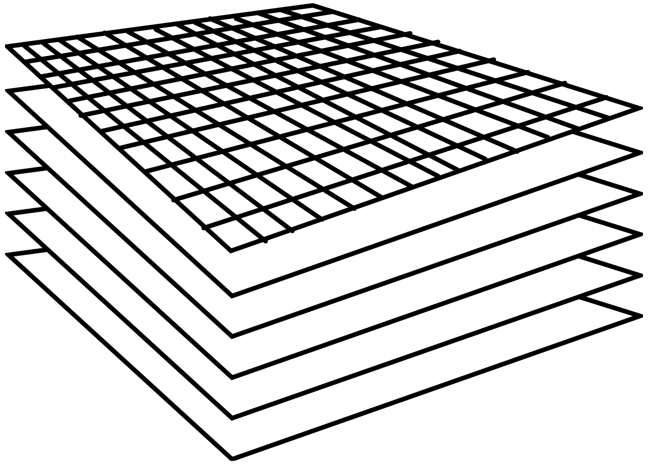
- Panchromatic (PAN) Images are 2D array of pixels.
- Multispectral and hyperspectral image data sets are recognized as 3-D pixel arrays.
- In a digital image the **x-axis is = column**

  y-axis is = row

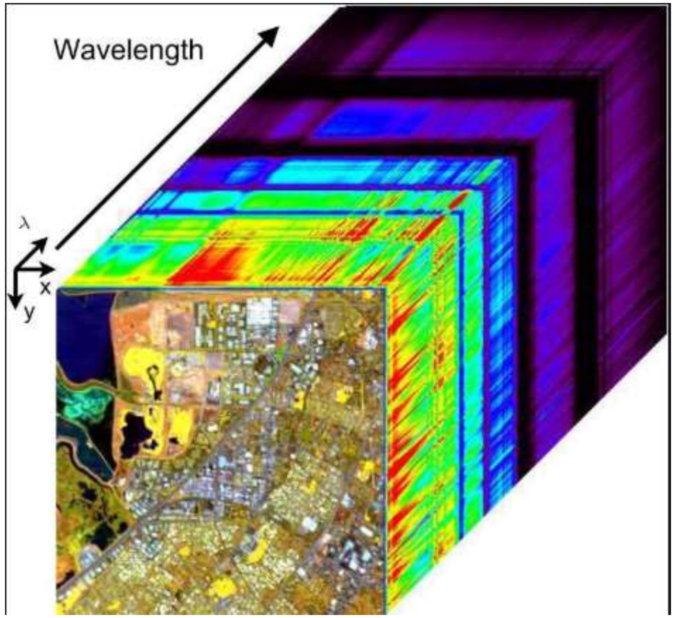
  z-axis is = band number or wavelength



Panchromatic (2-D)



Multispectral (3-D)



Hyperspectral (3-D cube)

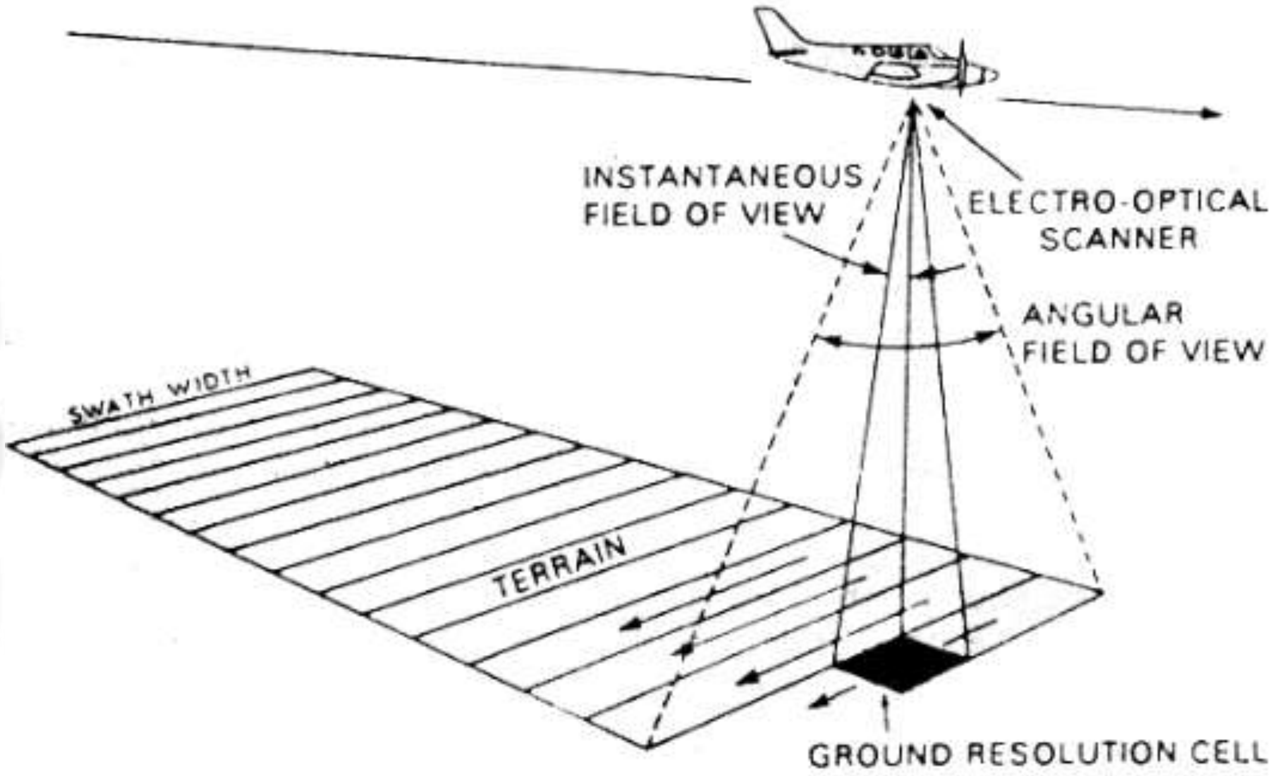
Pixel / Cell:

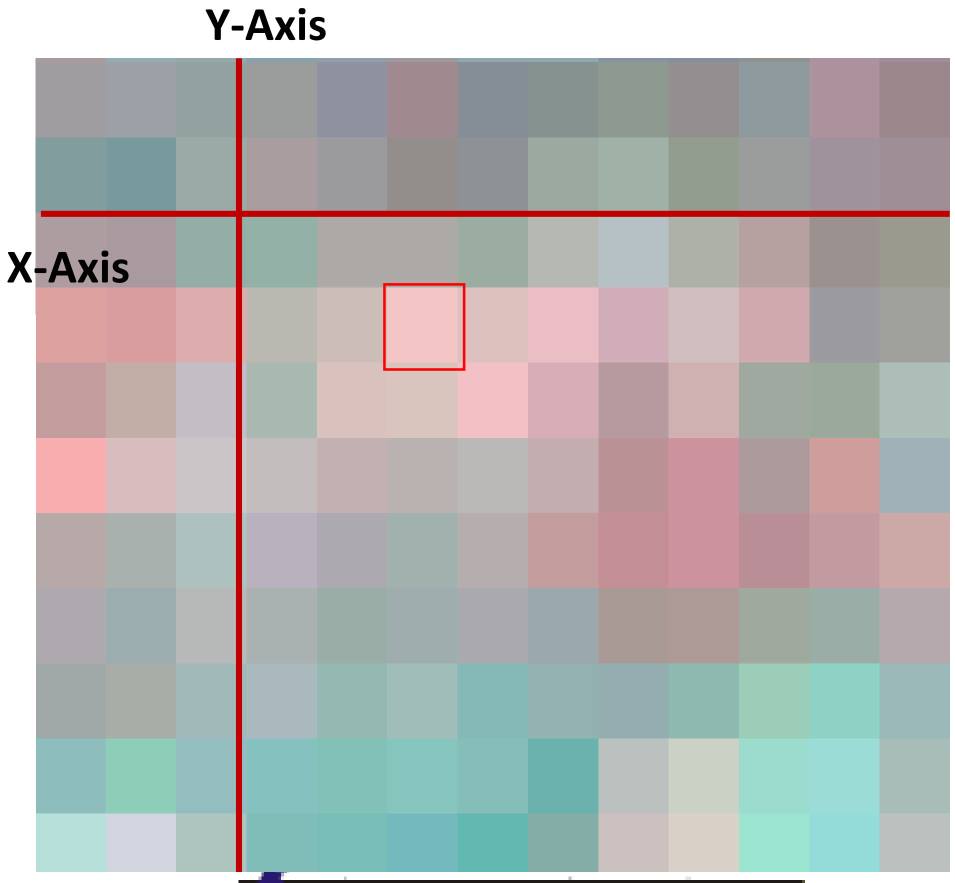
- An image is consisting of tiny, equal areas, or picture elements, arranged in regular rows and columns is called Pixel / Picture Element, and representing area covered on the earth surface in one pixel.

- The position of any pixel, is determined on x-y coordinate system.
- Each pixel also has a **numerical value, called a digital number (DN),** that records the intensity of electromagnetic energy measured for the ground resolution cell represented by that pixel.

- **DN is the average radiance /reflectance of a smaller area which is called ground resolution element or GRE.**

- Represents individual areas scanned by the sensor. **Smaller the pixel, the easier it is to see detail.**





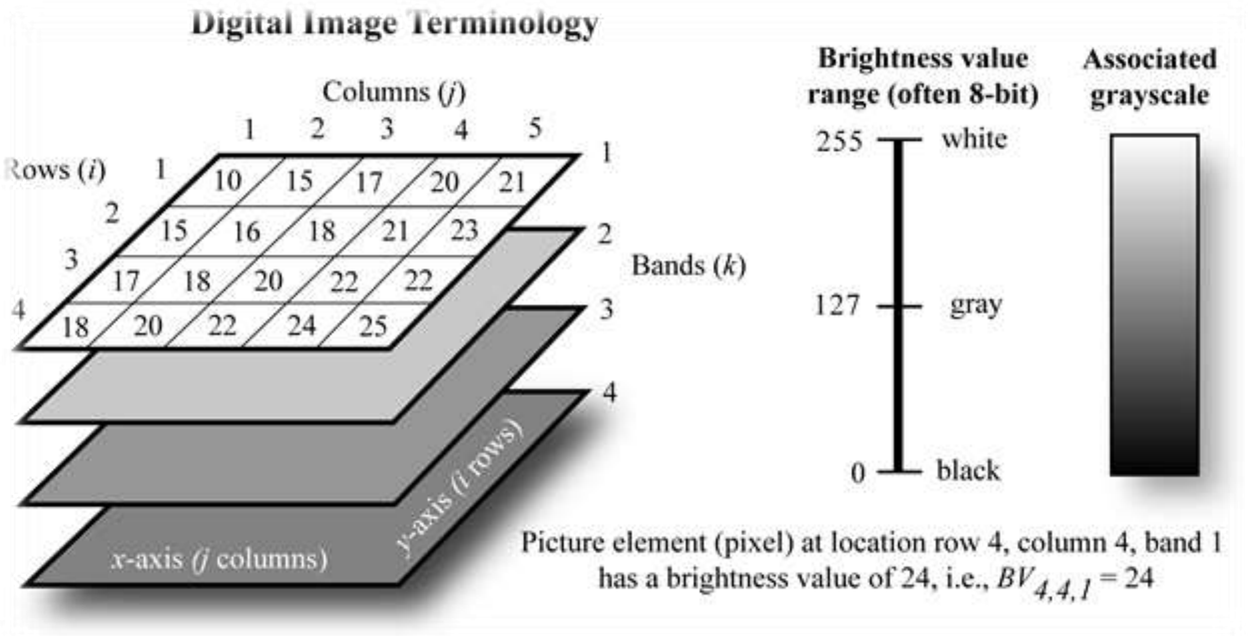
10	15	17	20	21
15	16	18	21	23
17	18	20	22	24
18	20	22	24	26
18	20	22	25	25

DIGITAL NUMBER

- Digital Number (DN), are stored as binary digits in a computer.

- The Value represented in a grey scale is in certain ranges such as 0-255 (8 bit image: 2^8 = 256).

- 0 and 255 represent black and white respectively.



2^1 = 2 levels (0,1)

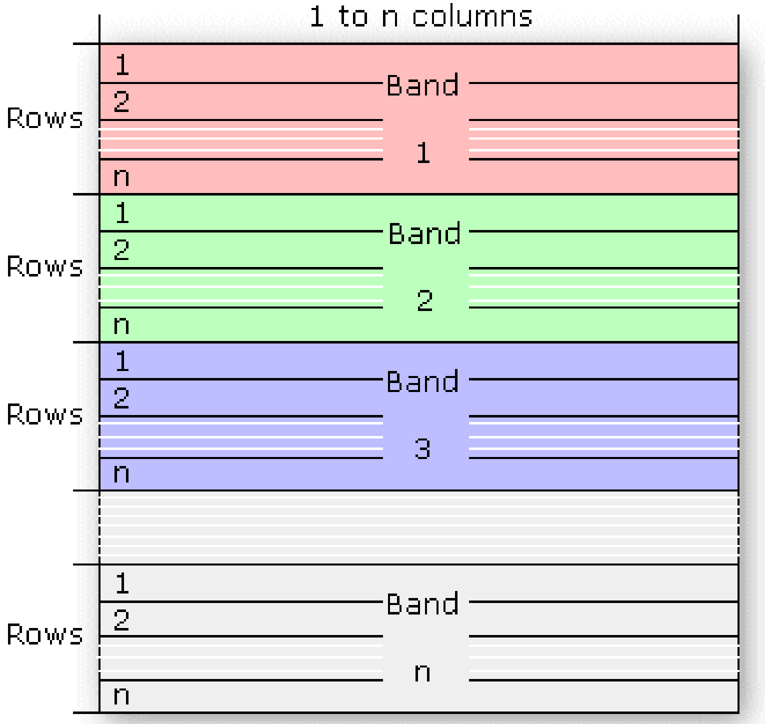
2^2 = 4 levels (0,1,2,3)

2^8 = 256 levels (0-255)

2^{12} = 4096 levels (0-4095)

IMAGE FILE FORMATS

- **Image file formats** are standardized means of organizing and storing digital images.



- **BSQ (Band Sequential Format)**
- **BIP (Band Interleaved by Pixel Format)**
- **BIL (Band Interleaved by Line Format)**

Band Sequential (BSQ) Format

- BSQ format stores information for the **image one band at a time**.
- In other words, **data for all the pixels for band 1 is stored first,** then data for all pixels for band 2, and so on.

Band 1=all pixel

↓

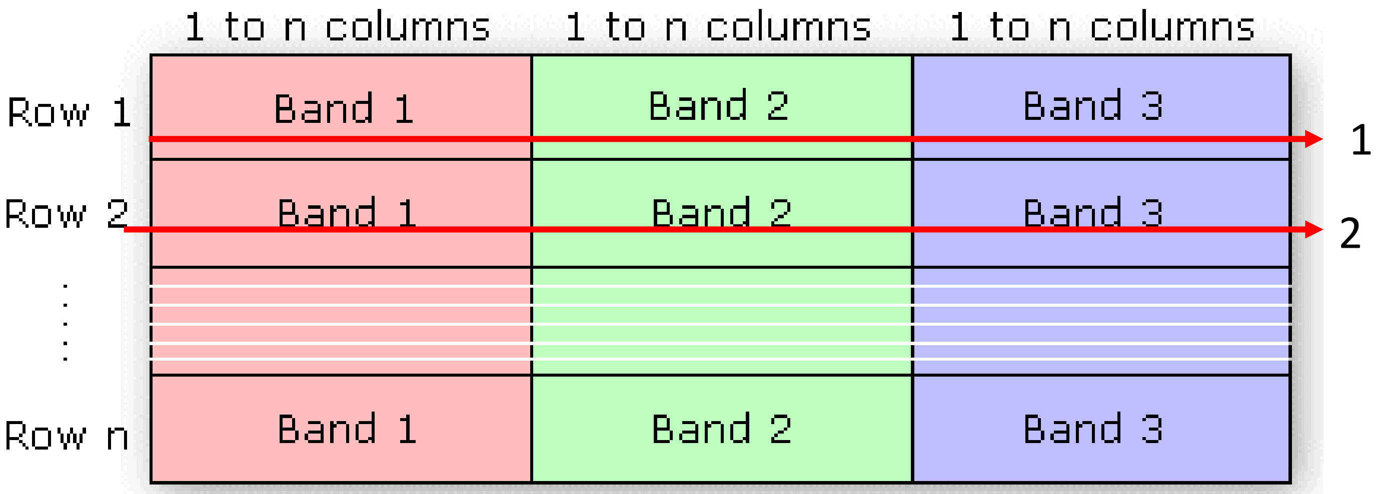
Band 2= all pixel

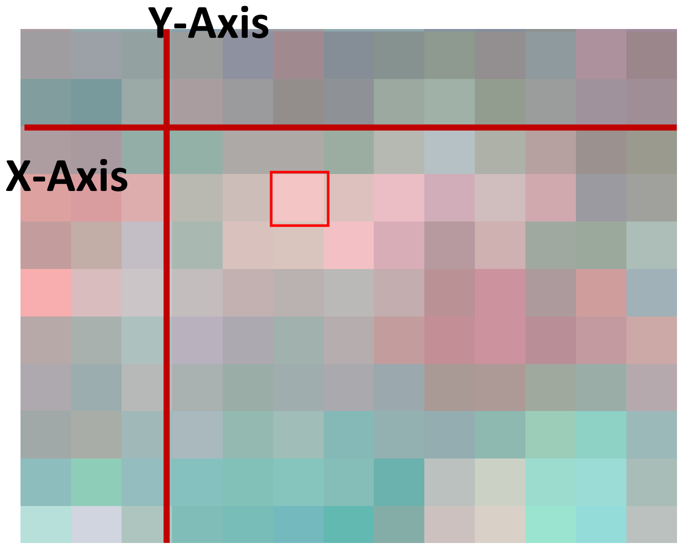
Band Interleaved by Line (BIL) Format

- BIL data stores pixel information **band by band** for each line, or row, of the image.

- For example, given a three-band image, all three bands of data are written for row 1, all three bands of data are written for row 2, and so on, until the total number of rows in the image is reached.

- **Good for images with 20-60 bands.**





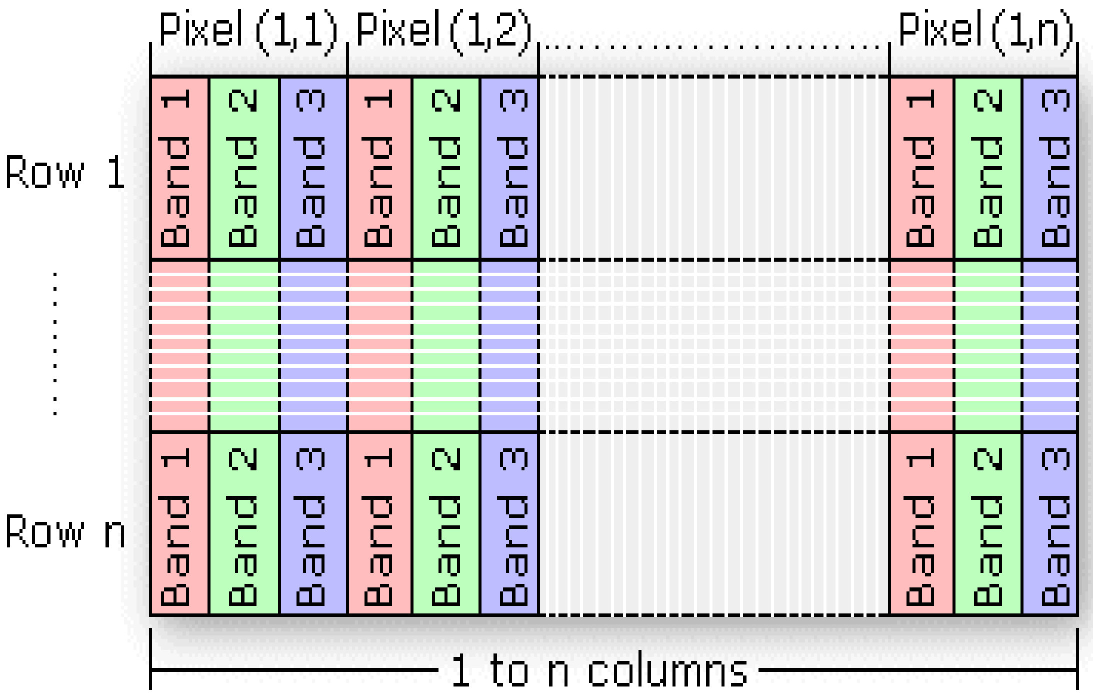
Band 1=row 1
Band 2=row1
Band 3= row 1

Band Interleaved by Pixel (BIP) Format

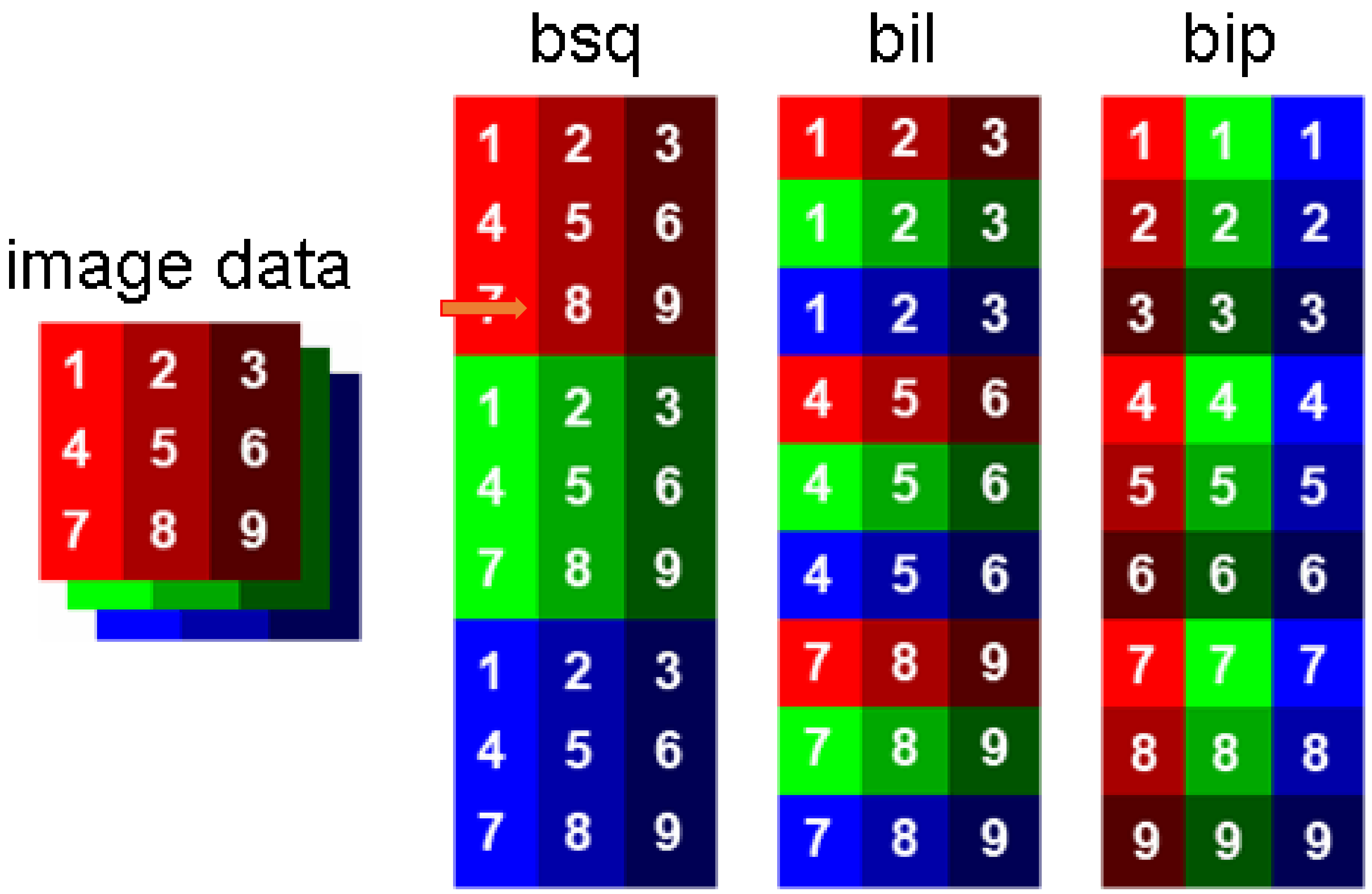
- **BIP data is similar to BIL data, except that the data for each pixel is written band by band.**

- For example, with the same three-band image, the data for bands 1, 2, and 3 are written for the first pixel in column 1;
- the data for bands 1, 2, and 3 are written for the first pixel in column 2; and so on.

- **Good for hyperspectral image**



Band 1=First pixel
Band 2= First pixel
Band 3= First pixel



Band 1=all pixel

Band 2= all pixel

Band 1=row 1
Band 2=row1
Band 3= row 1

Band 1=First pixel
Band 2= First pixel
Band 3= First pixel

Major Graphic File Formats

- There are hundreds of image file types. The PNG, JPEG, and GIF formats are most often used to display images.
- In addition to straight image formats, Metafile formats are portable formats which can include both raster and vector information.

Raster formats:

JPEG/JFIF: Joint Photographic Experts Group/JPEG File Interchange Format.

JPEG 2000: improve quality and compression ratios.

TIFF: Tagged Image File format is a flexible format.

GIF: Graphics Interchange Format,. GIF is most suitable for storing graphics with few colors.

GeoTIFF:

- GeoTIFF, the TIFF file that has geographic (or cartographic) data embedded as tags within the TIFF file.
- The geographic data of a GeoTIFF file can be used to position the image in the correct location and geometry on the screen of a geographic information display.

HDF:

- Hierarchical Data Format is a format designed by the National Center for Supercomputing Applications (NCSA) to store scientific data.
- HDF files are used for the transfer of graphical and numerical data between machines. HDF files store data usually relating to scientific data.

Digital Image Processing

❖ Remote Sensing can be performed either photographically or digitally.

❖ Digital remote sensing have several advantages over photographic remote sensing.

Photographic remote sensing	Digital remote sensing
❖ Can be performed in within optical region, especially photographic region of electromagnetic spectrum	❖ Can be performed in optical, thermal and in microwave regions
❖ **Cannot be collected in high resolution.** Digital processing is also not possible on photographs(or scanned photograph).	❖ Digitally captured images can overcome such problems associated with the photographs .

❖ With the advent of **very high resolution digital sensors , improves the spatial information of the digital images data.**

❖ Digital remote sensing sensors can be mounted on satellite as well as aerial platforms although satellite platforms are preferred.

Why Digital Image Processing

- Limitations of human eye in Discriminating shades of grey
- Subjectivity in interpretation
- Handling large volumes of data
- Digital data is amenable to generation of thematic Information

IMAGE PROCESSING

Image Pre-Processing

- Radiometric correction
- Geometric correction

Image Enhancement

- Radiometric Enhancement
- Spatial Enhancement
- Spectral Enhancement

Image Classification

- Unsupervised classification
- Supervised classification

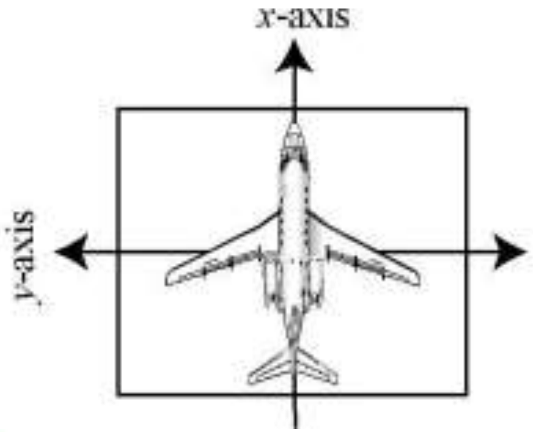
Geometric Distortions

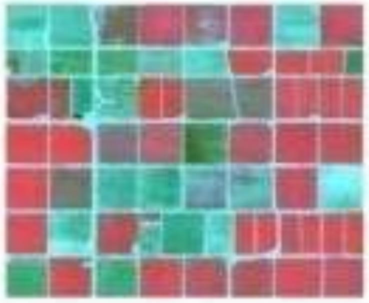
- During the scanning process, a number of systematic and nonsystematic geometric distortions are introduced

Systematic errors	Non systematic errors
Errors of which the parameters are known (rotation of the earth)	Errors of which the parameters are unknown (the calibration of the sensors)

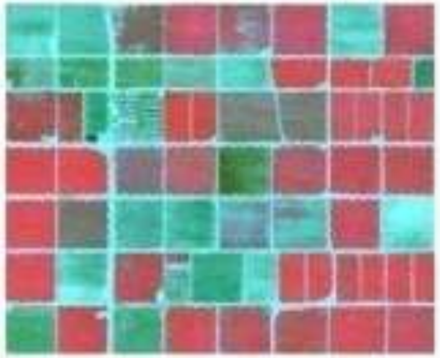
Nonsystematic Distortions: are not constant because they result from variations in the spacecraft attitude, velocity, and altitude and therefore are not predictable.

Change in altitude





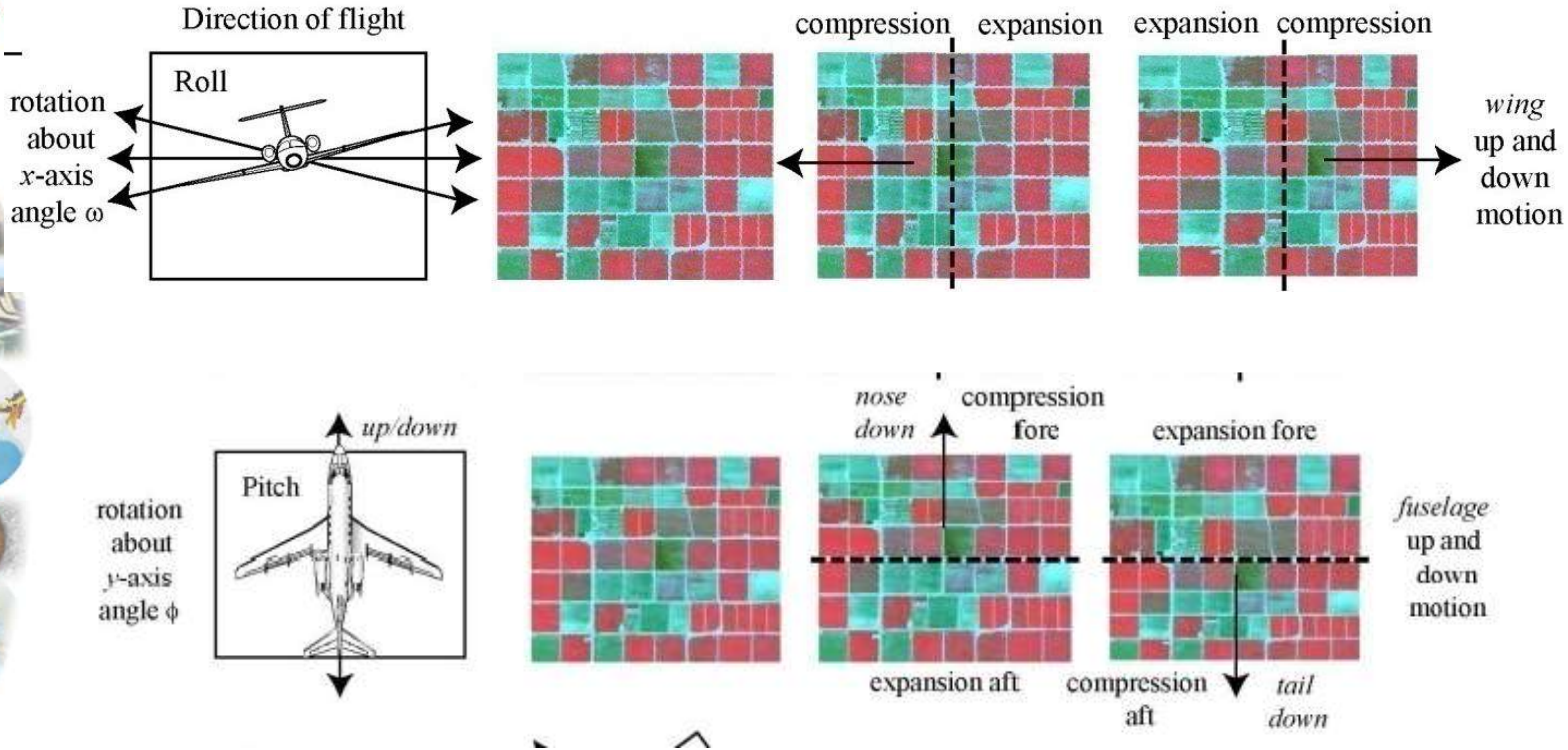
Nominal

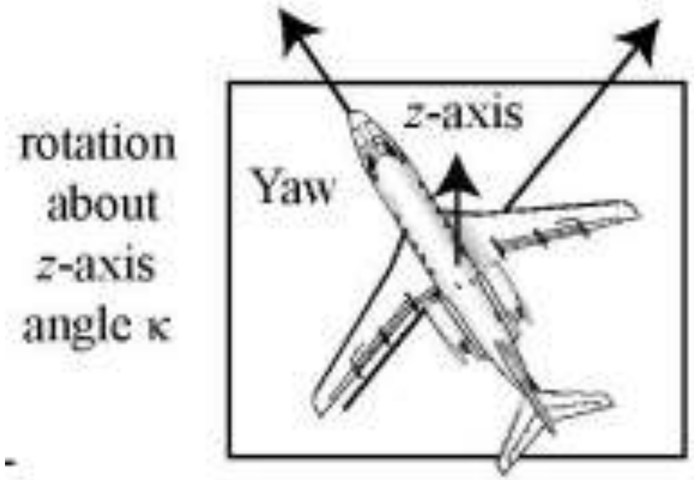


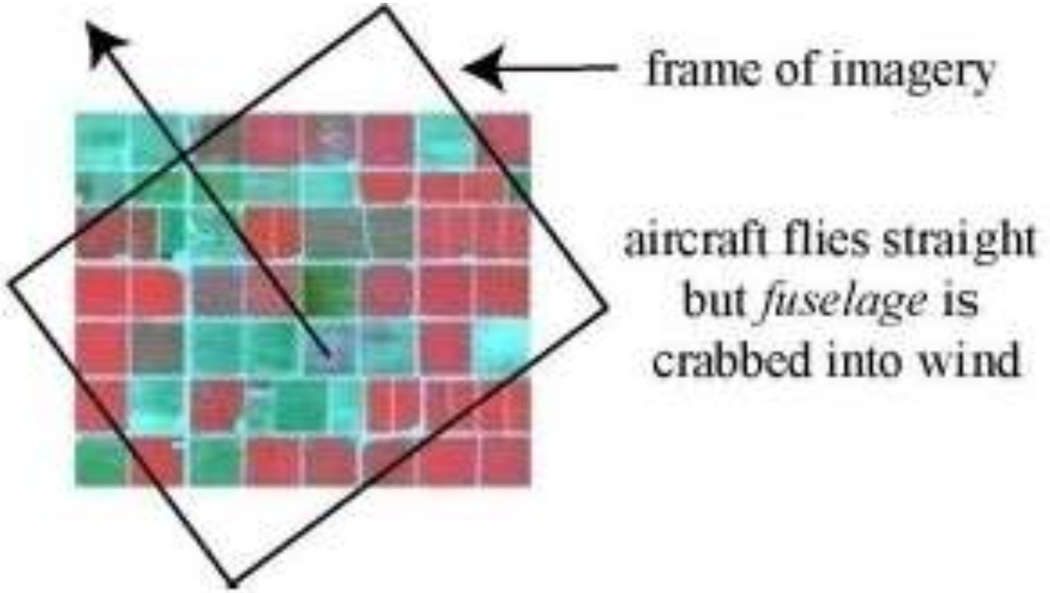
Decrease in altitude
Creates large scale image

Increase in altitude
Creates small scale image

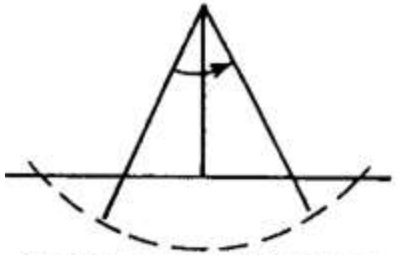
Change in Altitude

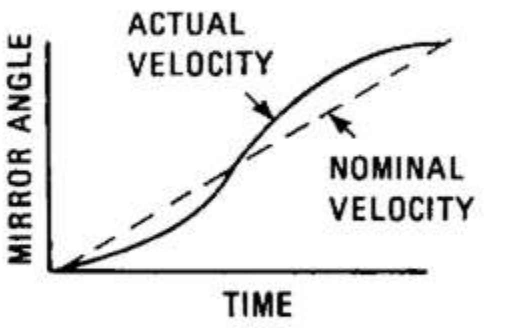


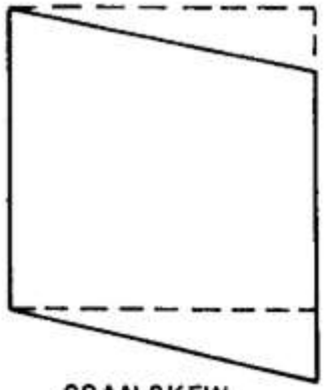


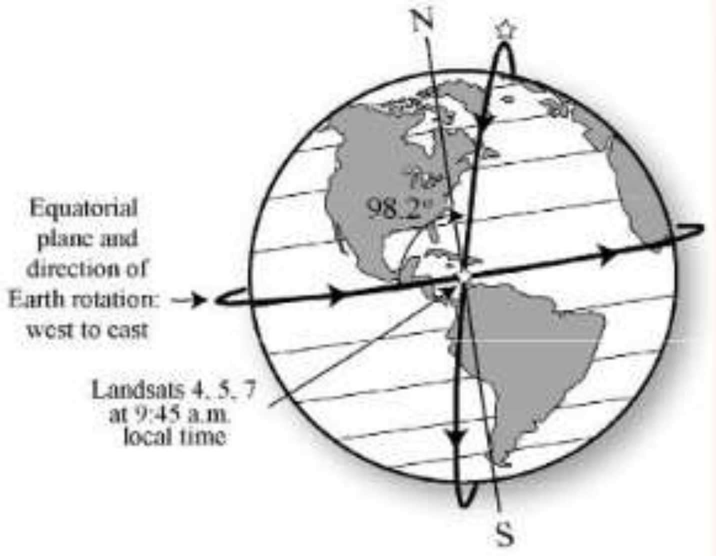


Systematic Distortions Geometric distortions whose effects are constant and can be predicted in advance are called systematic distortions. Scan skew, cross-track distortion, and variations in scanner mirror velocity belong to this category







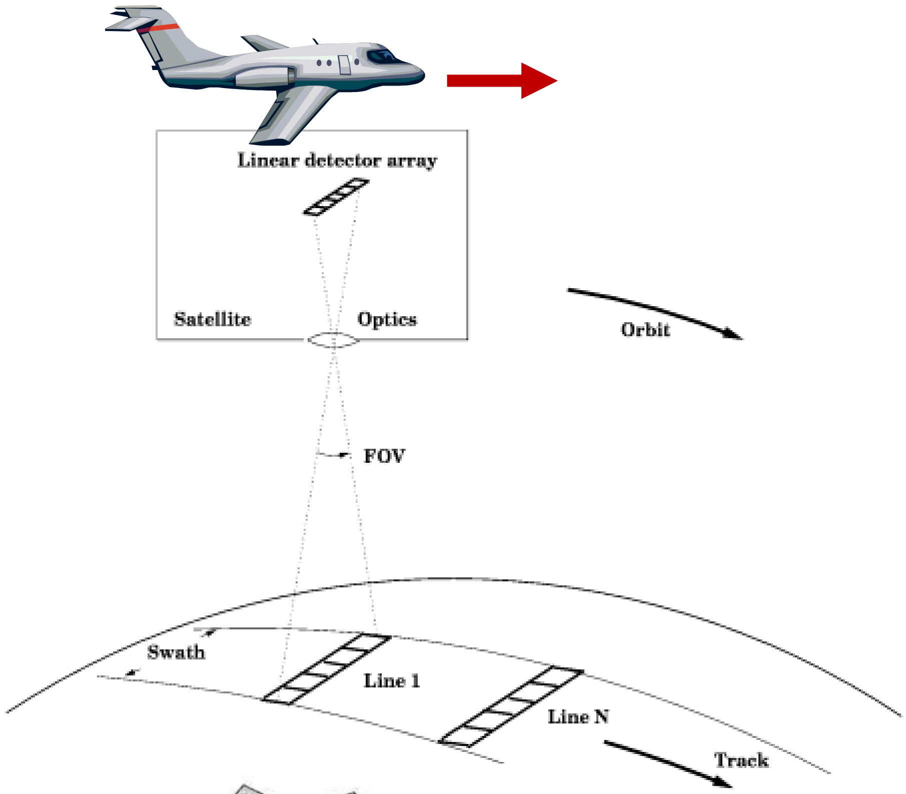


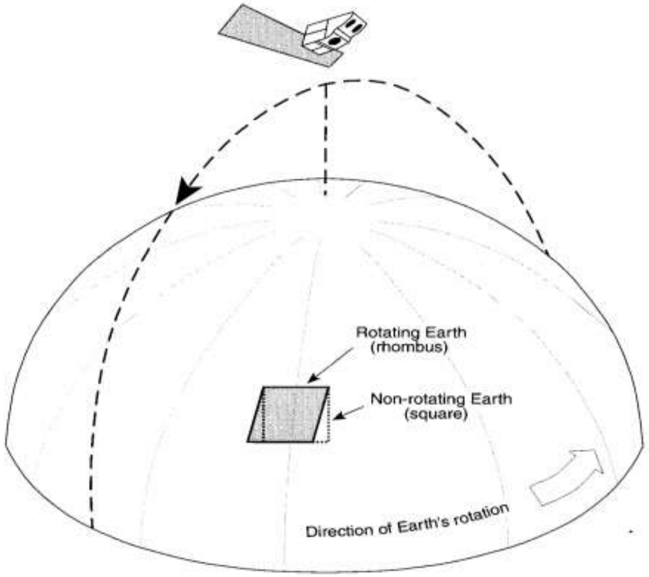
- **Scan Skew Distortion:** Caused when the ground swath is not normal and is skewed due to the forward motion of the platform during the time of scan.

- **Earth Rotation Effect:** Caused due the rotation of earth during the scan period resulting in along scan distortion. This results in a **shift of the ground swath** being scanned, causing along-scan distortion.

- **Platform Velocity:** Caused due to a change in speed of the platform resulting in along track scale distortion.

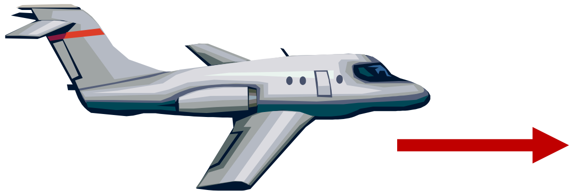
- If the velocity of the platform changes, the ground track covered successive mirror scans changes, producing **along-track scale distortion.**

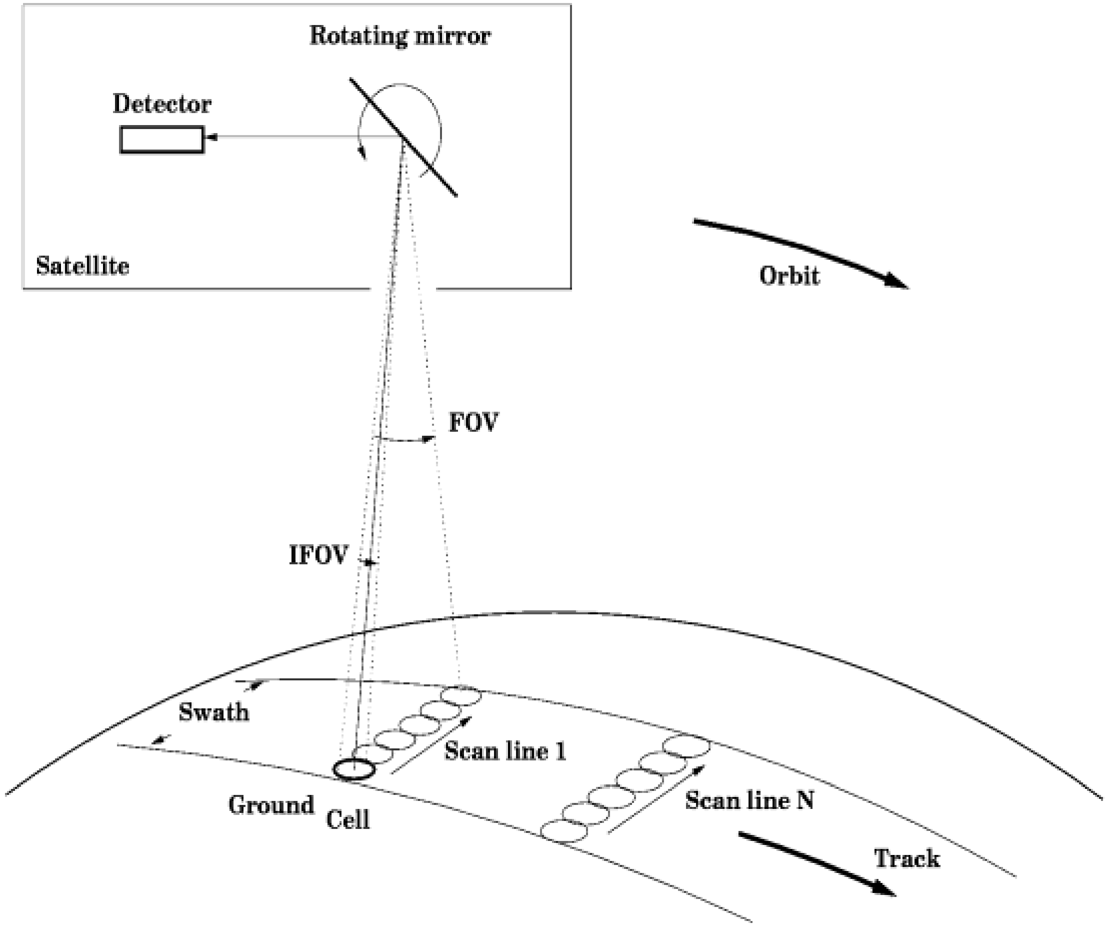




- **Mirror Scan Velocity:** Caused when the rate of scanning is not constant resulting in along scan geometric distortion.

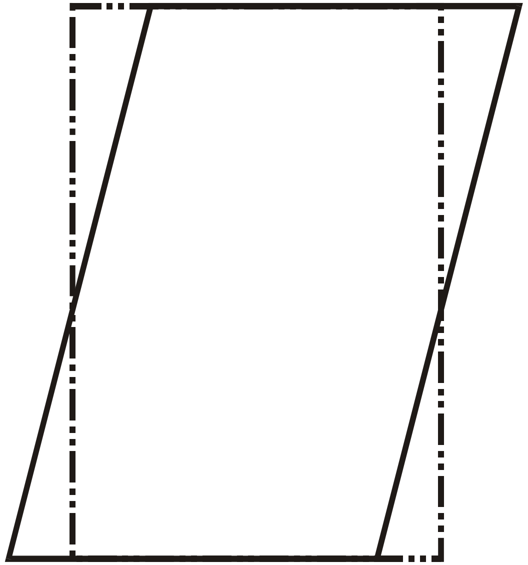
- **Aspect ratio:** Caused when the instantaneous field of view of sensor and spacing between each scan line are not equal resulting in pixels that are not square.



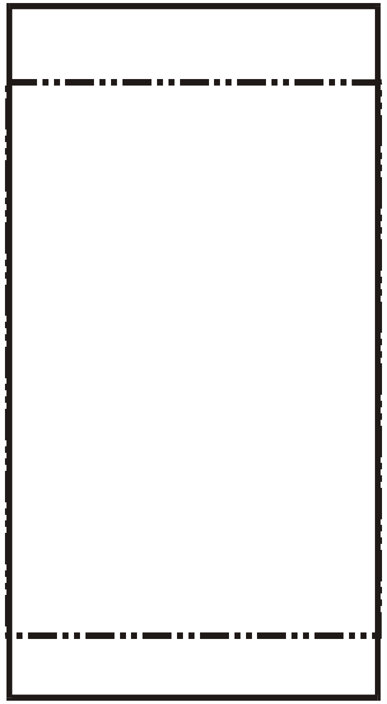


Displacements on Satellite Imagery

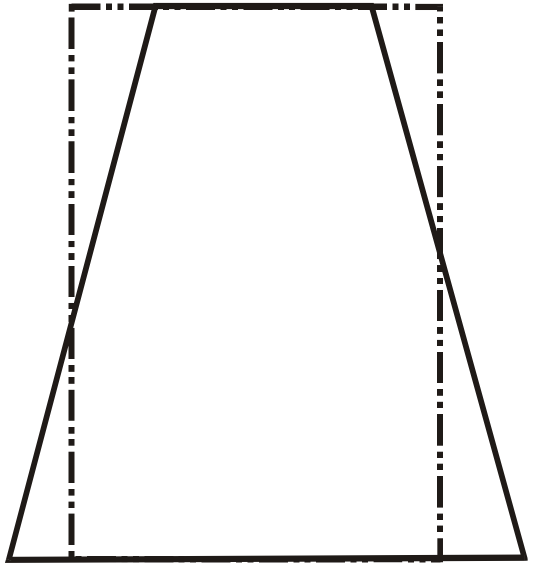
- Displacements due to the relationship between the sensor and the earth's surface



Earth rotation



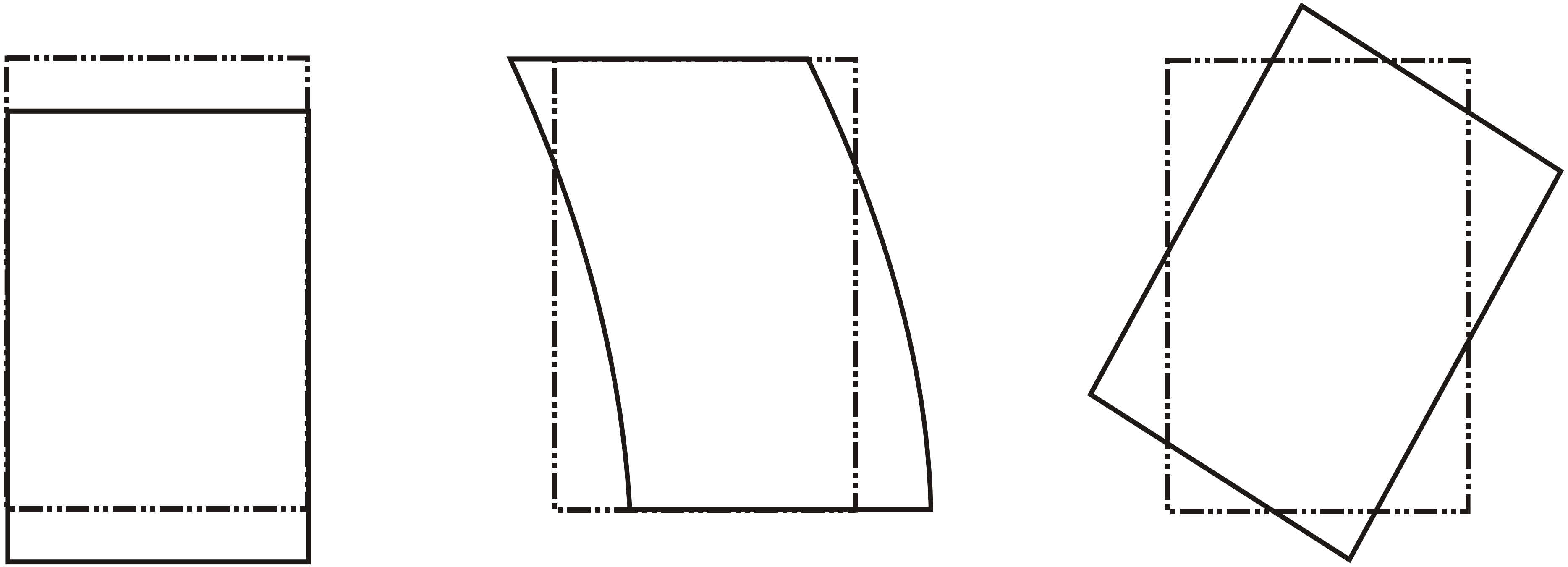
Platform velocity



Altitude variation

Displacements on Satellite Imagery

- Displacements due to sensor orientation



Forward/aft tilt | Sidewards tilt | Rotation

Radiometric Errors

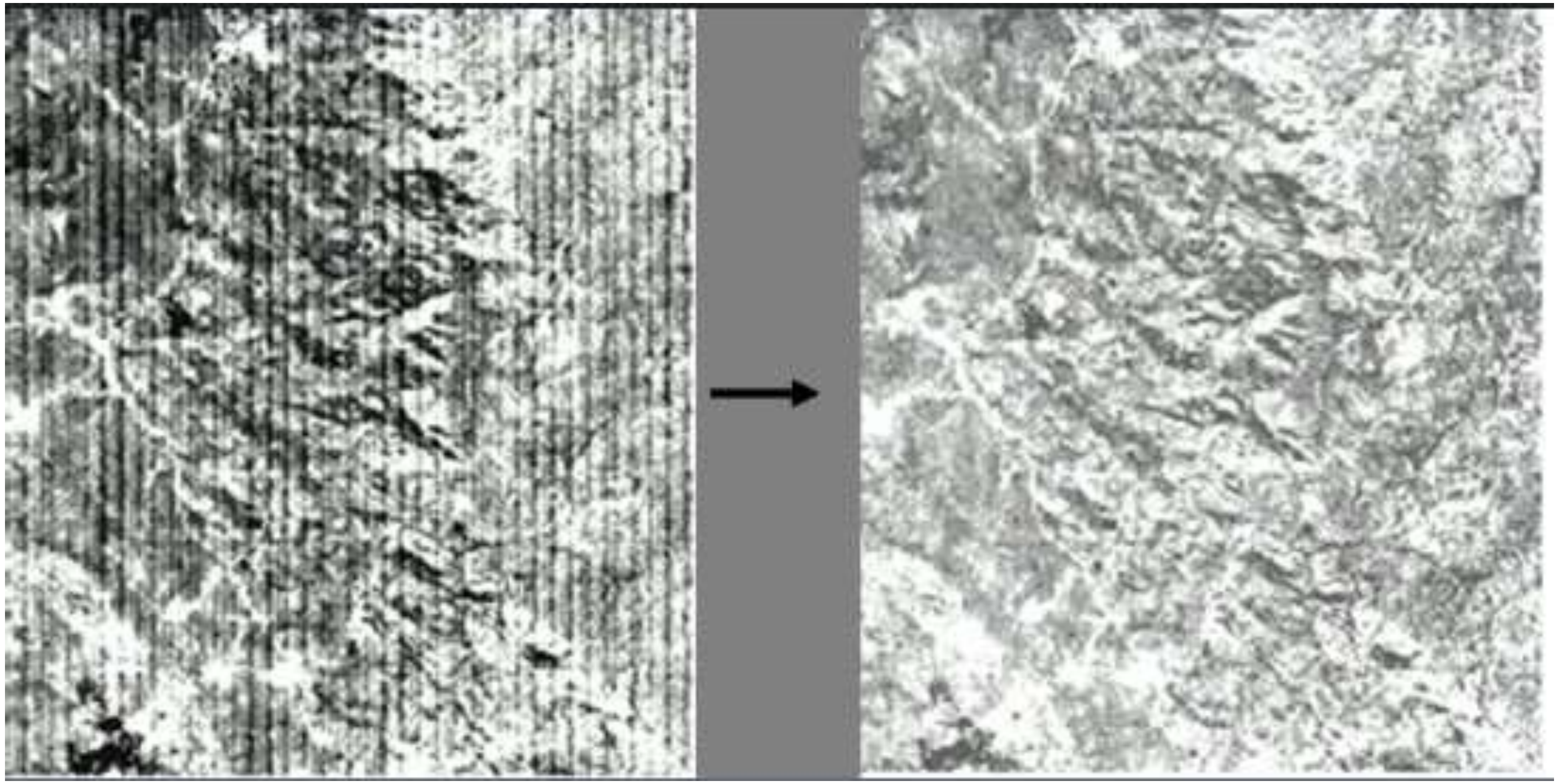
- **Internal cause**: When individual detectors do not function properly or are improperly calibrated.

- **External cause**: Atmosphere (between the terrain and the sensor) can contribute to noise (i.e., atmospheric attenuation) such that energy recorded does not resemble that reflected/emitted by the terrain.

Periodic Line Dropouts

- **Due to recording problems when one of the detectors of the sensor gives wrong data or stops functioning.**

  - **Line dropout - caused by a defective sensor system.**

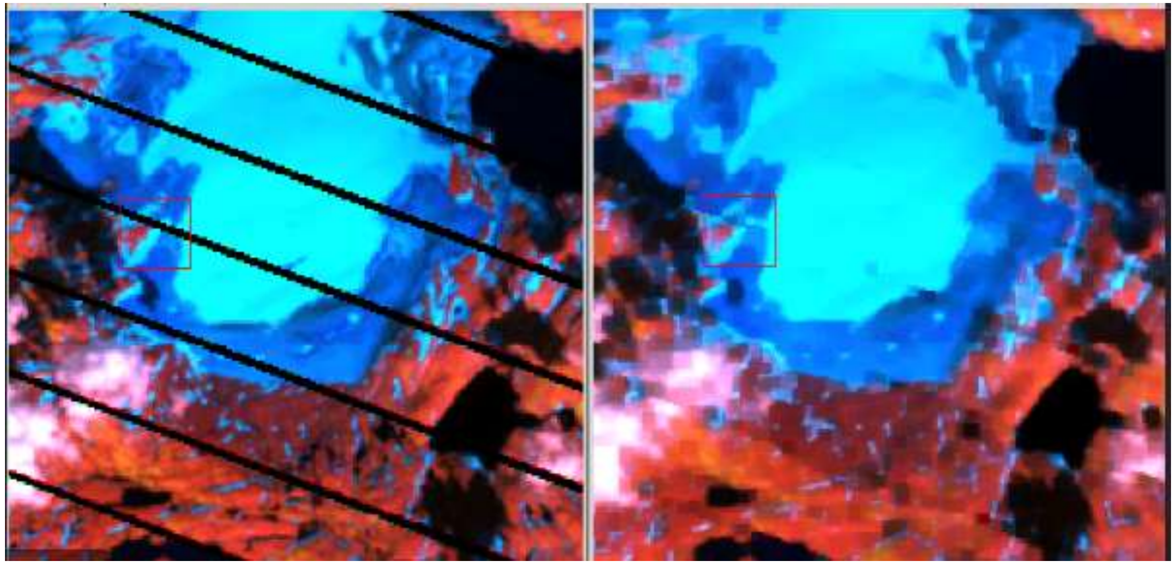


Line Striping

- For each spectral band, the detectors are carefully calibrated and matched.

- With time, however, the response of some detectors may drift to higher or lower levels; as a result every scan line recorded by that detector is brighter or darker than the other lines.

Line stripping - caused by different responses of detectors to equal input (de-calibration of detectors)



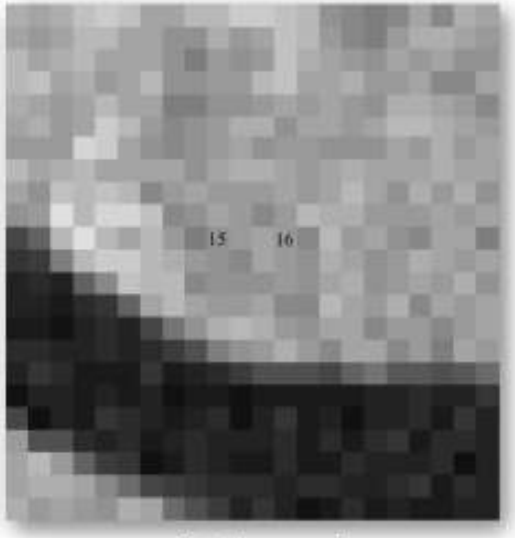
Random Noise

- *Random noise typically occurs as individual pixels with DNs that are much higher or lower than the surrounding pixels.*
- These spots also interfere with information extraction procedures such as classification. Random-noise pixels may be removed by digital filters

  - **Random noise or spike- caused by error during data transmission or to a temporary disturbance**

a. Landsat TM band 7 data of the Santee Delta with shot noise.

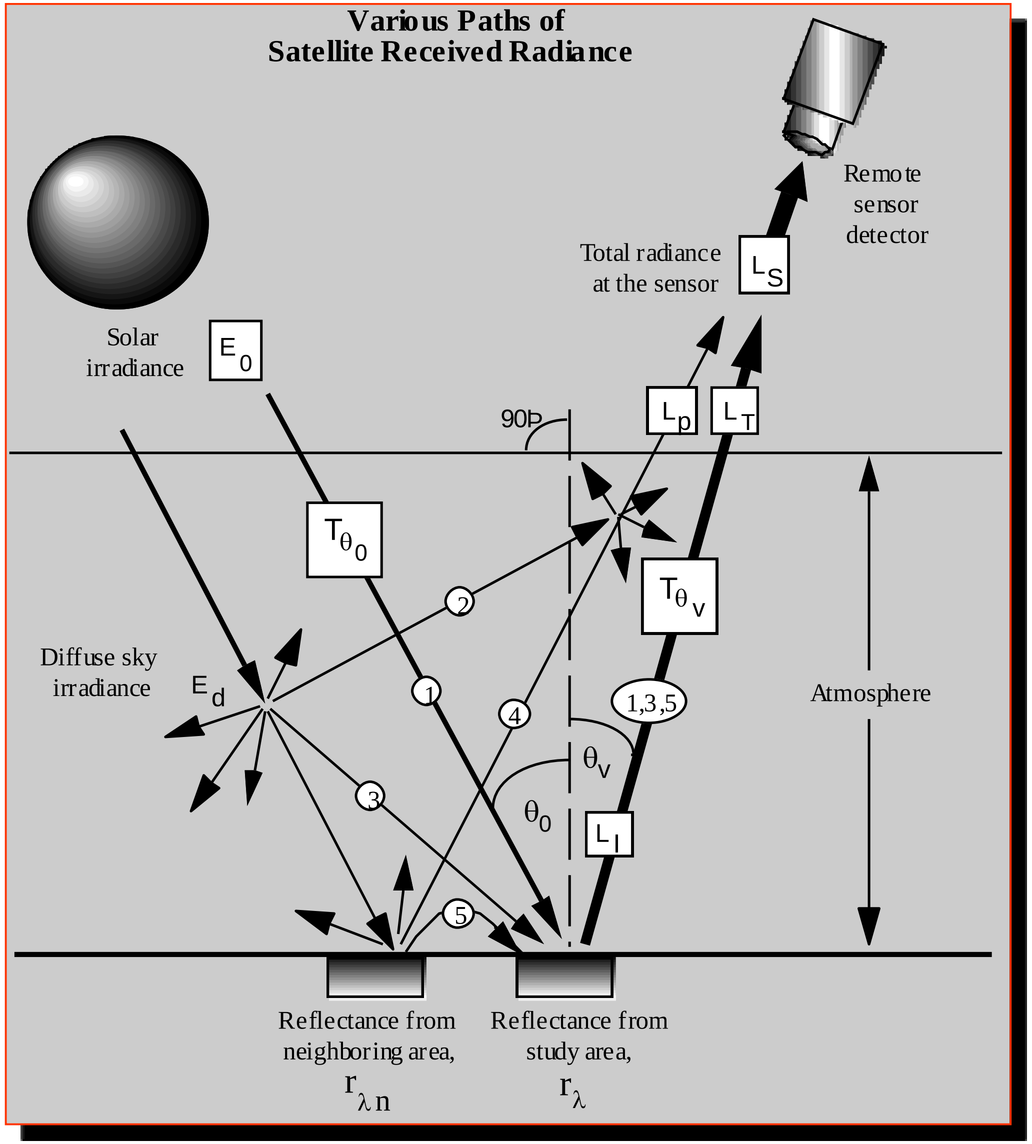
b. Two pixels along a bad scan line with shot noise.



c. Shot noise removed.

Atmospheric Scattering

- The atmosphere selectively scatters the shorter wavelengths of light.
- Example: For Landsat MSS images, band 4 (0.5 to 0.6 micro mt) has the highest component of scattered light and band 7 (0.8 to 1.1 micro mt) has the least .
- Atmospheric scattering produces haze, which results in low image contrast.
- The contrast ratio of an image is improved by correcting for this effect.



ABSOLUTE ATMOSPHERIC CORRECTION

- Solar radiation when it interacts with the Earth's atmosphere, it is selectively **scattered and absorbed**.

- The sum of these two forms of energy loss is called **atmospheric attenuation.**

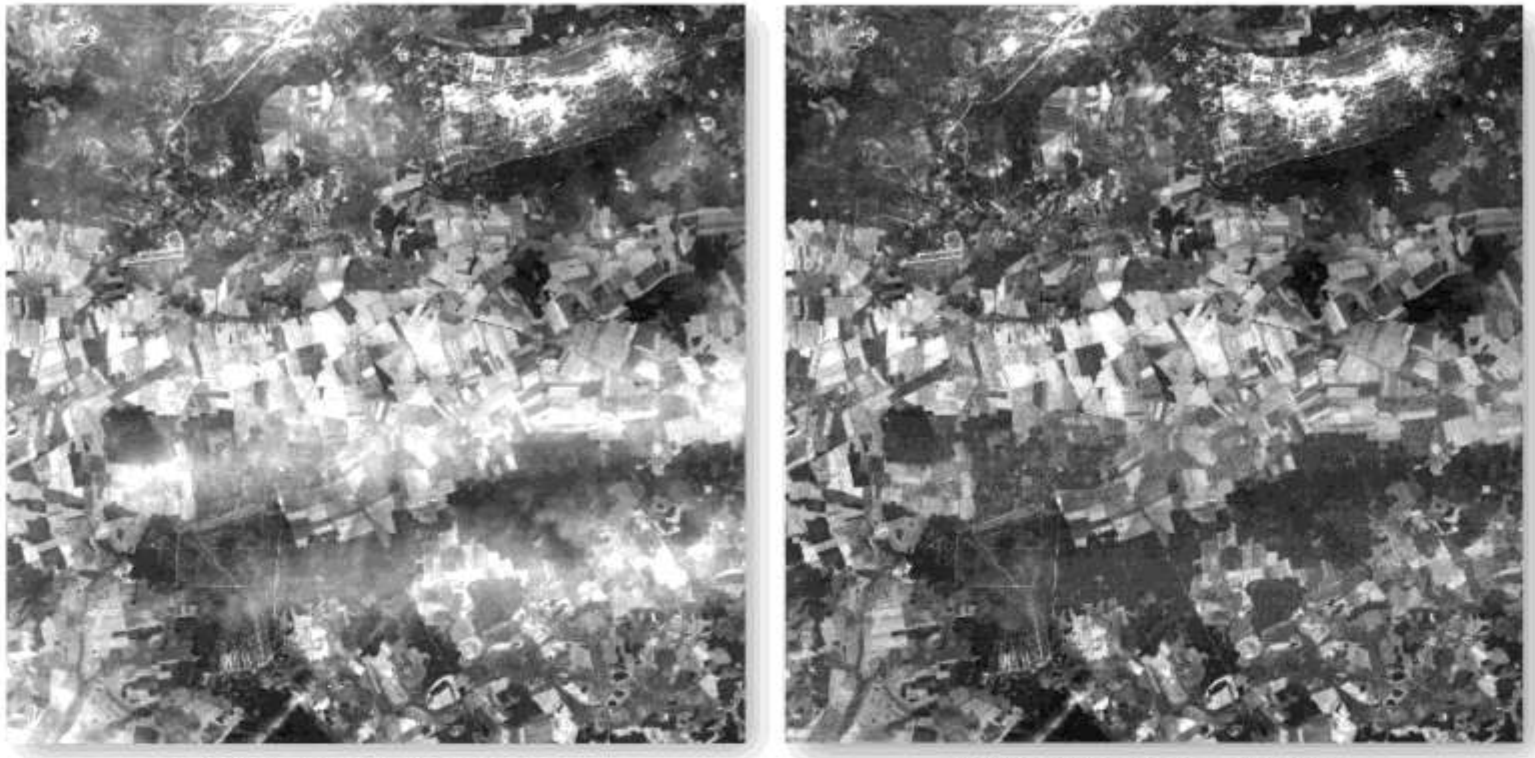
<u>Atmospheric attenuation may :</u>

1)make it **difficult to relate hand-held *in situ* spectroradiometer** measurements with remote measurements,

2)make it **difficult to extend spectral signatures through space** and time, and

(3)have an **impact on classification accuracy within a scene if atmospheric attenuation varies significantly throughout the image.**

- **The general goal of absolute radiometric correction is to turn the digital brightness values (or DN) into scaled surface reflectance values.**



a. Before atmospheric correction. b. After atmospheric correction.

a)Image containing substantial haze prior to atmospheric correction.

b) Image after atmospheric correction using ATCOR (Courtesy Leica Geosystems and DLR, the German Aerospace Centre).

Topographic correction

- Topographic slope and aspect also introduce radiometric distortion (for example, areas in shadow)

- The goal of a slope-aspect correction is to remove topographically induced illumination variation so that two objects having the same reflectance properties show the same brightness value (or DN) in the image despite their different orientation to the Sun's position

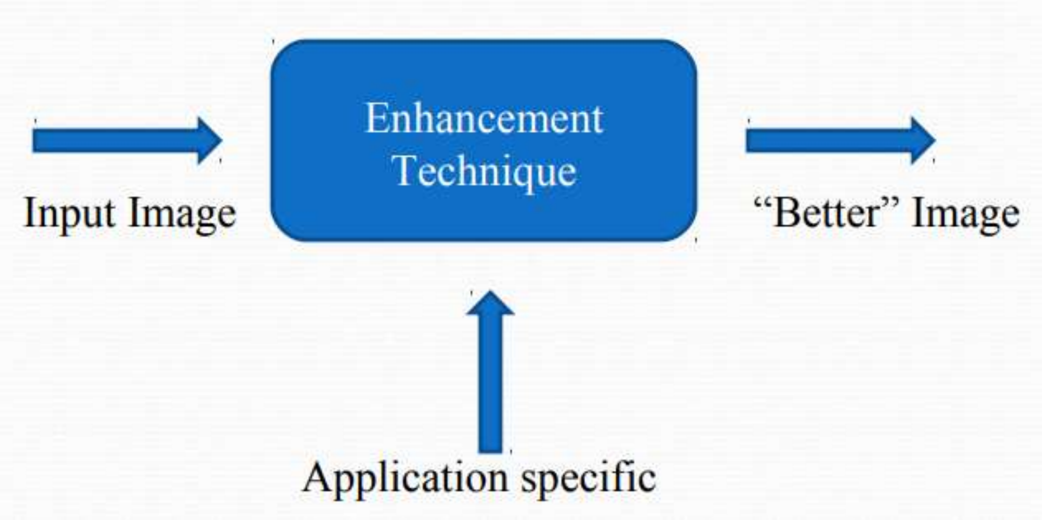
- Based on DEM, sun-elevation.

IMAGE ENHANCEMENT

- The purpose of enhancement is render the images more interpretable, i. e. feature should become better discernible.
- Enhancement is the modification of an image and increases the dynamic range of the chosen features so that they can be detected easily.

- It sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis.

- Before enhancement, images should be corrected for radiometric distortions, otherwise the distortions or noise may also get enhanced.



Enhancement types

Radiometric enhancement	Spatial enhancement	Spectral enhancement
(enhance images based on the values of individual pixels)	(enhance images based on the values of individual and neighboring pixels)	(enhance images by transforming the values of each pixel on a multi band basis)

Radiometric enhancement (enhance images based on the values of individual pixels):

- ❑ Technique that improves contrast between certain features by altering the screen colors assigned to specific ranges of pixel values.

Contrast Enhancement

- Contrast enhancement deals with rescaling of grey levels so that features of interest are better shown on the images.

- The number of actually recorded intensity levels in a scene is rather low and full dynamic range of the digital image (256 levels) is not utilized.

- As a result, the image has a low contrast.

- Rescaling of grey levels could improve the image contrast and allow better visibility of features of interest.

Common Method of Contrast Manipulation:

1. Linear Contrast Stretching
2. Multiple Linear Stretch (Piece-wise linear Stretch)
3. Logarithmic, Power or Functional Stretch
4. Gaussian Stretch
5. Histogram Equalization Stretching
6. Density Slicing

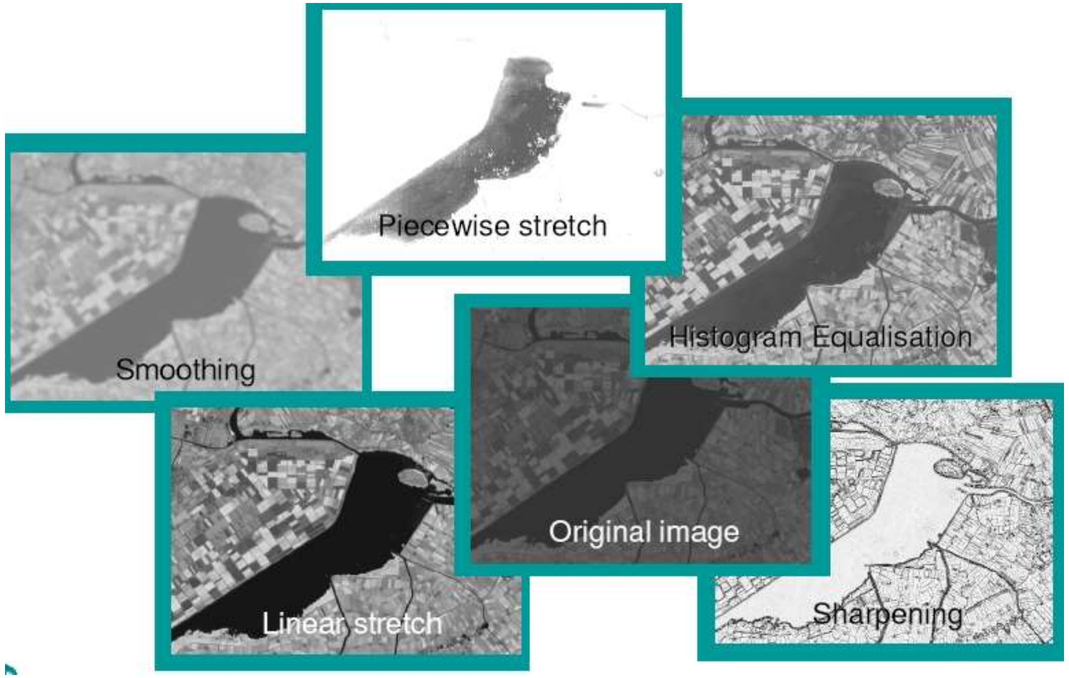


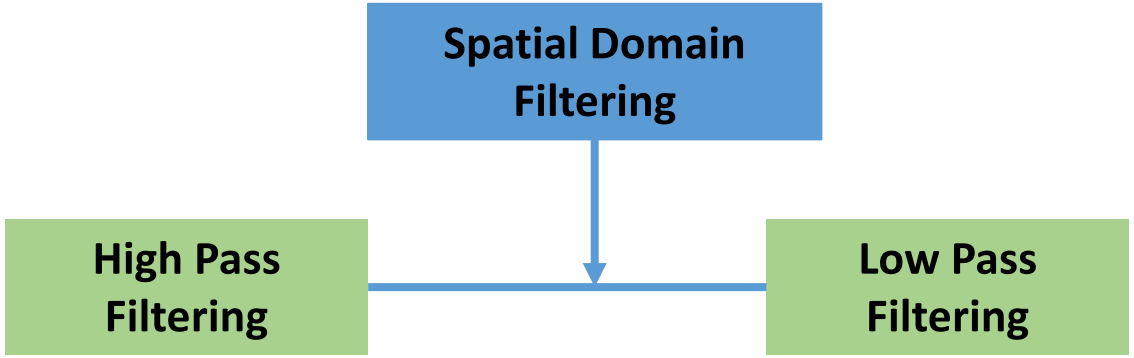
Image Filtering

- Image filtering is carried out to extract spatial scale information from an image.

Spatial Domain Filtering	Frequency Domain (Fourier) Filtering

Spatial domain:

- Refers to texture of image texture:
- Smooth areas have low spatial frequencies, grey values change gradually
- Rough areas have high spatial frequencies and grey values change abruptly.
- Frequency: no. of changes in DN values/ unit distance in any particular part of an image
- Two types: (a) Low- Frequency: few changes in DN values over a given area
- (b)High- Frequency: dramatic changes in DN values over a given area



- **Spatial domain** filtering is carried out by using windows, boxes or kernel and this techniques is highly being utilized in the field of remote sensing because of two reasons:

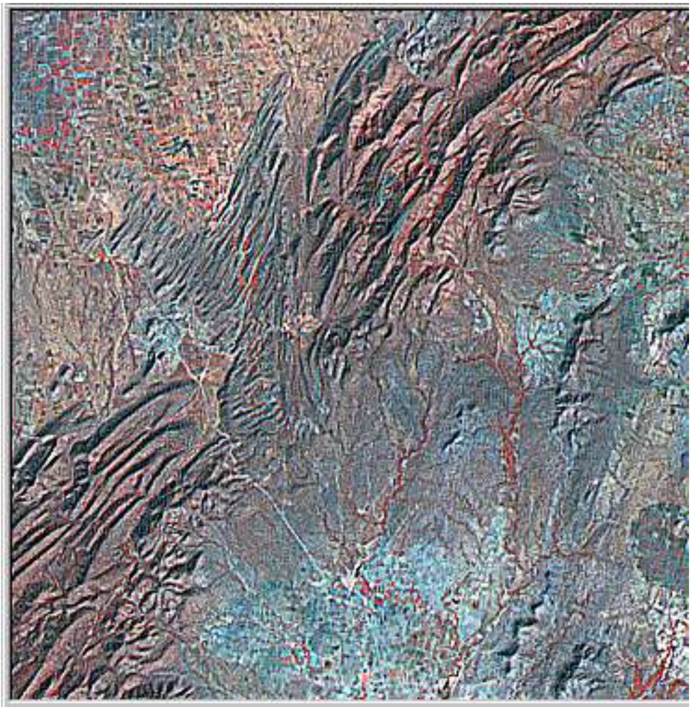
  - It is simple and easy to implement and requires lowest computational capabilities.
  - It meets the requirements of the data processing

❖ High Pass Filtering is used to enhance edge of two adjacent features. Also known as Edge Enhancement and it’s a sharpening of processes.

- ❖ **Low Pass Filtering (Image Smoothing): Enhance low frequency spatial information, reverse of edge enhancement technique. Suppress local variations.**

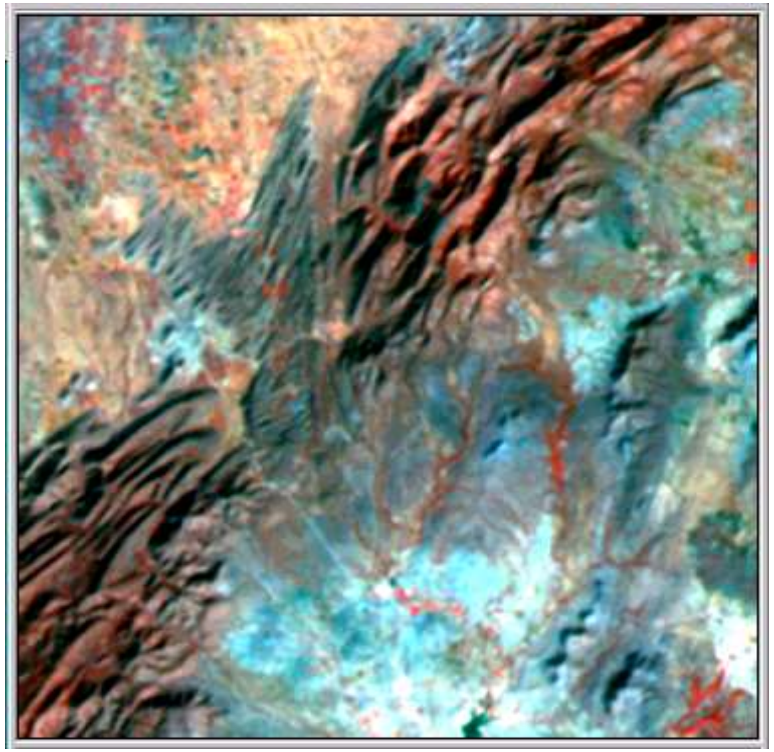
- ❖ **Useful when the aim is to study regional distribution over large geological domain**

High pass filtering



High-pass filters – enhance information of high frequencies (local extremes, lines and edges)

Low pass filtering



Low pass filter smoothens image and hence sharpness in the image is lost.

Frequency Domain (Fourier) Filtering

- A mathematical technique for separating an image into its various frequency components is Fourier Analysis and operates on one image at a time.

- Separates image into its component spatial frequencies.

Edge Detection

- **Mainly two types:**

1. Linear Edge Detection (Linear combination of pixels): Directional filters

These filters give edges in particular direction and are useful for detecting lineaments, contacts etc.

- **2. Non-Linear Edge Detection** (Non-Linear combination of pixels)

Spectral Enhancement Technique

- This technique is used for:

  a) Compression of similar band data;

  b) Extraction of new bands of data that are more interpretable to the eye;

  c) Mathematical transformation; and

  d) Increasing the variety of information in the display using available RGB guns.

- The most widely used techniques of spectral enhancement are:

  Spectral Ratios (Band Ratios or Indices):

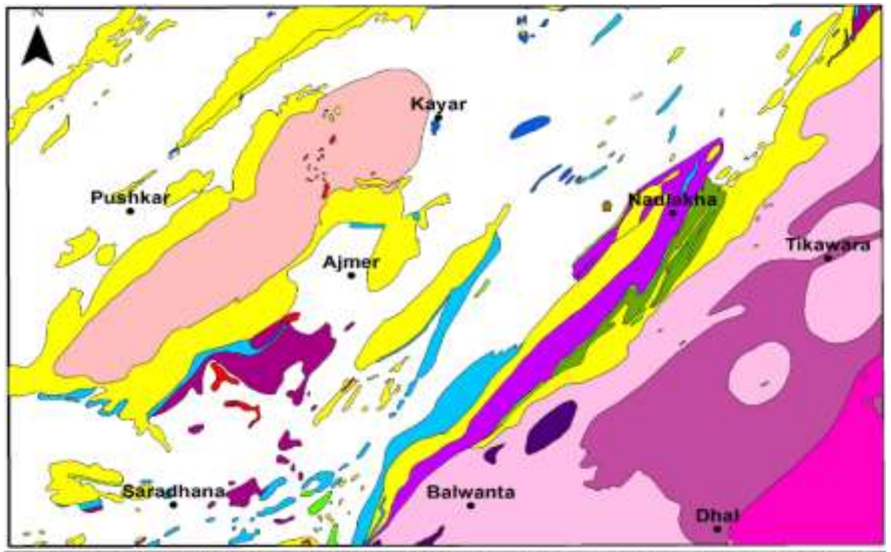
  Principal Components Analysis (PCA):

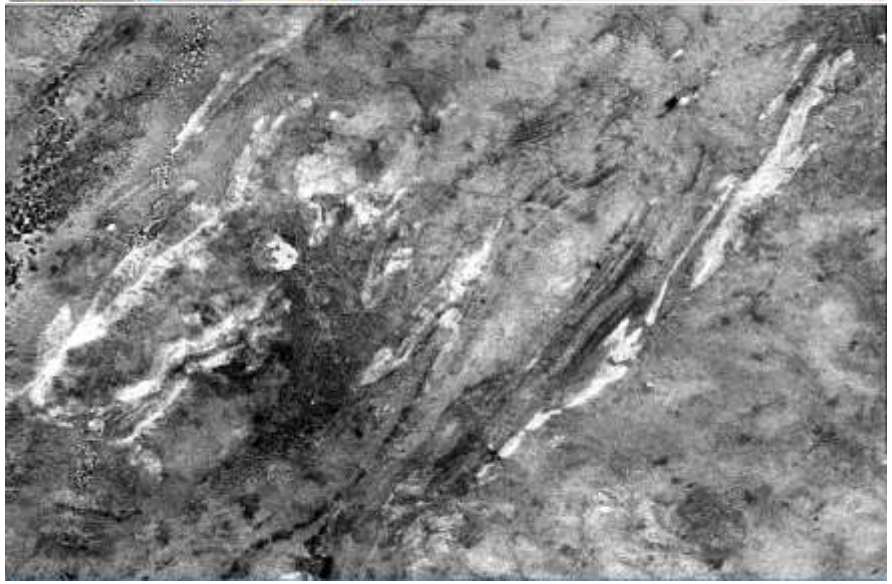
Spectral Ratios (Band Ratios or Indices):

- Band ratio is a technique where the values of the brightness of the pixels in a spectral band are divided by another band.

ASTER Band Ratio Algorithms

Feature	Band or Ratio	Comments	Reference
Iron			
Ferric iron, Fe^{3+}	2/1		Rowan; CSIRO
Ferrous iron, Fe^{2+}	5/3 + 1/2		Rowan
Laterite	4/5		Bierwith
Gossan	4/2		Volesky
Ferrous silicates (biot, chl, amph)	5/4	Fe oxide Cu-Au alteration	CSIRO
Ferric oxides	4/3	Can be ambiguous*	CSIRO
Carbonates / Mafic Minerals			
Carbonate / chlorite / epidote	(7+9)/8		Rowan
Epidote / chlorite / amphibole	(6+9)/(7+8)	Endoskarn	CSIRO
Amphibole / MgOH	(6+9)/8	Can be either MgOH or carbonate*	Hewson
Amphibole	6/8		Bierwith
Dolomite	(6+8)/7		Rowan, USGS
Carbonate	13/14	Exoskarn (cal/dolom)	Bierwith, Nimoyima, CSIRO

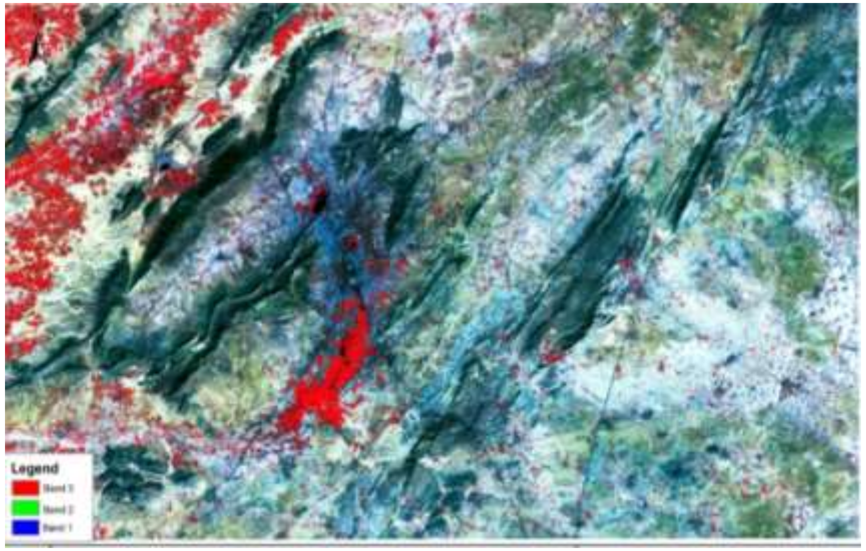


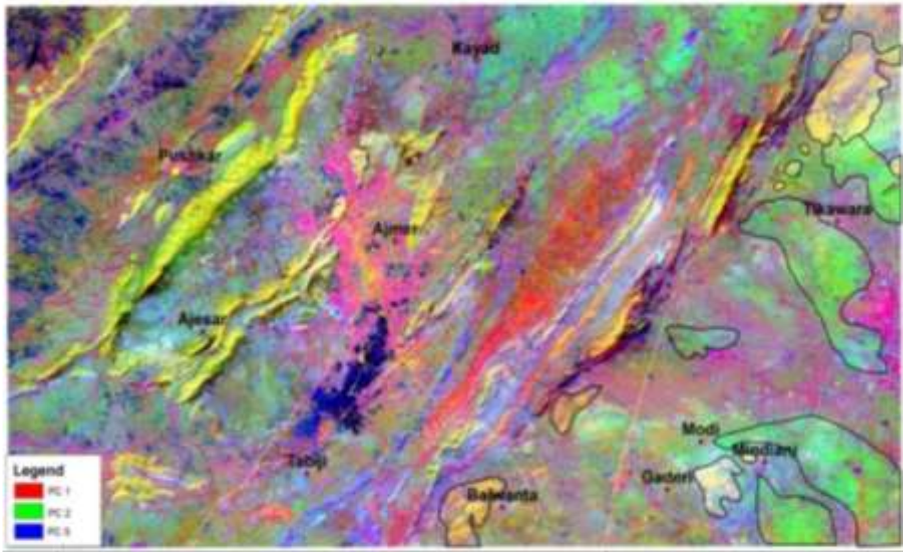


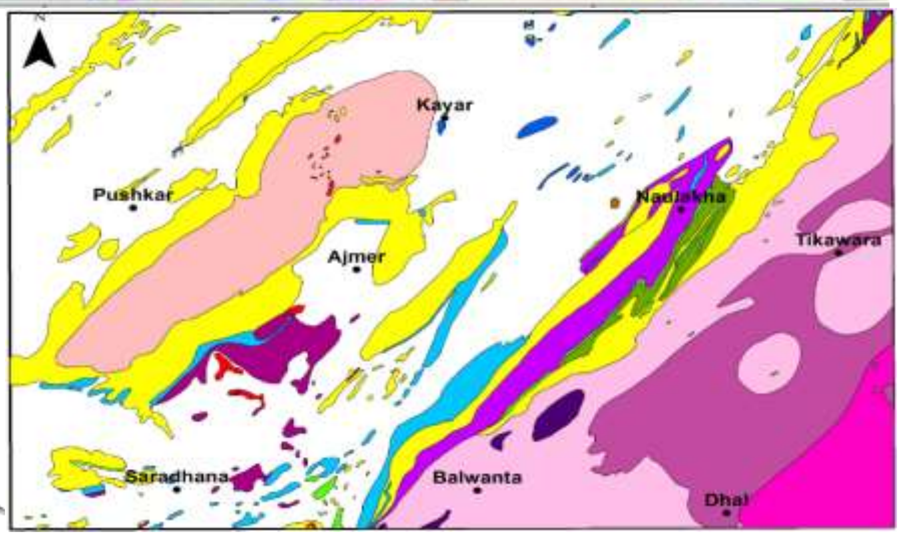
Band 7/Band6: Muscovite

Principal Components Analysis (PCA)

- *This Transformation technique is used for reducing dimensionality of correlated data. And* compressed information from all bands into fewer bands.







Color Transformation

Intensity-Hue-Saturation (HIS):

- Color viewing is a highly effective mode of presentation of satellite data.
- It leads to feature enhancement owing to the following three main reasons:

1. **Sensitivity of the human eye: Human eye can distinguish about 20-25 grey shades,** whereas sensitivity to colour variation is very high and it can distinguish more than a million colours.

2. **Numbers of variables available:** Black and white images carry information in terms of only one variables i.e. tone or brightness (grey level).

   A colour image consists of three variables: hue, saturation and brightness.

3. **Possibility of Collective multi-image display:**

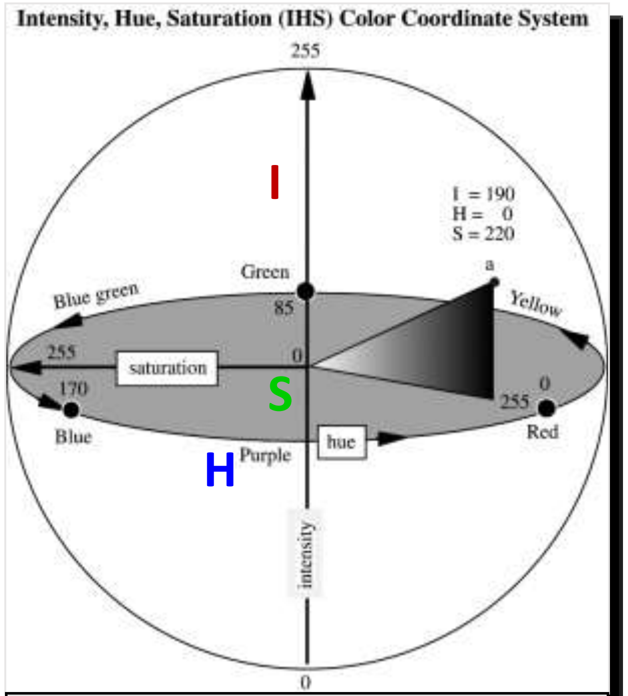
- Primary colors (red, green, and blue, or RGB system). An alternate approach to color is the intensity, hue, and saturation system (IHS).
- The IHS system is based on the color sphere in which the **vertical axis represents intensity**, **the radius is saturation**, and the circumference is hue.

✓ **The intensity (I)** axis represents brightness variations and ranges from black (0) to white (255); no color is associated with this axis

❖ **Saturation (S)** represents the purity of color and ranges from 0 at the center of the color sphere to 255 at the circumference

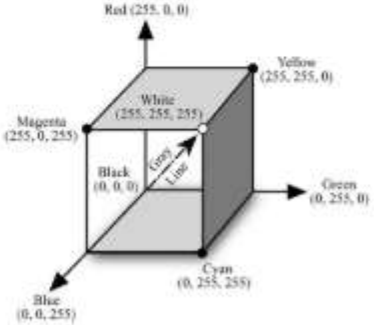
❑ **Hue (H)** represents the dominant wavelength of color.

❑ Hue values commence with 0 at the midpoint of red tones and increase counter-clockwise around the circumference of the sphere to conclude with 255 adjacent to 0.

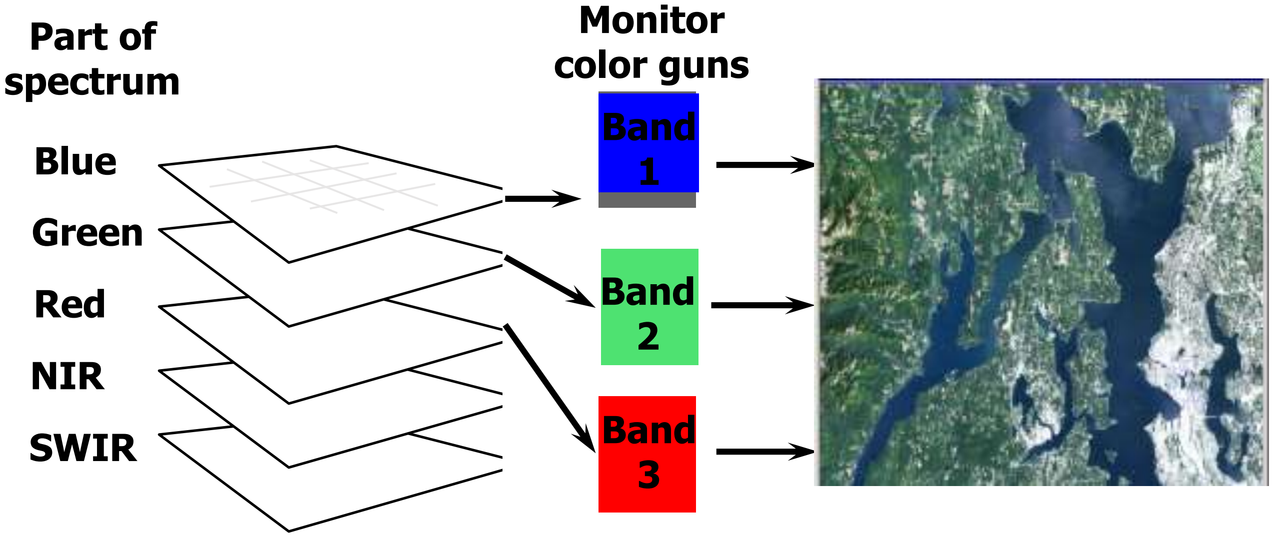


Jensen, 2003

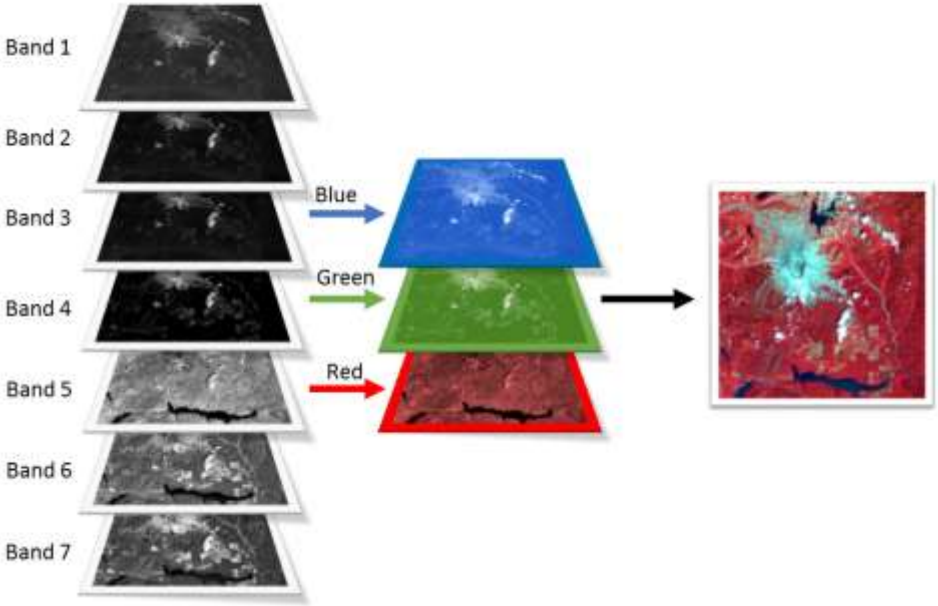
Digital color displays of remote sensing data show up to three bands of an image using the RGB color model.



Three bands are viewable simultaneously



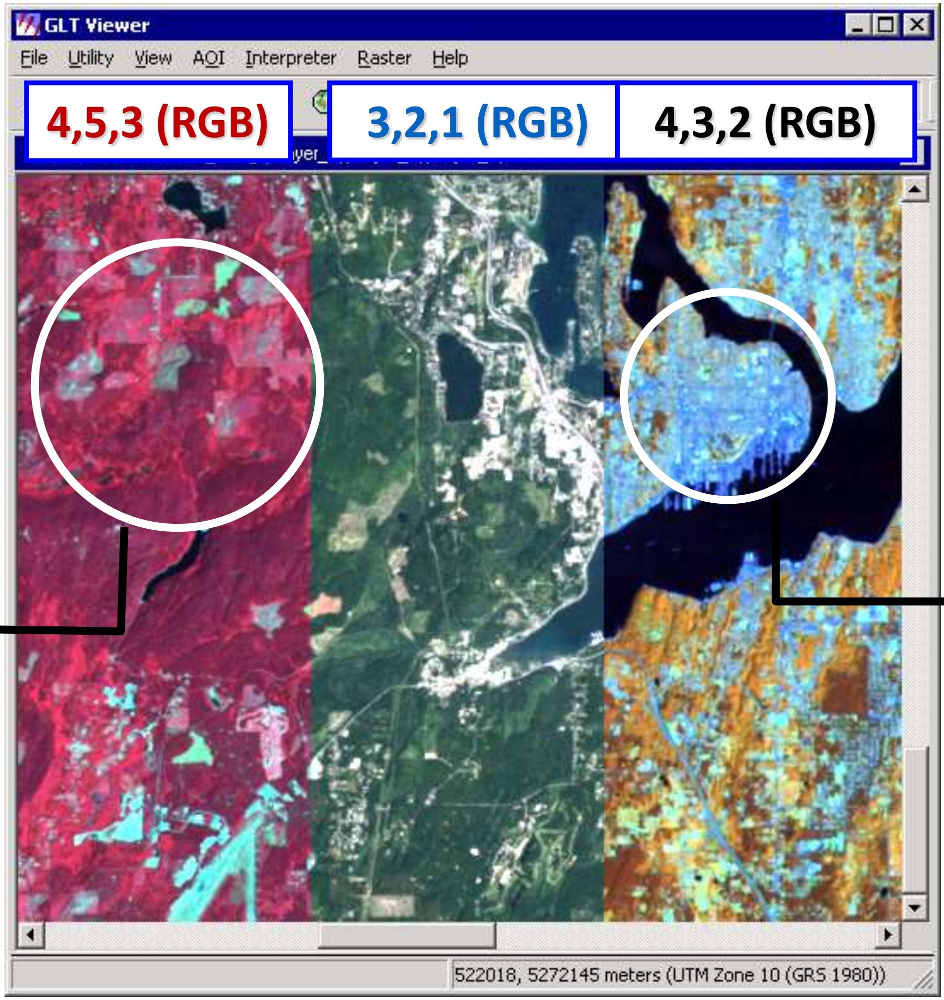
Layer stack



FCC

Band Combinations

- Features can become more obvious



Vegetation

Urban

Image Classification

- Classification is the process of assigning pixels of remotely sensed images into groups of homogenous characteristics.

- Image classification refers to the task of extracting information classes from a multiband raster image.

- The resulting raster from image classification can be used to create thematic maps.

Image classification

- Land use and land cover (LULC)
- Vegetation types
- Geologic terrains
- Mineral exploration
- Alteration mapping

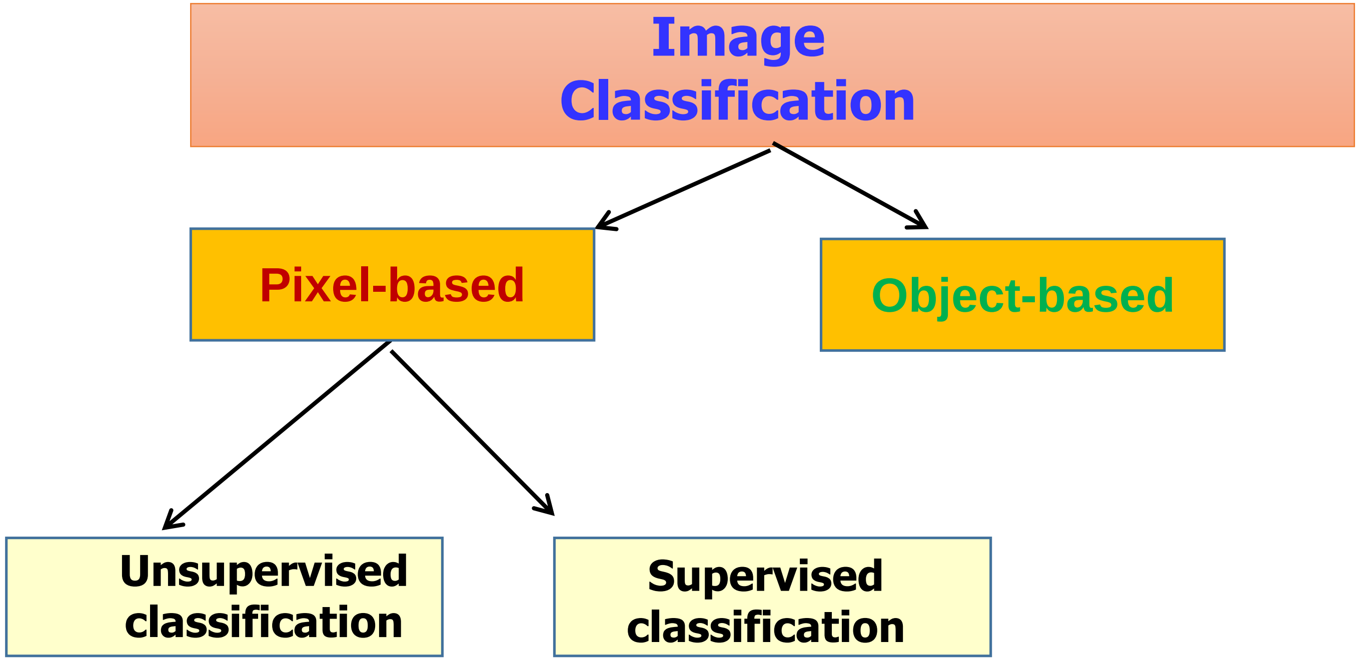


Image Classification

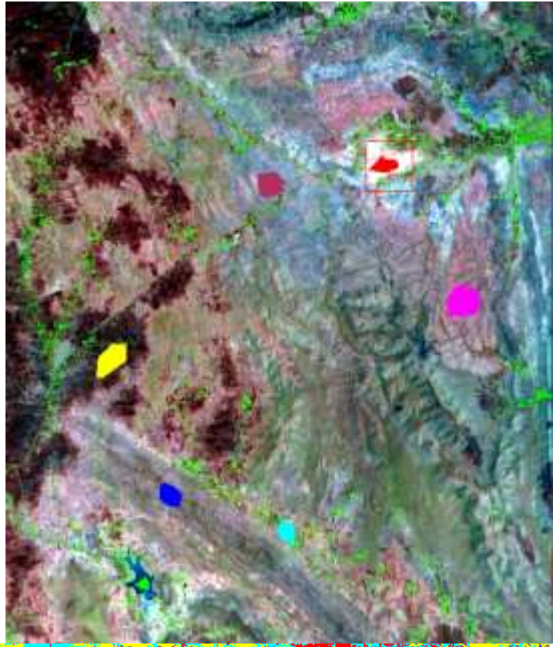
This could be done through supervised or unsupervised methods.

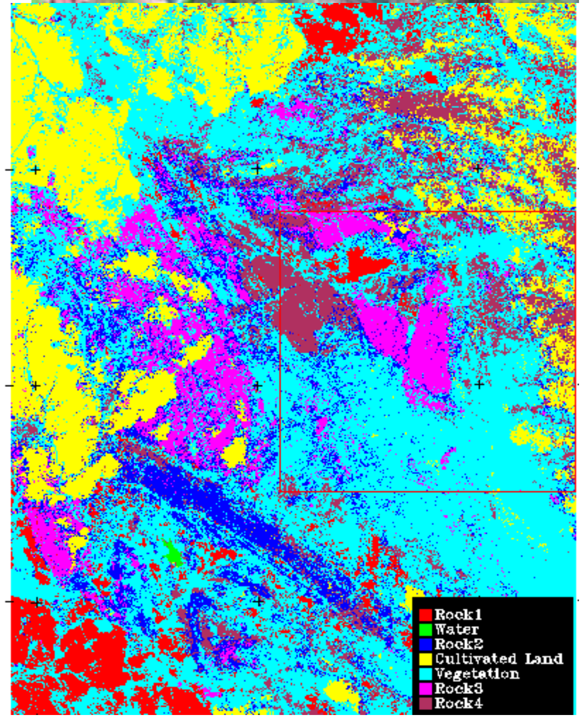
Supervised classification (SC) is when pixel classes have been designated by the user through identification of sites of known classification(i.e., training sites).

Unsupervised classification (UC) is done by the software by categorizing pixels into a pre-specified number of statistical clusters

• Types of Supervised Classifications

1. **Parallelpiped** – based on range or variance of class DNs
2. **Minimum Distance-to-Means** – based on mean class DNs
3. **Maximum Likelihood** – based on probability of class membership
4. **Spectral Angle Mapper** – class membership based on minimum difference from the n-dimensional spectral vectors of the classes





Types of Unsupervised Classifications

1. **K-means clustering** –(also known as C-means) method uses an iterative approach to determining classes.

2. **ISODATA (Iterative Self –Organizing Data Analysis Techniques)**– method uses an iterative approach that incorporates a number heuristic (trial & error) procedures to compute classes.

Object-based or object-oriented classification

- uses both spectral and spatial information for classification.
- The process involves categorization of pixels based on their spectral characteristics, shape, texture and spatial relationship with the surrounding pixels.

Change detection

- Change detection involves the use of multi-temporal datasets to discriminate areas of land cover change between dates of imaging.
- Ideally, it requires
  - Same or similar sensor, resolution, viewing geometry, spectral bands, radiometric resolution, acquisition time of data, and anniversary dates
  - Accurate spatial registration (less than 0.5 pixel error)


4/12/2020
2020

Image Processing Software

ArcGIS

Q-GIS

PCI Geomatica

Grass-GIS

ENVI

Get the information You Need from Imagery

erdas

PhotoScan

3D Modeling and Mapping

SAGA

ORFEO ToolBox

cnes

Thank You